The Difference in Knowledge Representations between Single Text and Multiple Texts Reading

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‘Like everyone, she must live and learn’

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Abstract

Although multiple texts reading (learning by integrating information from different texts) becomes increasingly important, too little is known about how it differs from single text reading to inform educational practices. A pathfinder network approach was used to examine to what extent multiple texts reading draws on additional skills compared with single text reading. Forty Dutch adult readers either first read an online scientific single text (about coffee) and next multiple texts (about chocolate), or vice versa (within-subjects design). Prior knowledge and reading strategies were assessed and two pair-wise relatedness judgement tasks were completed in order to create knowledge models (internal representations of information that is read) per reader and per task. The knowledge models resembled the linear model (i.e., a model based on where information is placed in the text, overlap with this model signifies less understanding) more than an expert model (i.e., an average model of experts' ratings, more overlap with this model signifies better understanding) and showed lower multiple texts than single text reading proficiency (i.e., understanding). Single text reading proficiency, prior knowledge and reading strategies did not predict multiple texts reading proficiency. It was concluded that these were not major factors (in the current research), and that the knowledge models formed by adult readers by reading a single text and multiple texts (both about an unfamiliar topic) differ.

The Difference in Knowledge Representations between Single Text and Multiple Texts Reading

In the contemporary knowledge society, learning by reading online texts becomes increasingly important (Leu, Kiili, & Forzani, 2016). Ideally, the vast amount of information sources on the internet would pave the way to a more complex, critically evaluated and multi-layered understanding of events and phenomena (Stahl, Hynd, Glynn, & Carr, 1996).

However, research shows that although adolescents consider themselves to be proficient in reading and evaluating online information (Kervin, Mantei, & Leu, 2018), learners at all levels encounter difficulties in managing information effectively in more complex online learning tasks (Salmerón, Strømsø, Kammerer, Stadtler, & van den Broek, 2018).

One main characteristic of online reading is the relatively higher occurrence of multiple texts reading, in which a person reads several texts about one topic to gain knowledge (as opposed to reading only one text); this kind of reading often requires a higher degree of navigating, evaluating and integrating than reading a single text (Salmerón et al., 2018; Han, Afflerbach, & Cho, 2018).

The assumption within the field is that multiple texts reading differs from single text reading, and additional factors are proposed to have an influence on multiple texts understanding on top of the factors related to single text reading (Barzilai & Strømsø, 2018; Han et al., 2018). As a consequence of the additional factors, multiple texts reading is deemed to be more difficult (see e.g., Britt & Rouet, 2012; Rouet & Britt, 2011; Bråten, Braasch, & Salmerón, 2016). Although much research has been done into multiple texts reading and how it relates to single text reading, this claim that multiple texts reading is more difficult and draws on additional skills compared with single text reading has not been researched directly. Two of the factors that are proposed to be more important for multiple texts than single text reading are prior knowledge (Barzilai, & Strømsø, 2018) and use of reading strategies (Caverly, Nicholson, & Radcliffe, 2004).

In the current research, it was examined whether multiple texts reading is more difficult than single text reading, and whether it (partly) draws on additional skills. This was done by examining the sophistication of the knowledge models readers create, which are internal representations of information that is read. In other words, these models are a representation of how well a reader has understood the text or texts. Knowledge models were examined for reading a single online text versus multiple online texts. The texts were from the domain of science, a domain where the shift to learning from online information is particularly noticeable (Kervin et al., 2018), because contrasting and evaluating multiple sources of information takes a central place (Goldman et al., 2016). In addition, it was investigated whether prior knowledge and use of reading strategies contribute to this possible higher difficulty of multiple texts reading.

Reading for understanding in a single text

Reading is a complex skill that encompasses many processes. Several attempts have been made to capture the complex construct of reading in a theory or framework. The current state of this research and theories is combined in the Reading Systems Framework of Perfetti and Stafura (2014). This framework depicts the reading process from the level of visual input up until the level of comprehension. Understanding of a text is formed in the higher-level processes of the framework, which are inferencing (creating links between information in different parts of the text or between information in the text and prior knowledge) and monitoring of comprehension. These higher-level processes build on lower-level processes: decoding (linking sequences of letters with sounds), identification of words, retrieving the meaning of words, and combining singular words into (sub)sentences.

Reading in which the proficient reader functions on the higher levels of the framework involves intensive reading (going through the text with the goal of comprehending the main points provided by the text; this form of reading can be considered reading for understanding), rather than skimming (reading bits and parts to form an impression of a text), scanning (looking for specific pieces of information) or extensive reading (reading for pleasure). People often read for understanding (i.e., they read with a goal of understanding/comprehending), especially when reading science texts (Britt, Richter, & Rouet, 2014).

These higher-level processes of the Reading Systems Framework are based on the theoretical construction-integration model of Kintsch (1988), in which reading consists of three layers (Britt & Rouet, 2012): the *surface code*, *text base*, and *situation model* (see Table 1 for an overview of the process of single text reading as well as examples for the different layers). The surface code consists of the exact words and syntax of a text (e.g., a sentence: 'The cat enjoyed herself chasing the red dot on the floor.'). The text base is created by the reader by making inferences between different parts of the text (e.g., 'herself' refers back to 'the cat'). The situation model is created when the learner connects the information from the text with his or her prior knowledge (e.g., the red dot probably refers to a laser, which is a cat toy).

While reading, the reader is constantly updating the situation model with new information from the text, prior knowledge associations, and insights (Zwaan & Radvansky, 1998). This can be envisioned as a cyclical process in which different sources of information are constantly integrated to create an inner representation of the text(s); information from the current cycle (i.e., what the reader is reading right now) is integrated with information from the previous cycle (i.e., what the reader has just understood), the memory representation of the text until that moment, and prior knowledge (Rapp & Van Den Broek, 2005). This process partly takes place automatically and partly depends on active construction (this latter type of construction for example encompasses reading strategies) (Rapp & Van Den Broek, 2005).

The product of the reading process is the final situation model; an inner representation of the information provided by the text(s). This is a memory structure. Knowledge stored in memory can be conceptualised as a network of pieces of information (nodes) and relationships between those pieces of information (links) (Schvaneveldt, Durso, & Dearholt, 1989). In this respect, a situation model can be seen as an (internal) knowledge model, and therewith reading for understanding (i.e., comprehending) can be conceptualised as a process in which the reader builds up and adjusts a knowledge model of the topic of the text(s) (for a spatial representation of a knowledge model see Figure 1).

Table 1

The process of single text reading

Model/theory	Layer	Definition layer	Example break down of texts in different layers	Layer relates to:
			Example text A from a textbook: *'If a flower is in a sunny environment, it converts carbon dioxide and water into oxygen and glucose'*	
Construction-integration model (Kintsch, 1988)	Surface code	Exact words and syntax of a text	Identification of the words, simple present verb tense, sentence structure, etc.	
	Text base	Created by the reader by making inferences between different parts of the text	+ 'It' refers back to 'flower'	
	Situation model	Created by the reader by connecting information from the text with prior knowledge	+ The process is called photosynthesis	Knowledge model of single text reading

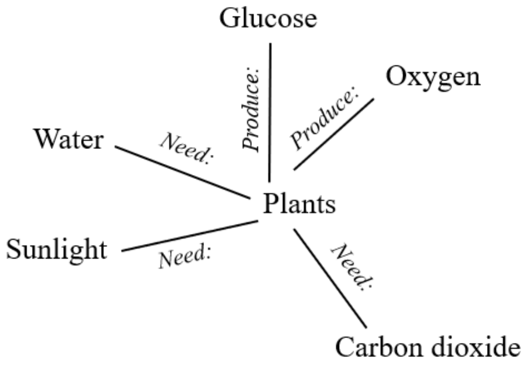

Figure 1. Example of a spatial knowledge model for a situation model (i.e., a spatial knowledge model for a single text)

Multiple texts reading

The processes described above primarily concern the reading of a single text. All these processes are also involved when reading multiple texts on a topic; the reader first has to understand each single text in itself before he or she can build an understanding of how information from the different texts fits together. In reading multiple texts, new knowledge is gained by integrating information from different texts into one single (internal) knowledge model. Integration takes place both within each single text and over the multiple texts; it consists of integrating different pieces of information with each other and with prior knowledge (Salmerón et al., 2018; Britt & Gabrys, 2002).

Concerning this integration of information, multiple texts reading is proposed to differ from single text reading (see e.g., Salmerón et al., 2018). In a single text, the author assists the reader in building a correct knowledge representation of the text, for instance by foregrounding (i.e., setting expectations) (Zwaan & Radvansky, 1998) or indicating the links between different pieces of information (Salmerón et al., 2018). In the case of multiple texts, it is up to the reader to notice where information overlaps, extends or contradicts between the texts (Salmerón et al., 2018). Several theories of multiple texts reading attempt to conceptualise the proposed additional processes involved in multiple texts reading. Two main theories are the documents model (Perfetti, Rouet, & Britt, 1999) and the multiple-document task-based relevance assessment and content extraction (MD-TRACE) model (Rouet & Britt, 2011). These theories propose that there are three additional layers involved in multiple texts reading when compared with single text reading. Two layers concern the content (*intertext model* and *mental model*), and one the reading task (*task model*) (see Table 2 and Figure 2 for an overview of the process of multiple texts reading as well as an example).

In single text reading, the knowledge model a reader forms of a text is comparable with the layer of the situation model. In multiple texts reading, the knowledge model a reader forms of the texts is comparable with the layer of the mental model (sometimes also called *situations model*). The mental model is the internal structure of situations and phenomena described in the texts, containing information that is the same, different, and contradicting between texts (Britt & Rouet, 2012). To build up this mental model, the reader should create a task model (which consists of the expected outcome of the reading activity, as formed by the reader) (Rouet & Britt, 2011) and an intertext model (which consists of source information about the text and how this impacts the content, and how different texts relate to each other as a whole, e.g., if text A contradicts text B) (Britt & Rouet, 2012).

Table 2

The process of multiple texts reading

Model/theory	Layer	Definition layer	Example break down of texts in different layers		Layer relates to:
			Example text A from a textbook: *'If a flower is in a sunny environment, it converts carbon dioxide and water into oxygen and glucose'*	Example text B from an online text: *'The human lungs convert oxygen from the inhaled air into carbon dioxide. Breathing is crucial for staying alive.'*	
Construction-integration model (Kintsch, 1988)	Surface code	Exact words and syntax of a text	Identification of the words, simple present verb tense, sentence structure, etc.	Identification of the words, simple present verb tense, sentence structure, etc.	
	Text base	Created by the reader by making inferences between different parts of the text	+ 'It' refers back to 'flower'	+ Breathing is the process of turning oxygen into carbon dioxide	
	Situation model	Created by the reader by connecting information from the text with prior knowledge	+ The process is called photosynthesis	+ Breathing also takes place in other mammals, so they also produce oxygen + Heartbeat is also crucial for living	Knowledge model of single text reading
MD-TRACE model (Rouet & Britt, 2011)	Task model	Mental representation of the reading task	e.g., find out how plants and people rely on each other		
Documents model (Britt & Rouet, 2012)	Intertext model	Contains content and source information from the text, and the links between content and source information, as well as between different texts	+ The textbook states that plants produce oxygen + The online text states that humans produce carbon dioxide + The texts are both about oxygen and carbon dioxide		
	Mental model	Internal structure of situations and phenomena described in the text, containing information that is the same, different, and contradicting between texts	Humans and plants rely on each other, because humans need oxygen, which is produced by plants (by photosynthesis) and plants need carbon dioxide, which is produced by humans (by the lungs)		Knowledge model of multiple texts reading

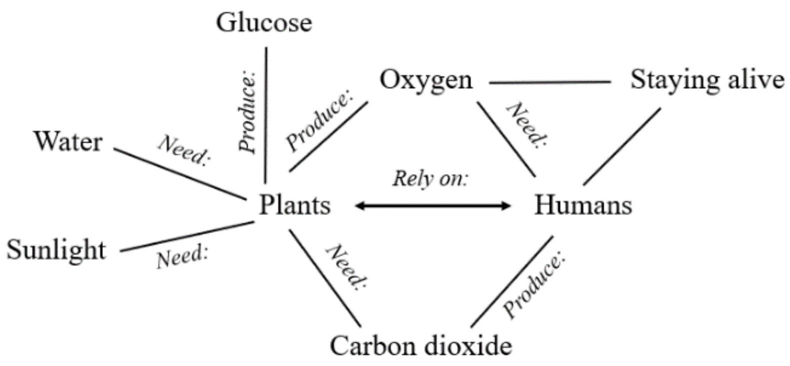

Figure 2. Example of a spatial knowledge model for a mental model (i.e., a spatial knowledge model for multiple texts)

Factors in multiple texts reading

In reading for understanding, there are external factors (e.g., lay-out and amount of discrepancies between texts) as well as internal factors (e.g., epistemic beliefs and interest) (Bigot & Rouet, 2007; Strømsø, Bråten, Britt, & Ferguson, 2013; Afflerbach, Cho, Kim, Crassas, & Doyle, 2013; Barzilai & Strømsø, 2018) that affect reading comprehension in an interplay of interactions (see e.g., Gil, Bråten, Vidal-Abarca, & Strømsø, 2010; Hagen, Braasch, and Bråten, 2014).

It has been proposed that some of these factors impact multiple texts reading differently than single text reading; in quantity (e.g., prior knowledge is relatively more important) as well as quality (e.g., epistemic beliefs about learning from multiple sources impact understanding while reading multiple texts, but not while reading a single text) (Barzilai & Strømsø, 2018; Han et al., 2018). Following the reasoning that multiple texts reading by definition always comprises the reading of a single text, it is assumed that the reading of multiple texts demands more from readers (and therefore is more difficult) than the reading of a single text (see e.g., Britt & Rouet, 2012; Rouet & Britt, 2011; Bråten et al., 2016). Two major factors that are found in research are prior knowledge (Barzilai, & Strømsø, 2018) and use of reading strategies (Bråten, Anmarkrud, Brandmo, and Strømsø, 2014).

Prior knowledge. Prior knowledge is a main factor in text comprehension, for single text as well as multiple texts reading (Barzilai, & Strømsø, 2018). For multiple texts reading, Bråten et al. (2014) showed that prior knowledge has both a direct effect on texts understanding (i.e., prior knowledge itself directly influences understanding) and an indirect effect (i.e., prior knowledge has an effect on another factor that influences understanding). An example of an indirect effect is that prior knowledge can influence what strategies readers use, which can influence understanding (see e.g., Moos & Azevedo, 2008; Afflerbach, 1990). Prior knowledge can take several forms; the main ones are topic-specific knowledge, domain-specific knowledge and schema (see e.g., Tarchi, 2010; Stahl et al., 1996), domain-specific thinking skills (see e.g., Rouet, Favart, Britt, & Perfetti, 1997; Griffin, Wiley, Britt, & Salas, 2017), and prior beliefs and attitudes (see e.g., Richter & Maier, 2017).

Prior knowledge has such a big influence on comprehension because it supports making correct inferences between different pieces of information in the text(s), especially when the text itself does not provide much structure (Tarchi, 2010; McNamara, 2001). In this regard, prior knowledge can be expected to have a bigger influence on multiple texts understanding than on single text reading. In multiple texts reading, connections between information in different texts must almost always be inferenced, as these connections are not provided in a single structure as is the case for reading a single text. For integration of information from different sources into one knowledge model making correct inferences between the multiple texts is crucial.

Use of reading strategies. Reading strategies are important for both single text (see e.g., Johnston & Afflerbach, 1985; Kolić-Vrhovec, Bajšanski, & Rončević Zubković, 2011) and multiple texts understanding (see e.g., Caverly et al., 2004). When a reader uses a reading strategy, he or she is actively and deliberately making inferences in addition to making passive ones (Van den Broek, Beker, & Oudega, 2015). This deliberativeness distinguishes a reading strategy from a reading skill (Afflerbach, Pearson, & Paris, 2008).

Effective use of reading strategies is context-dependent (Han et al., 2018; Anmarkrud, McCrudden, Bråten, and Strømsø, 2013). It depends, for instance, on the reading goal (Strømsø, Bråten, & Samuelstuen, 2003) and the academic domain the text was written in (Shanahan, Shanahan, & Misischia, 2011). Hock and Mellard (2005) stated that proficient readers are able to use several reading strategies, and adjust which strategy they use based on the effectiveness in a given reading context. Graesser (2007) even suggested that the situations in which the strategy can be used effectively are an integral part of the strategy. This context-dependence partly flows from the fact that using strategies takes a lot of skill, knowledge and effort (Bråten, Britt, Strømsø, & Rouet, 2011) and consequently is a high investment.

For multiple texts reading specifically, strategic processing (i.e., use of reading strategies) has been shown to be a mediating factor in the influence of motivation (Leu et al., 2016), prior knowledge, epistemic beliefs, need for cognition, interest, and effort (Bråten et al., 2014) on multiple texts understanding. Therefore, use of reading strategies is expected to be another main factor in multiple texts reading in addition to prior knowledge.

To build a single knowledge model based on multiple texts both within-text and between-text strategies are needed (Afflerbach & Cho, 2009a). Between-text strategies are only needed when there is more than one text, so can therewith be considered unique for multiple texts reading. Prior research has shown that these between-text strategies are critical to multiple texts understanding (Cho, 2014).

Between-text strategies encompass identifying and learning text content, monitoring, evaluating, and (in online reading) realizing and constructing potential texts (Afflerbach & Cho, 2009a; Anmarkrud, Bråten, & Strømsø, 2014). Some of the strategies directly impact integration, some have an indirect impact (e.g., determining the trustworthiness of sources can influence integration) (Cho & Afflerbach, 2015). A full overview of reading strategies can be found in Afflerbach and Cho (2009b). For clarity, a list of concrete reading strategies belonging to this category can be found in Table 3.

Table 3

List of concrete reading strategies that have a direct effect on integration

Strategy	Source
Self-explanation	Linderholm, Therriault, & Kwon, 2014; Ainsworth & Burcham, 2007
Checking consistency of claims, arguments, and evidence between texts	Coscarelli & Coiro, 2015
Writing annotations	Mulcahy-Ernt & Caverly, 2009
Comprehension-monitoring	Goldman, Braasch, Wiley, Graesser, & Brodowinska, 2012
Self-monitoring	Cho, Woodward, Li, & Barlow, 2017
Memorising	Strømsø et al., 2003
Comparing and contrasting information	Cho & Afflerbach, 2015
Corroborating (seeking out additional information to (dis)confirm the information just read)	Britt & Gabrys, 2002

As there generally is more guidance in making the right inferences within a single text than between two or more texts, it can be expected that in reading multiple texts more active, deliberate inference making is needed, in other words: reading strategies. Furthermore, multiple texts reading in general is proposed to be more difficult than single text reading (see e.g., Britt & Rouet, 2012; Rouet & Britt, 2011; Bråten et al., 2016) and the use of strategies becomes more important when the task or texts are difficult, or the reader has limited prior knowledge (Afflerbach et al., 2008). In addition, the central role reading strategies play in the impact of many factors on multiple texts understanding, including prior knowledge (see Leu et al., 2016; Bråten et al., 2014) suggests that use of reading strategies might be important even if the role of prior knowledge is accounted for.

Current study

The current study investigated to what extent multiple texts reading draws on additional skills compared with single text reading. It was investigated how well readers can comprehend a text or texts, in other words, how high their reading proficiency is for single text and multiple texts reading. *Single text reading proficiency* is defined as the ability of a reader to build a sophisticated knowledge model based on a single text (i.e., situation model). *Multiple texts reading proficiency* is defined as the ability of a reader to build a singular sophisticated knowledge model based on multiple texts (i.e., mental model).

There were two main research questions:

RQ1: To what extent does the single text reading proficiency of adult readers differ from their multiple texts reading proficiency?

RQ2: Do prior knowledge and use of reading strategies each predict multiple texts reading proficiency over and above single text reading proficiency?

Sophistication of a knowledge model is determined by first capturing the knowledge model of the reader (from now on called 'participant's model') with a comparing task and the pathfinder method (specifics can be found in the methods section). The participant model is then compared with a so-called *linear model* and an *expert model* by looking at the overlap between each of these models and the participant's model (see e.g., Fesel, Segers, Clariana, & Verhoeven, 2015). The linear model is a representation of where information is placed spatially in the text. Greater overlap with this model generally signifies less sophistication. It means that the reader remembered better how terms were spatially placed in the text (text-base memory) but he or she presumably has not gained many extra insights through inferencing. The expert model is the knowledge model of an expert reader or domain expert; greater overlap with this model signifies a more sophisticated model. It means that the learner drew inferences between information located at different places in the text(s) similar to those of an expert. So, 'sophistication of a knowledge model' in the current study was conceptualised as how much a participant model equals an expert model (higher sophistication) and linear model (lower sophistication). Note, however, that it is possible for the expert model to overlap the linear model (i.e., some pieces of information that are physically close to each other in the text also can be judged to be strongly related by experts), so the linear and expert model are not necessarily extremes on different ends of the same scale.

The according hypotheses to the research questions are:

H1: The knowledge models of adult readers resemble an expert model more in both single text reading and multiple texts reading than they resemble a linear model, and this effect is stronger in single text reading.

H2: Prior knowledge and use of reading strategies each predict multiple texts reading proficiency over and above single text reading proficiency.

The current study extends previous research in the domain of multiple texts (or multiple documents) reading by examining the assumption that multiple texts reading requires additional skills compared with single text reading. In addition, it introduces the pathfinder method, which has been used successfully before to measure single text understanding (see e.g., Raudszus, Segers, & Verhoeven, 2019; Fesel et al., 2015), as a method to capture multiple texts understanding. For measuring reading comprehension in general, this could provide an alternative for the wide-used method of multiple choice questions, which has been shown to shape the way people read (Rupp, Ferne, & Choi, 2006).

The current study is also practically relevant, because in schools learning from online information is increasingly included in the curriculum (Kervin et al., 2018). It sheds light on the necessity to specifically teach multiple texts reading in education. If multiple texts reading is the same skill as single text reading, there is no need to separately teach multiple texts reading; teaching single text reading would suffice as these skills would transfer to reading multiple texts. If multiple texts reading (partly) differs from single text reading, however, teaching multiple texts reading would have a merit. Furthermore, if a difference exists between these types of reading, it is interesting what should be taught to equip students with multiple texts reading skills. If, for instance, the study would show that the use of reading strategies (more) specific to multiple texts reading account for the higher difficulty of multiple texts reading, education could be targeted more at teaching these specific skills.

Method

Research design

The current study had a quantitative, quasi-experimental within-subjects design. All the participants read one (i.e., single) text about coffee and two (i.e., multiple) texts about chocolate and completed all the tasks and questionnaires. The single text (about coffee) was the only factor that differed between the participants; to rule out the possible confounding influence of writing style on text comprehension half of the participants read a text about coffee by the authors who also wrote the first text of the multiple texts about chocolate and the other half read a text about coffee by the author who also wrote the second text of the multiple texts about chocolate. Both single texts were about coffee and similar in content.

Participants

Forty adult readers participated in this study (16 men, 24 women; mean age 23.75 years, *SD* = 6.65). Seven participants did not currently follow education (anymore). The majority of the participants did currently follow education; most of them did a research university bachelor or university master (both 14 participants). The rest did an HBO bachelor/ bachelor of applied sciences (4 participants) or a PhD (1 participant). The highest degree of the participants who currently did not follow education (anymore) was university master (3 participants), HBO bachelor (2 participants) and VWO/ university preparatory education and MBO/ senior secondary vocational education (both 1 participant). All participants were Dutch native speakers and none of them had dyslexia. In addition, none of the participants received education related to chemistry after secondary school. The participants were either rewarded with 1 SONA credit for participation (i.e., credits students doing a bachelor within the social sciences at the university of Twente have to earn by participating in research to graduate) or received a voucher of €6. The participants all gave informed consent. The study was approved by the Ethical Committee of the University of Twente.

Instrumentation

Texts. In total, four scientific hypertexts were used (see Appendix A and B). Two were an adaptation of an internet post by two master students in the domain of food and health (Nynke Bergsma and Annemarie Zuur), and two were an adaptation of a book-excerpt by an expert on food and cooking (Harold McGee). The adaptations consisted of selecting excerpts from the originally longer texts and making small changes in the wording of some sentences to make the paragraphs follow logically upon each other.

The single text. The topic of the text was the chemical components and processes of coffee. There were two single texts to rule out the possible confounding influence of writing style on text comprehension. Either the text by Bergsma and Zuur or the text by McGee was read by each participant. The assignment of either single text 1 or single text 2 to participants was counterbalanced.

The multiple texts. Both hypertexts were read by the participants. The topic of both texts was whether chocolate is healthy from a chemistry point of view. The text by Bergsma and Zuur was about bioactive substances in chocolate, white chocolate, and the phenomenon of chocolate turning white when it gets older. The text by McGee was about dark and milk chocolate, cocoa butter, and fat and antioxidants.

The two single texts and the multiple texts were comparable in word length; the single texts each consisted of 756 words, and the multiple texts of Bergsma and Zuur and of McGee were 389 and 372 words in length, respectively (together adding up to 761 words).

In addition, the difficulty of texts as measured by propositional density (i.e., the number of units of information divided by the amount of words in the text) of both single texts (.32 for the text by Bergsma and Zuur, .32 for the text by McGee) was comparable to that of the multiple texts (.32 for the text by Bergsma and Zuur, .34 for the text by McGee). The definition of 'proposition' in the current study was in line with Benjamin (2012). In the following example it is illustrated what was counted as a proposition: the sentence 'The dry coffee beans are soaked in hot water and the caffeine is extracted' would be considered to comprise of five propositions; 'the coffee beans are soaked in water', 'the caffeine is extracted', 'dry' ('the coffee beans are dry'), 'in water', and 'hot' ('the water is hot').

Reading proficiency. Single and multiple texts reading proficiency were measured with two pair-wise relatedness judgement tasks (see Figure 3) and analysed with the pathfinder method.

Pair-wise relatedness judgement task. The task was a Dutch translation of the KU-mapper by Clariana and Wallace (2009). In each of the two tasks, 105 pair-wise comparisons were made of in total 15 concept terms from the text(s). The participants were presented with two terms at a time (e.g., ‘antioxidants-bitter’) and they made a judgement on how related the concepts were on a 9-point Likert scale (1 = *unrelated* and 9 = *highly related*). The order of the pairs of terms, as well as the order of the terms within a pair, was randomised. The participants were not allowed to go back to the text(s) while completing the task.

Figure 3. Example item pair-wise relatedness judgement task.

Pathfinder method. The proximity data of the participants, experts and propositional distances were first converted to similarity matrices, for the single text and the multiple texts. Subsequently, pathfinder models were extracted with the software JPathfinder (see Figure 4 for an example). The pathfinder method searches for the shortest paths between nodes (Schvaneveldt, 1990). In line with the recommendation of Schvaneveldt (1990) to derive multiple pathfinder networks from proximity data with different values of the r parameter and q parameter, and in line with the research of Taricani and Clariana (2006), four pathfinder networks were derived. The q parameter was set to q = n -1 for all networks (in which n is the number of nodes); the r parameter was set to r = 1, r = 2, r = 3, and r = ∞ for the different networks.

The choice for the value of the r-parameter (1, 2, 3, or ∞) only impacted the average expert networks, however. The three expert pathfinder networks with r=1, r= 2, and r=3 were identical to each other. Compared to the pathfinder network with r= ∞ they consisted of considerably more links (also far more than any participant network) and the correlations between the individual expert networks and the average expert network(s) were lower. Therefore, only the networks with r = ∞ were used for further analyses, since these networks are comprised of only the most salient links (Schvaneveldt, 1990). Links not included in a network were coded 0, links that were included were coded 1. The expert models were averaged into one expert model (one for each single text and one for the multiple texts).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Sourness	-													
2. Bitter	8	-												
3. Cocoa beans	8	8	-											
4. Heart- and vascular disease	7	8	7	-										
5. White chocolate	3	4	3	7	-									
6. Free radicals	8	7	7	7	3	-								
7. Cocoa butter	5	5	7	3	6	3	-							
8. Antioxidative effect	9	8	8	7	2	6	6	-						
9. Whitish coating	4	2	6	5	7	3	8	3	-					
10. Compact structure	2	4	6	3	8	2	7	3	7	-				
11. Fat(molecules)	3	2	7	8	7	3	9	2	8	8	-			
12. Phenols	8	8	8	7	7	9	5	9	2	2	2	-		
13. Bioactive substances	9	8	9	7	4	9	6	9	2	4	6	9	-	
14. Dark chocolate	9	9	9	7	6	8	6	8	8	3	4	9	9	-
15. Milk chocolate	6	5	6	4	6	6	7	2	7	7	6	7	7	7

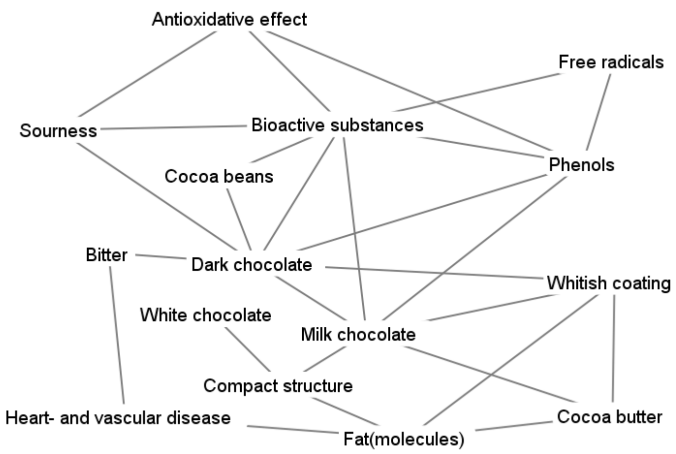

Figure 4. Example method. From top to bottom: proximity matrix of a participant (participant 17) and the derived pathfinder network (both translated from Dutch to English)

Linear model. The participant knowledge networks were compared with a linear and an expert model. The linear model was based on propositional distances between terms, which were calculated by $n_{propositions}$+1, to rule out the possibility of a value of 0 when the terms were right next to each other. In the case of the multiple texts, terms existing only in one text were given a value of 100000 ('infinite'). The resulting linear models can be seen in Figure 5 and 6.

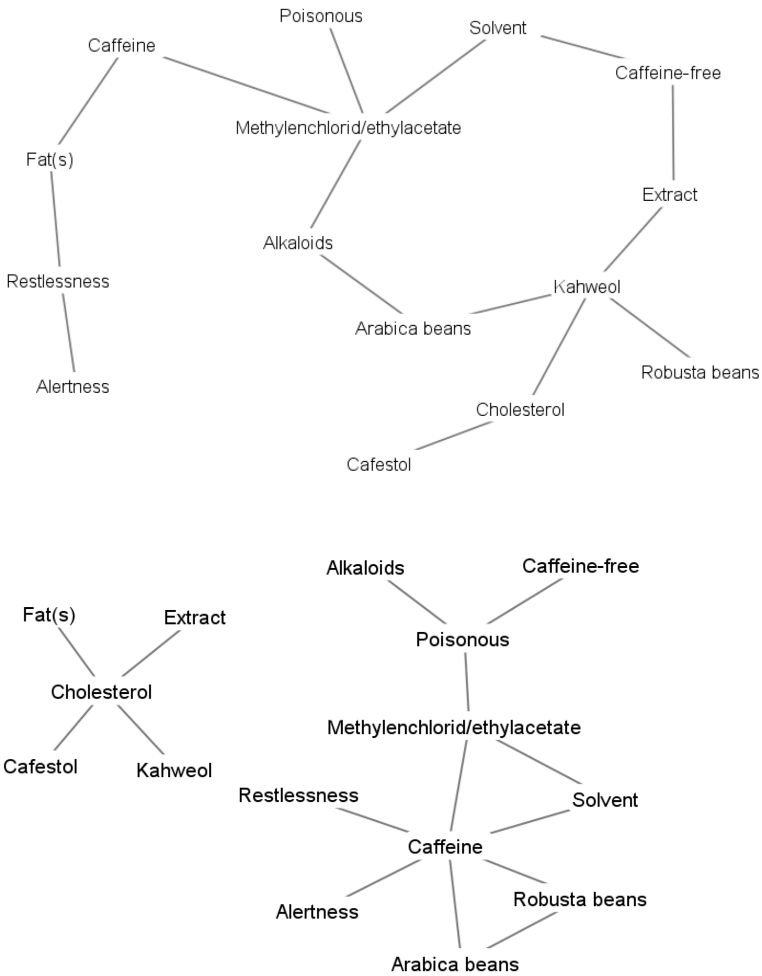

Figure 5. Linear model of the single text (the upper one is the model of single text 1, the one beneath the model of single text 2)

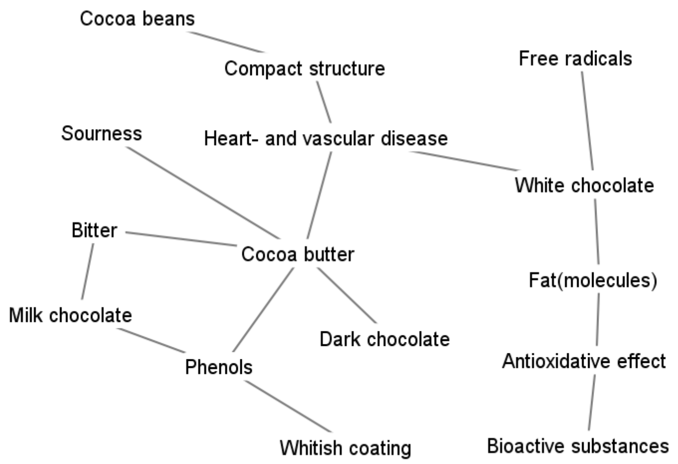

Figure 6. Linear model of the multiple texts

Expert model. The expert model was formed by letting 6 experts in the domain of chemistry read the texts (i.e., a single text and the two multiple texts) and complete the pair-wise relatedness judgement task, from which average pathfinder model were extracted with the software JPathfinder. The experts (4 men, 2 women, mean age = 42.50 years, *SD* = 11.67) had all successfully completed a master program (3 experts) or a PhD (3 experts) in chemistry, and were currently doing a PhD (1 expert) or did not follow an education (5 experts). The experts' scores on the pair-wise relatedness judgement were reasonably similar; the correlations of the scores of each expert (i.e., the score matrix of each expert) with the average scores of all the experts (i.e., the matrix of the average scores of all experts) ranged from r= .73 to r= .82 for the single text and r= .57 to r= .74 for the multiple texts. For the resulting networks the correlations of each of the expert networks with the average expert network ranged from r= .33 to r= .52 for the single text and r= .23 to r= .57 for the multiple texts (note that these correlations were lower because of the nature of the scores, i.e., binary instead of a nine-point scale). These correlations are somewhat lower than those found in Raudszus et al. (2019) and Fesel et al. (2015). However, Acton, Johnson, and Goldsmith (1994) observed in their research that although experts' knowledge models often tend to differ from each other (in their study the correlations were around .31 for the knowledge models), an average expert model is still a good referent for measuring understanding (i.e., it can still be used to predict to what extent students understand the materials). The expert models can be seen in Figure 7 and 8.

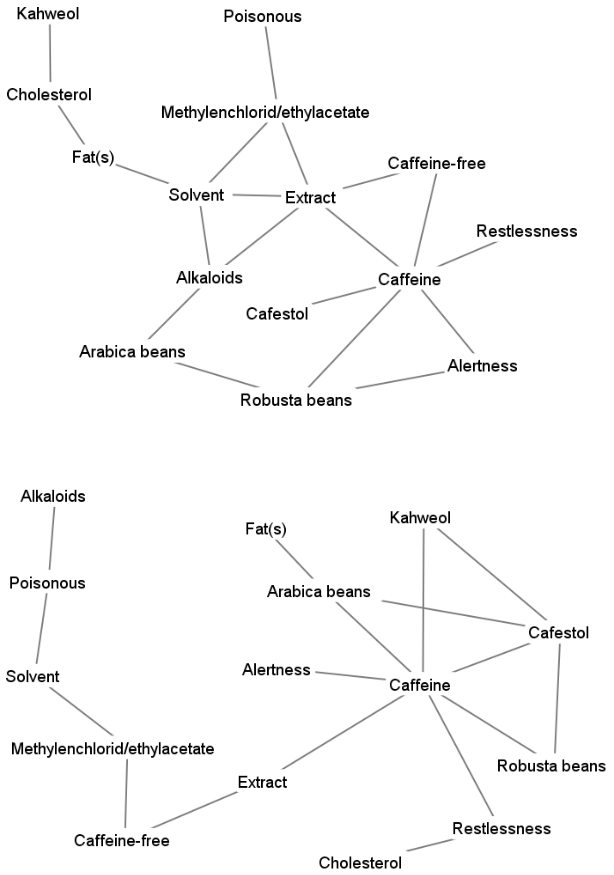

Figure 7. Average expert model of the single text (the upper one is the model of single text 1, the one beneath the model of single text 2)

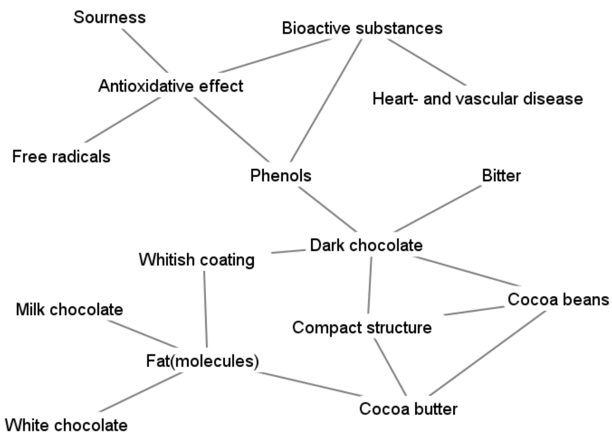

Figure 8. Average expert model of the multiple texts

Self-reported prior knowledge questionnaire. Prior knowledge of the topics of the single text and the multiple texts was measured with 3 questions, in which the participants indicated on a 7-point Likert scale (1 = *very little* and 7 = *a lot*) how much they knew about coffee, chocolate, and chemistry. An example item of these three statements is ‘I estimate my prior knowledge on chemistry to be:’. The prior knowledge data were averaged into two scores for each participant, for the single text (coffee and chemistry question) and multiple texts (chocolate and chemistry question), with an overall minimum score of 1 and maximum score of 7.

Self-reported use of reading strategies questionnaire. Use of reading strategies in the multiple texts was measured with an adaptation of the Multiple-Texts Strategy Inventory by Bråten and Strømsø (2011). Compared to the original questionnaire, changes were made in the language (the statements were translated to Dutch) and in the content (the original statements about climate change were rewritten to statements about the effects of chocolate on health). The questionnaire consisted of 15 statements; 10 statements measuring cross-text elaboration (e.g, ‘I considered whether different explanations of whether chocolate is healthy can be reconciled’) and 5 statements measuring accumulation (e.g., ‘While I read the different texts, I gathered as much factual information as possible’). The full questionnaire can be found in Appendix C. The participant indicated on a 10-point Likert scale (1 = *not at all* and 10 = *to a very large extent*) how much (s)he used the strategy. A factor analysis on the Use of Reading Strategies questionnaire showed that the two reading strategies (cross-text elaboration, accumulation of information) could not be distinguished in the data, in contrast to what was found in Bråten and Strømsø (2011). The scores on the Use of Reading Strategies questions were therefore averaged into a single score for each participant with an overall minimum score of 1 and maximum score of 10. The reliability of this questionnaire, as measured by Cronbach’s alpha, was .77.

Procedure

The study consisted of one session of 45 to 60 minutes. The participants completed the study online. In most of the cases, they did the research on their personal computer and the researcher was not present. First, the participants filled in the informed consent and the demographic and prior knowledge questionnaire and read a global introduction of the experiment.

Hereafter, they went through two phases of the research (single and multiple texts reading phase or vice versa). Both of these phases started with a short introduction of the text(s) and a presentation of the learning/reading goal of the text(s) (e.g., 'find out to what extent chocolate is healthy'). After reading this information, the participants entered a Google-like environment (see Appendix A and B), where they accessed the text(s) by clicking on a link which was the result of a 'Google-search'. In the case of the single text, there was one link they could click on; in the case of the multiple texts there were two (after reading the first text the participants were referred back to the 'Google-page' to access the second text). The environment was added to make the reading task feel more authentic to the readers. After reading the text(s), the participants read a short instruction about the pair-wise relatedness judgement task and completed this task. The order of these phases (single text reading phase and multiple texts reading phase) was counterbalanced.

Thereafter, students completed the Use of Reading Strategies questionnaire and indicated how motivated they felt to read the text about coffee and the texts about chocolate. Lastly, the participants could leave their email address to get the study results.

Data-analysis

The overlap scores (percentage overlap) of a participant's pathfinder model with the linear and expert model for single and multiple texts reading (in total 4 scores for each participant), were calculated by the formula $\text{links}_{\text{in-common}}/(\text{links}_{\text{compared model}} + \text{links}_{\text{participant-model}}$

– $\text{links}_{\text{in-common}}$), in which compared model is either the linear model or the expert model. These overlap scores could range from 0 to 1. A higher overlap score with the linear model indicated a higher degree of text-base memory; in other words, the reader remembered better which terms were physically closer to each other in the text. A higher overlap score with the expert model indicated a higher degree of text-understanding; links between concepts were more frequently made even though they were not necessarily mentioned explicitly in the text(s).

There was one participant with one missing score for a comparison in the pair-wise relatedness judgement task due to a technical difficulty. This participant was given the average score for this item, so the influence of this missing score on the overlap scores was minimal. The assumptions were met for the Repeated Measures Ancova (hypothesis 1), and the Hierarchical Multiple Regression Analysis (hypothesis 2). For hypothesis 1 it was tested whether there was a main effect of Compared Model (Linear model/ Expert model) on the similarity scores and whether there was an interaction between Compared Model (Linear model/ Expert model) and Text Type (Single text reading/ Multiple texts reading) on the similarity scores. For hypothesis 2 it was tested whether prior knowledge explained extra variance in multiple texts reading proficiency (overlap with the expert model) when single text reading proficiency was controlled for and whether use of reading strategies explained extra variance in multiple texts reading proficiency (overlap with the expert model) when prior knowledge (of the multiple texts), and single text reading proficiency were controlled for.

Results

Descriptive statistics

The descriptive statistics for hypothesis 1 (estimated marginal means and standard errors) and hypothesis 2 (correlations) can be found in Table 4 and Table 5, respectively.

Table 4

Estimated marginal means (EMM) and standard errors (SE) for the percentage overlap (dependent variable) for the independent variables Compared model (Linear model/ Expert model) and Text Type (Single text/ Multiple texts) (n= 40)

	Linear model		Expert model	
Text type	*EMM*	*SE*	*EMM*	*SE*
Single text	.276	.012	.251	.013
Multiple texts	.255	.012	.064	.006

Before answering the research questions, it was first checked whether the overlap scores for single text 1 and single text 2 were comparable. Independent t-test showed that there was a significant difference between single text 1 (*M*= 0.31, *SD*= 0.08) and single text 2 (*M*= 0.24, *SD*= 0.05) on the overlap scores with the linear model ($t(38)= 3.40$, $p< 0.05$). This did not have any consequences for the main analyses, as the overlap scores with the linear model are not included in the analysis for hypothesis 2 (hierarchical regression analysis) and the overlap scores are averaged in the analysis for hypothesis 1 (repeated measures analysis). There was no difference between single text 1 (*M*= 0.25, *SD*= 0.08) and single text 2 (*M*= 0.25, *SD*= 0.08) on the overlap scores with the expert model ($t(38)= 0.25$, $p= .80$).

In addition, it was checked whether the single text and multiple texts were comparable in prior knowledge and motivation for the topic of the text(s). Paired-sampled t-tests showed that there was a small significant difference in prior knowledge of the topic of the texts ($t(39)= -3.48$, $p< 0.05$); prior knowledge of the topic of chocolate, i.e., multiple texts (*M*= 3.98, *SD*= 1.05) was slightly higher than that of coffee, i.e., single text (*M*= 3.64, *SD*= 1.17). For motivation, there was no significant difference ($t(39)= -1.18$, $p= .24$) between the multiple texts on the topic of chocolate (*M*= 4.80, *SD*= 1.45) and the single text on the topic of coffee (*M*= 4.55, *SD*= 1.41). To account for the difference in prior knowledge, this variable was added to the analysis of hypothesis 1 as a covariate.

Table 5

Correlations between the predictors used in the hierarchical regression analysis to predict multiple text reading proficiency, and motivation and prior knowledge of the single text (n= 40)

Predictors	1.	2.	3.	4.	5.	6.	7.
1. Multiple texts reading proficiency	-						
2. Single text reading proficiency	-.21	-					
3. Prior knowledge (multiple texts)	-.14	.17	-				
4. Use of reading strategies	-.23	.16	.37*	-			
5. Prior knowledge (single text)	-.18	.02	.85**	.37*	-		
6. Motivation (multiple texts)	-.17	.11	.40*	.56**	.30	-	
7. Motivation (single text)	-.18	-.09	.21	.44**	.35*	.57**	-

*Note *p< .05*

As can been seen in Table 5, use of reading strategies correlated positively with the prior knowledge and motivation of both the single text and the multiple texts. Furthermore, the prior knowledge of the single text correlated positively with the motivation for the single text (but did not correlate with the motivation for the multiple texts). Similarly, the prior knowledge of the multiple texts correlated positively with the motivation for the multiple texts (but did not correlate with the motivation for the single text). There were no significant correlations between the dependent variable (multiple texts reading proficiency) and any of the predictors. Similarly, single text reading proficiency did not correlate with any of the other predictors.

Single text and multiple texts reading proficiency: repeated measures Ancova

To investigate single text and multiple texts reading proficiency (hypotheses 1), a Repeated Measures Ancova was conducted, with percentage overlap as dependent variable, and the within-factors Text Type (Single text reading / Multiple texts reading) and Compared Model (Linear model / Expert model) as independent variables. In addition, the variable prior knowledge was controlled for by adding its difference scores (prior knowledge of the multiple texts minus prior knowledge of the single text) as a covariate in the analysis.

The results indicated that there were main effects of Compared Model ($F(1, 37) = 74.66$, $p < .05$, $\eta_p^2 = .66$) and Text Type ($F(1, 37) = 92.34$, $p < .05$, $\eta_p^2 = .71$) on the overlap scores. To determine whether the difference in prior knowledge between the single text and multiple texts was of influence, the interaction of its difference scores with the variable Text type was relevant. The interaction between (difference in) Prior knowledge and Text type was not significant ($F(1, 37) = 0.17$, $p = .69$, $\eta_p^2 = .00$).

In addition, there was a significant interaction between Compared Model and Text Type ($F(1, 37) = 29.13$, $p < .05$, $\eta_p^2 = .43$), as depicted in Figure 9. Follow-up analyses using paired samples t-tests showed that for the comparison with the linear model there was no difference between single text and multiple texts reading ($t(39) = 1.34$, $p = .19$, $d = 0.21$). For the comparison with the expert model participants scored lower in the multiple texts reading condition than in the single text reading condition ($t(39) = 12.30$, $p < .05$, $d = 1.94$). When comparing within text type, there was no difference for single text reading in overlap between the linear and expert model ($t(39) = 1.36$, $p = .18$, $d = 0.21$), but for multiple texts reading participants scored lower on overlap with the expert model than with the linear model ($t(39) = 13.20$, $p < .05$, $d = 2.09$).

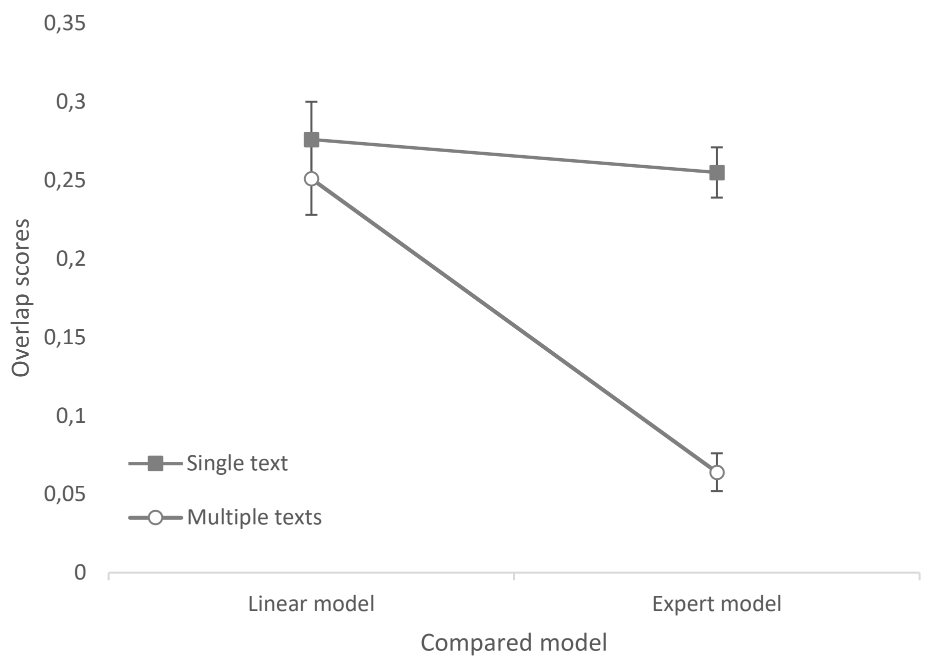

Figure 9. Graph of the interaction effect between Compared model (Linear model/ Expert model) and Text type (Single text reading/ Multiple texts reading)

Multiple texts reading proficiency and reading factors: hierarchical regression analysis

To investigate the relationship between single text reading proficiency, prior knowledge, use of reading strategies, and multiple texts reading proficiency (hypothesis 2), a hierarchical multiple regression analysis was conducted. The results of the hierarchical regression can be found in Table 6. The dependent variable was multiple texts reading proficiency (i.e., overlap of the participant's model of the multiple texts with the average expert model of the multiple texts). In the first step, single text reading proficiency (overlap with the expert model of the single text) was added to the model. This model was not significant (p= .19, R^2= .04, ΔR^2= .02). In the second step, prior knowledge (of the multiple texts) and use of reading strategies were added to the model. This model also was not significant (p= .36, R^2= .09, ΔR^2= .01).

Table 6

Results of the hierarchical regression predicting multiple texts reading proficiency (n= 40)

Predictor	ΔR^2	*B*	*SE B*	*β*
Step 1	.02			
Constant		0.09	0.02	-
Single text reading proficiency		-0.10	0.07	-0.21
Step 2	.01			
Constant		0.13	0.04	-
Single text reading proficiency		-0.08	0.08	-0.17
Prior knowledge		-0.00	0.01	-0.05
Use of reading strategies		-0.01	0.01	-0.19
Total adjusted ΔR^2	.03			

Note. ***$p < .001$, **$p < .01$, *$p < .05$

Discussion

The current study aimed to extend our understanding of multiple texts reading by investigating the relationship among multiple texts reading proficiency, single text reading proficiency, prior knowledge, and use of reading strategies in adult readers. It was found that adult readers' knowledge models resembled a linear model more than an expert model, and, on average, showed lower multiple texts reading than single text reading proficiency. Single text and multiple texts reading did not differ from each other in overlap with the linear model, but in overlap with the expert model multiple texts reading got worse (while single text reading remained the same). Furthermore, single text reading proficiency, prior knowledge, and use of reading strategies were found not to predict multiple texts reading proficiency.

Contrary to what was expected in hypothesis 1, the knowledge models of adult readers were more similar to the linear models than the expert models. This result is not what would be expected based on the model of Perfetti and Stafura (2014) and the fact that the participants in general were highly educated and expected to be proficient at reading even for texts of greater complexity. However, the result is in line with Kervin et al. (2018) and Salmerón et al. (2018), who stated that readers of all levels encounter problems in a complex reading task. In earlier studies using the pathfinder method (Fesel et al., 2015; Raudszus et al., 2019), it was found that children's knowledge models resembled a linear model more than an expert model. In these studies, it was concluded that the likely reason was the low age and reading level of the children, as well as their prior knowledge. The results of the current study suggest, however, that it might especially be unfamiliarity with the domain of the text that makes readers' knowledge models resemble a linear model more than an expert model. One of the criteria for participation in the current study was having little knowledge about the domain (not having any education in chemistry after secondary school). This theory fits with the notion of Afflerbach (1990) that experts easily access and apply schemata when they read a text about a familiar topic. Readers who have no or limited knowledge about the text they are reading do not have these well-developed schemata and this would likely result in them organising and storing information differently than experts would do.

In accordance to what was predicted in hypothesis 1, the readers showed lower multiple texts reading proficiency than single text reading proficiency. This suggests that integration of information from multiple texts is indeed more difficult (i.e., demands more of the reader, for instance in skills) than integrating information within a single text. This finding fits with the predictions based on the MD-TRACE model (Rouet & Britt, 2011) and the Documents model (Britt & Rouet, 2012).

Regarding the second research question, it was found that multiple texts reading proficiency was not predicted by single text reading proficiency. Single text and multiple texts reading proficiency did not correlate with each other. This was a surprising finding. These results suggest that some readers are better at single text reading (relative to other adult readers), and some are better at multiple texts reading (relative to other adult readers). This is in contrast to what would be expected based on the fact that the reading of multiple texts also comprises reading a single text.

It might be the case that single text reading and multiple texts reading are more different in their process than they are currently considered to be. It could for instance be that readers interpret reading one (online) text as a different reading situation than reading multiple texts. Schilit, Price, Golovchinsky, Tanaka, and Marshall (1999) wrote that a single text is often read in the context of studying and reviewing, while multiple texts are often read in the context of researching and surveying a field. These reading situations (partly) require different reading behaviour; a single text might be read more intensively, while multiple texts might be scanned and skimmed more (especially in the first encounter with texts on a topic). In this light, the result that single text reading does not predict multiple texts reading is less surprising, as proficiency in reading intensively does not necessarily predict proficiency in scanning and skimming. Future research could look into this further, by looking specifically at the reading behaviour readers show during online single text and multiple texts reading (this could for instance be studied by self-reporting or with use of technologies like eye-tracking).

Prior knowledge also did not predict multiple texts reading proficiency, in contrast to what was expected in hypothesis 2. This does not fit with the findings of Barzilai and Strømsø (2018) and Bråten et al. (2014), who found that prior knowledge is a major factor in (multiple texts) reading understanding. However, the finding in the current study could be explained based on the observation of Kendeou and Van Den Broek (2007) that prior knowledge does not by definition consist of 'true' or 'beneficial' knowledge or beliefs, it can also be the case that readers hold misconceptions. If this is the case, this 'prior knowledge' can have a negative effect on comprehension. This is especially true for scientific texts, as many people possess erroneous intuitions about how scientific phenomena can be explained (Britt, Richter,

& Rouet, 2014). As prior knowledge was measured in this study by self-reporting, correct knowledge could not be distinguished from misconceptions. Therefore, it is possible that the prior knowledge of the participants hindered their understanding more than promoted it.

Lastly, contrary to hypothesis 2, use of reading strategies was also found to not predict multiple texts reading proficiency. This is not what would be expected based on the research of Cho (2014), Caverly et al. (2004), Leu et al. (2016), and Bråten et al. (2014). However, a core aspect of effectively using reading strategies is adapting the strategy use to the context (see e.g., Anmarkrud et al., 2013; Hock & Mellard, 2005). If the participants indeed used much scanning and skimming reading behaviour in the multiple texts, the strategies asked in the questionnaire might not have been useful for integrating and understanding the texts (the strategies were more in line with intensive reading behaviour). In that case, the reading strategies would not be expected to predict multiple texts reading proficiency.

It could also be the case that there was an effect of reading strategies, but that it did not show up in the data. Afflerbach et al. (2008) stated that readers are particularly prone to using reading strategies when they perceive a text or reading task to be complex. The participants who were most likely to consider the texts as quite difficult will probably have been the ones with the poorest reading skills or familiarity with the topic (and therefore be the ones who initially would be expected to score the lowest on multiple texts understanding). Therefore, they might use relatively more strategies than participants who already know more about the topic or have better reading skills (who would consequently consider the texts as being less complex). This could result in a compensation effect, in which both types of readers would end up getting approximately the same scores on multiple texts reading proficiency, which could result in use of reading strategies not emerging as a factor. This kind of compensation effect was also observed in the study of Strømsø et al. (2003).

The current study has some limitations. First, there was no measure of how much attention the participants paid to the texts and the tasks while they were reading them. As a consequence, it cannot be determined with certainty whether a participant had a low reading comprehension score (in the single text/ multiple texts) because he or she did not have the ability to integrate the information better, or because he or she did not pay enough attention to accurately integrate the information from the text(s). In addition, the way in which the pathfinder method was used in the current study did not allow for self-selection of the terms. Consequently, the method could only make a judgement on understanding on a pre-defined learning goal. In a more natural context of multiple texts reading, however, it is often the case that readers formulate a reading goal themselves and change this goal during the reading process (Cho & Afflerbach, 2015; Rouet & Britt, 2011). In this case it would not be possible to compare the knowledge models with experts' models, however. There also was no typically used, standardised measurement of reading ability, which would have made it possible to compare the estimation of reading comprehension by the pathfinder method to a more commonly used measurement of reading comprehension.

One further limitation is the assumption of the pathfinder method that proximity data can capture the links between different concepts in a knowledge model. When there is a contradiction between concepts it can be questioned whether relatedness or similarity is still a good measure. Contradictions, by nature, have most of their features in common, except for one or a few. For example: light and dark are considered opposites but they both have to do with saturation of light, the flow of time, and contrast, and are abstract rather than concrete. Are these concepts highly related or not related at all? They appear to be both. This poses challenging questions for the pathfinder method as a way to capture complex knowledge models. In future research it would be interesting to let readers label the links in the pair-wise comparison task or in their resulting pathfinder model (labels could for example be 'is caused by' or 'is the opposite of'). This could give insight into what readers consider to be 'related'.

Interesting directions for future research could be to compare single text and multiple texts reading for texts that are relevant to the readers (for example texts they have to read for a course). This would offer the chance to observe the reading of texts in a more authentic and natural situation, in which the students presumably would also be more motivated to understand the texts. It would also be interesting to look at texts of different levels of difficulty. This would give insight into whether readers (on average) always experience more difficulty in integrating multiple texts than a single text, or whether this effect only arises in more challenging texts. Furthermore, as the current study provided evidence for that multiple texts reading demands more from readers than single text reading but failed to identify the factors that make it so, future research in other factors might be warranted. This could for instance be factors such as metacognition or self-efficacy, as put forward by Afflerbach et al. (2013).

Conclusion

The current study showed that the knowledge models of highly educated adult readers created in reading more complex texts resembled a linear model more than an expert model. Furthermore, it showed that the knowledge models of single text reading and multiple texts reading of adult readers differ from each other. Adult readers were shown to have a harder time understanding information coming from multiple texts than information within a single text. Lastly, prior knowledge and use of reading strategies were shown not to be the major factors contributing to multiple texts reading proficiency (in the current study). The implication of these findings is that single text reading skills do not fully transfer to multiple texts reading skills. For educational practice this means that if the goal is to make readers (also) proficient in processing information from different texts (and therewith online information), multiple texts reading should be learned or taught in addition to single text reading.

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Appendix A: Single texts Google-like environment and texts

Figure 1. Google-like environment of single text 1

Figure 2. Google-like environment of single text 2

FOOD-INFO

Since 1999

Aangepast zoeken Zoek

Home Wetenswaar Onderwerpen Vragen en antwoorden Producten E-nummers Over Food-Info Contact Links

Wat zit er in koffie?

Koffie bevat meer dan achthonderd verschillende componenten, die met elkaar de smaak en de geur bepalen. Koffie (zonder suiker en melk), is een caloriearme drank, die hoofdzakelijk uit water en kleine componenten bestaat. Hiertoe behoren o.a. cafeïne, cafestol en kahweol.

Koffiebonen

Het geslacht Coffea heeft drie soorten, die bonen leveren voor het maken van koffie: Coffea arabica (Arabische koffie), Coffea canephora (Congo koffie of robusta koffie) en Coffea liberica (Liberische koffie). De eerstgenoemde soort is de belangrijkste koffieleverancier. Van de geproduceerde koffie op de wereld bestaat 74% uit Arabische koffie, 24% uit robusta koffie en de rest is Liberische koffie. Coffea arabica en Coffea canephora zijn kwalitatief en kwantitatief verschillend in hun chemische compositie: arabica bonen bevatten minder cafeïne (1.2% van het droge gewicht van de bonen voor arabica bonen, 2,2% voor robusta bonen) en meer olie (16.0% voor arabica bonen, 10.0% voor robusta bonen).

Cafeïne

Cafeïne is een alkaloïde die van nature voorkomt in koffie en in kleinere hoeveelheden in thee en coladranken. Omdat het een stof is die wereldwijd veel wordt gebruikt, hebben onderzoekers er ook veel studie naar gedaan. Cafeïne heeft een licht stimulerend effect op het centraal zenuwstelsel, wat resulteert in verhoogde concentratie en alertheid. De stof wordt snel via de maag en dunne darm opgenomen in de bloedbaan en heeft effect na zo'n 15 minuten. Na ongeveer 5 uur is de helft van alle cafeïne die is opgenomen weer uit het lichaam verdwenen, afgebroken door de lever of uitgescheiden via de urine. Onderzoek heeft aangetoond dat cafeïne de alertheid, leerprestaties en de reactiesnelheid verbetert. Cafeïne in overmatige hoeveelheden kan leiden tot rusteloosheid, beven, duizeligheid, suizende oren en hartkloppingen. Ook moeilijk in slaap vallen is een bekend effect.

Kahweol en Cafestol

Koffiebonen bevatten vet, het zogenaamde koffievet. Dit vet wordt met het hete water uit de bonen geëxtraheerd en komt als kleine vetdruppeltjes in de koffie terecht. Cafestol en kahweol zijn zulke vetten. Beide stoffen behoren tot de zogenoemde terpenoïden. Ze verhogen in beperkte mate het cholesterolgehalte van het bloed. Bij filterkoffie, gezet met een papieren filter zoals in Nederland gebruikelijk is, blijven deze stoffen echter in het filter achter. Mensen met een verhoogd cholesterolgehalte doen er daarom goed aan te kiezen voor koffie die is gezet met een papieren filter of voor oploskoffie. Ook cafeïnevrije koffie heeft geen invloed op het cholesterolgehalte van het bloed.

Manieren van zetten

Filterkoffie
In Nederland wordt koffie meestal gezet met een koffiefilter. Die koffie bevat weinig cholesterolverhogende stoffen, omdat het papieren filter het koffievet tegenhoudt.

Cafetière-koffie
Kookkoffie, ook wel cafetière-koffie genoemd, bevat veel cholesterolverhogende stoffen. Voor cafetière-koffie wordt gebruik gemaakt van een metalen filter dat naar beneden gedrukt wordt. Deze filters houden het vet niet tegen, waardoor de cholesterolverhogende stoffen in de koffie terecht komen.

Senseo
Bij koffiezetten in een Senseo apparaat wordt niet veel druk opgebouwd en daardoor belanden weinig cholesterolverhogende stoffen in de koffie. Het grootste deel blijft bovendien achter in het papieren filter.

Niet alleen de bereidingswijze is van belang, ook de soort koffie is van belang. De groeicondities van de plant bepalen hoeveel kahweol en cafestol gevormd worden. Arabica bonen bevatten bijvoorbeeld meer terpenoïden dan robusta bonen. De verschillen tussen de verschillende rassen zijn echter vrij klein. Bovendien is de meeste koffie in de supermarkt een mengsel van verschillende rassen en afkomstig uit verschillende landen.

Cafeïnevrije koffie

De eerste succesvolle poging om cafeïne uit koffie te extraheren werd gedaan door de Duitse scheikundige Runge in 1820. De methode van decafeïneren bestaat eruit de groene koffiebonen te behandelen met een oplosmiddel en vervolgens de bonen te scheiden van het oplosmiddel waarin de cafeïne opgelost is. In één methode worden de groene bonen onder druk behandeld met stoom. Bij deze behandeling zwellen de bonen op, waardoor hun oppervlakte groter wordt. Hierdoor wordt het makkelijker de cafeïne uit de bonen te halen. De volgende stap is het onder druk extraheren van de cafeïne met een oplosmiddel, net onder het kookpunt van het oplosmiddel. In het ideale geval verwijdert het oplosmiddel alleen de cafeïne, en geen andere bestanddelen. Na het decafeïneren blijft slechts een klein deel van de cafeïne over in de koffie. Oplosmiddelen die tegenwoordig vaak gebruikt worden zijn methyleenchloride en ethylacetaat. Een andere methode is om 'superkritisch' gas (gas onder hoge druk) te gebruiken.

Begrippen

Alkaloïden: deze stoffen zijn giftig. In de meeste gevallen van alkaloïde vergiftiging is er matige tot ernstige schade aan de lever. Planten die alkaloïden bevatten maken geen deel uit van een traditioneel Europees dieet.

Centraal zenuwstelsel: hersenen en ruggenmerg.

Auteurs

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Annemarie Zuur, student Master of Science programma Nutrition and Health (Voeding en Gezondheid) , Wageningen Universiteit

Figure 3. Single text 1, based on a text written by Nynke Bergsma and Annemarie Zuur

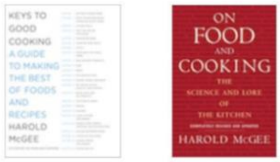
DE NIEUWSGIERIGE KOK

ONDERZOEK DE WETENSCHAP EN TRANSFORMATIE VAN ETEN MET HAROLD MCGEE

HOME | HAROLD MCGEE | KOKEN: GEHEIMEN | INGREDIËNTEN | PROCESSEN | CONTACT

Wat zit er in koffie?

zoek



Ontvang updates van de Nieuwsgierige Kok per email

Uw emailadres | Abonneer

Koffiebonen bevatten cafeïne, een bitter alkaloïde dat sterk op ons lichaam inwerkt. Koffie begint als zaad, een opslagplaats van eiwitten, koolhydraten en olie, en is het resultaat van hoge hitte: de robuuste belichaming van gebrande ingrediënten en smaken. Er zijn meer dan 800 geurcomponenten geïdentificeerd.

Koffiebonen: Arabica en robusta

Koffiebonen zijn de zaden van twee soorten van een tropische verwant van de gardenia: de Coffea arabica en de Coffea canephora. Ongeveer twee derde van de wereldhandel bestaat uit arabica bonen, die complexer zijn en evenwichtiger smaken dan robusta bonen. Arabica bevat minder cafeïne (minder dan 1,5% van het gewicht van droge bonen, tegen 2,5% bij robusta), meer olie (16% tegen 10%) en meer suiker (7% tegen 3,5%). De robusta-soorten traden pas op de voorgrond toen hun betere weerstand tegen ziekten van belang werd in Indonesië en elders.

Cafeïne

Cafeïne is een chemische stof die het gedrag beïnvloedt, en als zodanig de meest genuttigde ter wereld. Het is een alkaloïde met een verstorende werking op een bepaald signaleringssysteem van allerlei verschillende cellen, en heeft dus ook allerlei verschillende gevolgen voor het menselijk lichaam. Cafeïne stimuleert in de allereerste plaats het centraal zenuwstelsel, gaat slaperigheid en vermoeidheid tegen, en bevordert de reactiesnelheid. Het stimuleert ook de energieproductie in de spieren, en dus uw vermogen om iets tot stand te brengen. Het verbetert, naar het schijnt, uw humeur en geestelijke prestaties. Cafeïne bereikt een maximaal gehalte in het bloed tussen een kwartier en 2 uur na de consumptie, en dat gehalte wordt in 3-7 uur weer tot de helft afgebroken. Minder wenselijk is dat een grote dosis cafeïne rusteloosheid, nervositeit en slapeloosheid veroorzaakt. De stof heeft ingewikkelde gevolgen voor hart en bloedvaten, en kan tot een onnatuurlijk snelle hartslag leiden.

Kahweol en Cafestol

Bepaalde vormen van gezette koffie blijken ongewenste gevolgen voor het cholesterolgehalte in ons bloed te hebben. Dat komt door de twee lipiden (vetachtige stoffen) cafestol en kahweol, maar die komen alleen in de koffie terecht als ze er niet uitgefilterd zijn. Ze zitten dus bijvoorbeeld in boerenkoffie, koffie uit een cafetière en espressokoffie. Het belang van dat effect is niet bekend, want de cholesterolverhogers gaan vergezeld van een grote hoeveelheid stoffen die verhinderen dat het cholesterol oxideert en schade aanricht.

Manieren van zetten

Er zijn allerlei manieren om koffie te zetten. De meeste ervan extraheren 20-25% van de stoffen in de boon en geven een kop koffie die voor 1,3-5,5% van zijn gewicht uit vaste stoffen uit de boon bestaat. Normale Amerikaanse filterkoffie is de slapste, Italiaanse espressokoffie de sterkste. In Amerikaanse koffie zit 15 maal zoveel water als koffie, in Italiaanse 5 maal zoveel. Elke zetmethode heeft haar nadelen. Een percolator werkt met kokend water en extraheert vaak te veel. Veel automatische filterapparaten kunnen geen water leveren dat heet genoeg is; ze compenseren dat met een langere zettijd, maar daarbij gaat geur verloren en wordt bitterheid geëxtraheerd. Handmatige filterpotten maken de beheersing van de extractietijd moeilijk. In een cafetière blijft een suspensie van kleine deeltjes in de koffie achter, en die blijven bittere stoffen afstaan.

Cafeïnevrije koffie

Decafé is rond 1908 in Duitsland uitgevonden. Het wordt gemaakt door groene koffiebonen in water te weken om de cafeïne op te lossen, de cafeïne aan de bonen te onttrekken door ze met een oplosmiddel (methyleenchloride, ethylacetaat) te behandelen, en ze te stomen om de restanten van het oplosmiddel te laten verdampen. Bij het 'Zwitserse' procedé is water het enige oplosmiddel; de cafeïne wordt met koolstoffilters uit het water verwijderd, en de andere in water oplosbare stoffen worden dan weer aan de bonen toegevoegd. Men vermoedt dat de restanten van sommige organische oplosmiddelen die bij andere procedés gebruikt worden, zelfs in kleine hoeveelheden (rond 1 deel per miljoen) schadelijk voor de gezondheid zijn, maar het meest gebruikte middel – methyleenchloride – geldt tegenwoordig als veilig. Sinds enige tijd wordt onder hoge druk ('superkritisch') niet-giftig koolzuur gebruikt. Een gewoon kopje koffie bevat 60-180 milligram cafeïne, een kopje cafeïnevrije koffie 2-5 milligram.

Alkaloïden

Alkaloïden zijn bittere stoffen die in planten zijn ontstaan in ongeveer dezelfde tijd dat de zoogdieren ontstonden, en zowel door hun smaak als door hun uitwerking zijn ze bijzonder geschikt om juist onze tak van het dierenrijk af te schrikken. Bijna alle bekende alkaloïden zijn in hoge doses giftig, en de meeste leiden in lagere doses tot een verandering van de dierlijke spijsvertering. Van de normale consumptieplanten kunnen alleen aardappels een potentieel schadelijke hoeveelheid alkaloïden bevatten: het zijn de stoffen die groen uitgeslagen aardappels en de uitlopers van aardappels bitter en giftig maken.

Auteur

McGee, H. Uit: Over eten en koken. Wetenschap en overleving in de keuken. Derde druk. 2001. Vertaald uit het Engels. 433-447.

Figure 4. Single text 2, based a text written by Harold McGee

Appendix B: Multiple texts Google-like environment and texts

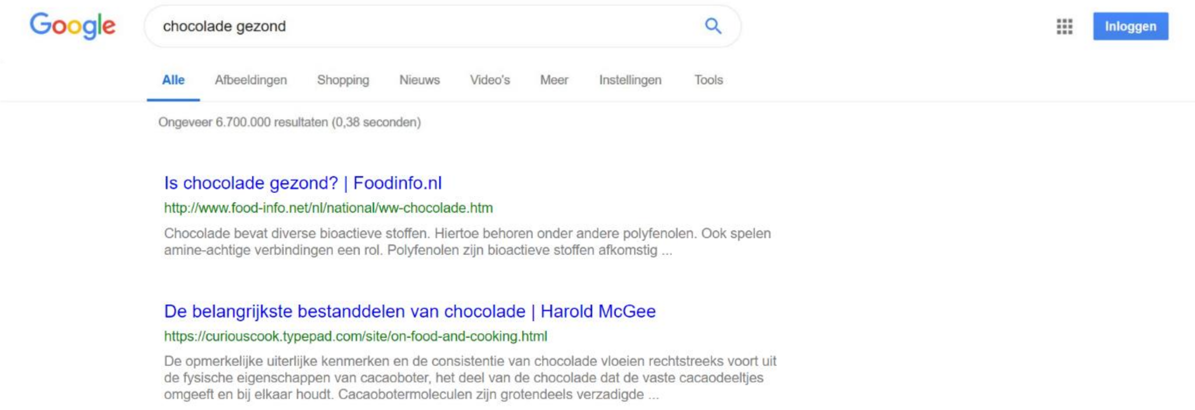


Figure 1. Google-like environment of the multiple texts

FOOD-INFO

Since 1999

Aangepast zoeken Zoek

Home Wetenswaar Onderwerpen Vragen en antwoorden Producten E-nummers Over Food-Info Contact Links

Is chocolade gezond?

Werkzame stoffen chocolade

Chocolade bevat diverse bioactieve stoffen. Hiertoe behoren onder andere polyfenolen. Een ander voorbeeld van bioactieve stoffen in chocolade is amine-achtige verbindingen. Polyfenolen zijn bioactieve stoffen afkomstig uit het plantenrijk. De belangrijkste groep van polyfenolen wordt gevormd door de familie van de flavonoïden. Polyfenolen hebben een antioxiderende werking op het lichaam. Hierdoor beïnvloeden polyfenolen de kwaliteit en de stabiliteit van het levensmiddel. Uit onderzoek blijkt dat polyfenolen door de antioxiderende werking wellicht ook de kans op hart- en vaatziekten verkleinen. Een antioxidant beschermt het lichaam namelijk tegen vrije radicalen. Dit zijn reactieve, schadelijke stoffen die in het lichaam gevormd kunnen worden en mogelijk een rol spelen bij het ontstaan van ziekten als hart- en vaatziekten en kanker. Verschillende soorten chocolade bevatten verschillende hoeveelheden fenolen. Witte chocolade bevat bijvoorbeeld geen vaste cacaodeeltjes, waardoor de naam chocolade niet geheel op zijn plaats is. Witte chocolade is eenvoudig het mengsel van cacaoboter, vaste melkbestanddelen en suiker.

Witte uitslag op chocolade

Chocolade slaat na een lange bewaartijd wit uit aan de buitenkant. Dit wordt veroorzaakt doordat het vet in de chocolade zijn oorspronkelijk volledige verspreiding verliest en samenklontert. De witte laag is de cacaoboter die naar de oppervlakte is gekomen en door kristallisatie uit het chocolademengsel is getreden. Overigens kan deze chocolade gewoon gegeten worden, deze is niet bedorven. Er is hier alleen sprake van een achteruitgang van de kwaliteit.

Begrippen

Antioxidanten: verbindingen die in het lichaam vrije radicalen onschadelijk kunnen maken.

Bioactieve stoffen: alle stoffen, die een bepaalde biologische activiteit of functie hebben. Het gaat meestal om de groep van stoffen die van nature voorkomt in producten of kunstmatig wordt toegevoegd aan voedingsmiddelen of supplementen en voor de mens een gezondheid bevorderend effect heeft, maar niet essentieel is.

Fenolen: tot de fenolen behoren onder andere de flavonoïden, een groep van stoffen afkomstig van planten.

Flavonoïden: flavonoïden vormen een grote familie van plantaardige stoffen. Ze bepalen in groenten en fruit de grote variatie in kleuren en hebben een antioxiderende werking.

Vet: Vet, of beter gezegd, de vetzuren, kan worden ingedeeld in drie hoofdtypen. De chemische structuur van verzadigde vetzuren is geheel verzadigd met waterstofatomen, die van enkelvoudig onverzadigde vetzuren mist één waterstofatoompaar, en die van meervoudig onverzadigde vetzuren mist meerdere waterstofatoomparen.

Vrije radicalen: moleculen met één of meer ongepaarde elektronen, die oxidatieve schade kunnen aanrichten in het lichaam.

Auteurs

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Figure 2. Multiple text 1, based on a text written by Nynke Bergsma and Annemarie Zuur

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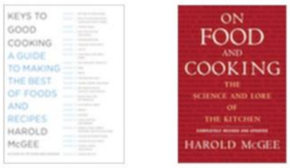
De belangrijkste bestanddelen van chocolade

zoek



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Cacaoboter

Het uiterlijk en de consistentie van chocolade vloeien voort uit de fysische eigenschappen van cacaoboter, het deel van de chocolade dat de vaste cacaodeeltjes omgeeft en bij elkaar houdt. Cacaobotermoleculen zijn grotendeels verzadigde vetten met een regelmatige structuur (de meeste zijn opgebouwd uit slechts drie vetzuren). Die structuur betekent dat de vetmoleculen een dicht netwerk van compacte, stabiele kristallen kunnen vormen, waarbij weinig vloeibaar vet overblijft dat tussen de kristallen kan wegsijpelen

Vetten en antioxidanten

Cacaobonen zijn net als alle andere zaden rijk aan voedingsmiddelen. Ze zijn vooral rijk aan verzadigde vetten, en die zijn berucht omdat ze het cholesterolgehalte in het bloed laten stijgen, en dus de kans op een hartaandoening vergroten. Veel van het verzadigde vet in cacaoboter is echter een vetzuur dat het lichaam meteen omzet in een onverzadigd vet. Het eten van chocolade geldt dus niet als gevaarlijk voor het hart, en kan zelfs gunstig zijn. Cacaodeeltjes zijn een buitengewoon goede leverancier van antioxiderende fenolen, die 8% van het cacaogewicht uitmaken. Hoe hoger het gehalte aan vaste cacaobestanddelen in chocolade of snoepgoed, des te hoger het gehalte aan antioxidanten.

Verschillende soorten chocolade

Uit wat voor bestanddelen chocolade bestaat en in wat voor verhouding hangt af van het soort chocolade. Donkere chocolade bevat vaste cacaobestanddelen, cacaoboter en vaak suiker, maar geen vaste melkbestanddelen. Hoe hoger het aandeel van de vaste cacaobestanddelen, des te intenser de chocoladesmaak, inclusief het bittertje en de wrangheid. Chocolade met een sterke smaak geeft ook meer smaak aan mengsels van room, eieren en bloem; de eiwitten van die andere ingrediënten binden zich aan de fenolen en dringen de wrangheid terug. Melkchocolade is de populairste vorm van chocolade. Het product bevat vaste melkbestanddelen en veel suiker, die samen de combinatie van cacao en cacaoboter overheersen. Vanwege het lage cacaobotergehalte is melkchocolade vaak zachter dan bitterzoete chocolade.

Fenolen

Fenolen zijn opgebouwd uit een simpele, dichte ring van zes koolstofatomen en minstens één fragment van een watermolecuul (een zuurstof/waterstofcombinatie). Afzonderlijke ringen kunnen worden aangepast door aan een of meer koolstofatomen andere atomen te hangen, en twee of meer ringen kunnen onderling verbonden worden tot polyfenolen. De geur van fenolen is makkelijk te herkennen; ze bepalen bijvoorbeeld de smaak van kaneel en vanille.

Auteur

McGee, H. Uit: Over eten en koken. Wetenschap en overleving in de keuken. Derde druk. 2001. Vertaald uit het Engels. p 686-703.

Figure 3. Multiple text 2, based a text written by Harold McGee

Appendix C: Use of Reading Strategies questionnaire

1. Ik probeerde de componenten, processen en effecten op de gezondheid van chocolade te begrijpen door de inhoud van de verschillende teksten te vergelijken
2. Ik probeerde op te letten of de teksten elkaar tegenspraken
3. Ik probeerde te achterhalen hoe de inhoud van de verschillende teksten samenhing
4. Ik probeerde ideeën te vinden die in beide teksten voorkwamen
5. Ik ging na of de teksten tegensprekende informatie bevatten
6. Ik overwoog of verschillende verklaringen van of chocolade goed is voor de gezondheid met elkaar verzoend konden worden
7. Ik probeerde verschillende causale verklaringen van de invloed van chocolade op de gezondheid met elkaar te vergelijken
8. Ik probeerde inhoud van verschillende teksten samen te vatten
9. Ik probeerde de relatie tussen de componenten, processen en effecten op de gezondheid van chocolade na te gaan
10. Ik probeerde een compleet beeld te krijgen van de componenten en processen van chocolade die meespelen in of chocolade gezond is of niet
11. Ik focuste me erop zoveel mogelijk feitelijke informatie uit beide teksten te onthouden
12. Ik probeerde vooral zoveel mogelijk informatie uit de teksten te halen
13. Terwijl ik de verschillende teksten las, probeerde ik zoveel mogelijk feitelijke informatie te verzamelen
14. Ik probeerde zo veel mogelijk te onthouden uit beide teksten
15. Ik probeerde zo goed mogelijk datgene te onthouden waarvan ik dacht dat het belangrijk was in de verschillende teksten