Webpage reading: Psychophysiological correlates of emotional arousal and regulation predict multiple-text comprehension

Full length article

Webpage reading: Psychophysiological correlates of emotional arousal and regulation predict multiple-text comprehension

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Abstract

This study aimed to investigate psychophysiological responses while reading multiple webpages on a debated topic. We measured heart rate (HR) as an index of emotional arousal and heart rate variability (HRV) as an index of emotional regulation. Forty-seven lower secondary school students in grade 7 read four webpages varying for reliability and position on the topic of the potential health risks associated with the use of mobile phones, while their cardiac activity was registered. Post-reading performance of multiple-text comprehension at intertextual level was measured by an essay, which was coded for sourcing (reference to the source information and connection with its content) and argumentation on the topic. Results showed that the type of webpage did not differentiate HR and HRV while reading. However, HR and HRV predicted comprehension across texts as reflected in argumentation, after controlling for prior knowledge and reading comprehension. Specifically, HR was a negative predictor and HRV a positive predictor; the less the students were emotionally reactive to the content read and the more they were able to self-regulate while reading, the greater their multiple-text comprehension, such as the ability to argue about the debated topic. Theoretical and practical contributions of the study are discussed.

Keywords: Online multiple-text comprehension; Emotion; Emotion regulation; Psychophysiological correlates; Digital reading

1 Introduction

Reading online multiple texts is a common activity for todays' students who search the Web for various purposes, among them school assignments. Internet has become “the” source of information, especially for unfamiliar topics, providing an unparalleled opportunity to access a huge number of sources in a global learning environment. However, this opportunity poses new challenges to students who read the Internet to acquire knowledge, as they must deal with multiple texts and understand information contained within and across texts (Brand-Gruwel & Gerjets, 2008~~,~~ (; Brand-Gruwel & Stadtler, 2011;) ~~2012,~~ Bråten, Anmarkrud, Brandmo, & Strømsø, 2014; Stadtler & Bromme, 2013).

Research on multiple-text comprehension has flourished in the last decade, concentrating on person-related cognitive factors (e.g., Barzilai & Eshet-Alkalai, 2015; Bråten & Strømsø, 2010; Mason, Ariasi, & Boldrin, 2011). Except for very few studies, the role of affective factors when reading multiple texts on the same topic has been neglected. In this regard the recent Cognitive Affective Engagement Model (CAEM) of multiple-source use has been proposed as a theoretical framework that unifies “cold” and “warm” perspectives in the comprehension of multiple texts (~~List & Alexander, 2017a, b~~)((List & Alexander, 2017a)). The “cold” perspective refers only to the cognitive processes involved in the complex task of constructing a coherent and integrated representation of a topic or issue from conflicting texts. The “warm” perspective takes into account affective and motivational factors that underlie multiple-text comprehension, as well as cognitive factors.

With the CAEM as theoretical reference, the present study focuses on affective factors, including emotional arousal and regulation at the physiological level as objective measures of emotional engagement while reading webpages (Sinatra, Heddy, & Lombardi, 2015). Psychophysiological correlates of a reading task have very rarely been examined in educational research on single-text comprehension (Daley, Willett, & Fischer, 2014; Scrimin, Patron, Ruli, Pagui, Altoè, & Mason, 2017(2018 (not 2017) like in the reference list.)) and not yet on multiple-text comprehension in secondary school students, who become daily "consumers" of information on the Internet.

To avoid ambiguity, it should be pointed out that in the current study self-regulation is identified as the basic ability to change or inhibit emotions and related thoughts, as reflected at the psychophysiological level (Appelhans & Luecken, 2006). Students' bio-behavioral responses to emotional materials reflect their emotion regulation (Butler, Wilhelm, & Gross, 2006; Davis & Levine, 2013), which is considered as a protective function against environmental challenges (e.g., El-Sheikh, Hinnant, & Erath, 2011). Therefore, unlike many educational studies, self-regulation is not considered in the multi-component perspectives that involve a variety of processes through which students are able to attain personal goals (e.g., Winne & Hadwin, 1988; Zimmermann & Schunk, 2011).

1.1 Cold and warm processing of multiple texts

Multiple-text comprehension involves more than just constructing the meaning of each single text, as described in the well-known models of text comprehension (e.g., Kintsch, 1998). The documents model was the first framework proposed to explain how students integrate information across a variety of texts to construct a unified representation of a specific topic or issue (Britt, Perfetti, Sandak, & Rouet, 1999). This model focuses on two representations that must be created to comprehend multiple documents – the intertext model and the mental model (Britt & Rouet, 2012). The intertext model refers to the representation of information about the sources, that is, author, type of document, purpose, date of publication, etc. The intertextual representation also links sources to content and the source-content link is essential to remembering who said what, and to discriminate biased source information from trustworthy information. Moreover, connections between source-content links are included in an intertext model by a source-source link, so that a good reader understands that there are multiple perspectives on a debated issue (e.g., should nuclear power plants be built?), with texts in agreement or disagreement with a particular perspective (e.g., pro or con nuclear power) (Bråten, Strømsø, & Britt, 2009; Kammerer, Amann, & Gerjets, 2015). In this regard, the term *sourcing* refers to the processes through which readers identify the metadata about a text or document (e.g., authors, publication date), evaluate, and use them (Goldman & Scardamalia, 2013; Scharrer & Salmerón, 2013).

The second representation included in the documents model (Britt et al., 1999) is an integrated mental model of the common issues or situations presented across texts. Such an integrated mental model allows readers to reconcile discrepancies across texts by taking into account document information and being able to coherently represent conflicting information.

As underlined by Bråten, Ferguson, Strømsø, and Anmarkrud (2014), an integrated mental model about scientifically controversial issues usually takes the form of an argument schema which includes a main claim about a stance on the controversy followed by supporting evidence. All other information in an argument is organized around the main claim in the form of supporting reasons, counter-oppositions, qualifiers, and rebuttals (Toulmin, 1958). Good arguments as integrated mental models across texts are expected to avoid one-sidedness and take into consideration conflicting perspectives (i.e., counterarguments) and evidence in their support (Kuhn, 1991).

The recent MD-TRACE (Multiple Document Task-based Relevance Assessment and Content Extraction, Rouet & Britt, 2011) framework focuses more analytically on the processes underlying multiple-text comprehension, that is, comparing, contrasting, and corroborating information across documents. These are the processes through which readers can identify consistencies and discrepancies between the contents read, and generate an integrated and unitary representation of a controversial issue.

Both the documents model (Britt et al., 1999) and the MD-TRACE (Rouet & Britt, 2011) share a cognitivist focus on multiple-text comprehension, which is considered as a series of cognitive processes and behaviors activated in a sequential and iterative way - in other words, cold cognition (~~List & Alexander, 2017a, b~~((List & Alexander, 2017b)). Very recently, ~~List and Alexander (2017a, b)~~(List and Alexander (2017a) Only a) proposed the Cognitive Affective Engagement Model (CAEM) of multiple-source use to unify cold (cognitive) and warm (affective) perspectives on the comprehension of multiple texts. CAEM conceives multiple-source use through a series of text processing behaviors, for example text selection and access of document information, which are driven by task or motivation factors. A poor performance in source use can be explained through skill or motivational deficits.

In this respect, the biased effects of prior attitude – a construct that has a cognitive and motivational nature – emerged on processing and evaluation of sources and information. In a study with high school students, those with a strong attitude on a controversial topic were more likely to write a biased essay that included larger proportions of information not presented in the reading materials, compared with students taking a neutral attitude (van Strien, Kammerer, Brand-Gruwel, & Boshuizen, 2014). In an eye-tracking study with university students, readers with a strong attitude toward a controversial topic paid less attention to the logos of the websites that included information inconsistent with their attitude compared to readers with a weak attitude. The former also evaluated these websites as less credible and reported more information consistent with their attitude in an essay (van Strien, Kammerer, Brand-Gruwel, & Boshuizen, 2016).

According to the CAEM, once students have defined a task in terms of its topic and expected cognitive products, four default stance profiles toward task completion may emerge on the basis of affective engagement and behavioral disposition: disengaged, affectively engaged, evaluative, and critical analytic (List & Alexander, 2016a, 2016b, 2017a, 2017b). On the one hand, if students are disengaged, they cannot process multiple sources deeply, but rather look for "the answer" with minimal cognitive effort. On the other hand, when students adopt a stance characterized by a strong affective engagement, they may be more limited in their critical processing of textual sources and

integration of their information, as an intense affective response may interfere with the latter. An evaluative stance requires students to have well-developed habits of source evaluation, which may be acquired by instructional interventions. Thus students are able to apply heuristics, but this does not guarantee deeper engagement with the complex task that implies resolution of conflicting information across texts and its integration.

A critical analytic stance to multiple source processing may be considered ideal. Yet, it is infrequent because it implies effective and efficient cognitive processes that are driven not only by skills and habits but also by affective dispositions (Muis et al., 2015; Trevors, Muis, Pekrun, Sinatra, & Muijselaar, 2017). The various default stances – included in the CAEM – may lead to different source use behaviors in terms of text processing and sourcing, which result in various levels of comprehension performance according to the degree of information manipulation (~~List & Alexander, 2017a, b~~((List & Alexander, 2017a). Only a)).

1.2 Psychophysiological emotional arousal and regulation

Considering the CAEM, in order to further our understanding of multiple-text comprehension, we examined emotional arousal and regulation at the psychophysiological level as objective measures of emotional engagement while reading webpages (Sinatra et al., 2015), which has rarely been examined in research on single-text comprehension (Daley et al., 2014; Scrimin et al., 2017(2018 (not 2017) like in the reference list.)). In educational research, students' emotions are usually assessed using self-reports (e.g., Frenzel, Pekrun, & Goetz, 2007; Goetz, Hall, Frenzel, & Pekrun, 2006; Pekrun, Lichtenfeld, Marsh, Murayama, & Goetz, 2017). There are two recent studies that have investigated the role of university students' self-reported epistemic beliefs and emotions when reading multiple conflicting texts. Both studies revealed the mediating role of emotions, which were predicted by epistemic beliefs, and related to learning outcomes (Muis et al., 2015; Trevors et al., 2017). However, despite their advantages, self-reports may not be able to accurately reflect students' affective responses to various situations, especially in younger students.

1.2.1 Heart rate

We used a psychophysiological measure of arousal that does not rely on participants' conscious attention, that is, heart rate (HR). Heart rate is an indicator of the primary responses of the autonomic nervous system, in particular the sympathetic nervous system. Depending on the stimulus, increases in HR reactivity may reflect either higher levels of emotional arousal or intense and challenging cognitions (Kreibig & Gendolla, 2014). It has been documented that HR reactivity is positively associated with fluid intelligence and perceptual reasoning in middle-school students (Gao, Borlam, & Zhang, 2015), cognitive ability in adults of different ages (Ginty, Phillipps, Der, Dery, & Carroll, 2011), and reading processes and outcomes in university students (Scrimin et al., 2017(2018 (not 2017) like in the reference list.)).

However, when emotional arousal is too high, cognitive performance may decrease (Valiente, Swanson, & Eisenberg, 2012). This may be particularly true when a task requires complex processing, such as multiple-text comprehension, which implies integrating relevant information. There is a progressive restriction in the number of cues that an individual is able to process as a function of an increase in arousal (Eysenck, 1982). According to the resource allocation model (Ellis & Ashbrook, 1988), high levels of psychophysiological arousal reduce the integration of relevant aspects during cognitive processing and, as a result, performance in a reading task may diminish. While reading emotionally engaging webpages, students that become over-aroused may have a lower performance when deep multiple-text comprehension is required. With this regard, recent research has indicated that high emotional reactivity – as reflected in electrodermal activity – to an emotionally negative school-related video impairs the ability to refer to source information, and to connect it to the content provided after reading a series of webpages with conflicting information on the same topic (Mason, Scrimin, Tornatora, & Zaccoletti, 2017). It should be noted that in this study, psychophysiological emotional arousal was measured before reading webpages, not as a response to the reading materials. It seems worth investigating whether HR *during* webpage reading – a very common task in the Internet era – also predicts deeper comprehension of multiple texts.

1.2.2 Heart rate variability

Heart rate variability (HRV), that is, the physiological variation in the interval between heart beats, is used to refer to self-regulation by the parasympathetic system (Kreibig & Gendolla, 2014). The parasympathetic system reduces heart rate, allowing energy regaining and storage, through the influence of the vagal nerve on the heart. That is, the vagal nerve acts as a "brake" (Porges, 2007). When it is activated, the cardiac system is slowed down and prevented from becoming overexcited. When the "brake" is removed, the cardiac system is activated and ready to respond. In other words, the more the vagal brake is activated and the learner is in a balanced state of concentration and calm, the more she can physiologically self-regulate and adapt to task requirements. Furthermore, increases and decreases in HRV reflect the application or withdrawal, respectively, of the vagal brake on sympathetic activation, and indicate changes in self-regulatory effort. For example, vagal suppression is common during psychological stress, indicating the withdrawal of parasympathetic activity (Beauchaine, Gatzke-Kopp, & Mead, 2007), whereas efforts to regulate emotion and behavioral response evoke an increase in HRV (Daley et al., 2014).

Hence, when arousal is high because the sympathetic nervous system is responding to emotionally engaging materials or stressful demands from the environment, the parasympathetic nervous system deactivates, withdrawing the vagal "brake" (Porges, 2007). In this state the student must make a great effort in her stress response, and has only limited resources available for learning. On the contrary, when the student is in a balanced state of calm and concentration, which is linked with psychophysiological self-regulation, she is able to select optimal responses to meet situational demands (Gross, 1998; Thayer & Lane, 2000), and is better able to comprehend multiple texts. A regulated psychophysiological emotional response (Appelhans & Luecken, 2006) is linked to better outcomes in terms of cognitive resources (Calkins & Keane, 2004) and performance in attention and memory tasks (Hansen, Johnsen, & Thayer, 2003; Thayer, Hansen, Saus-Rose, & Johnsen, 2009).

A study of single-text comprehension has used a cardiovascular index (respiratory sinus arrhythmia) of parasympathetic activity (the "brake") as a process measure while reading a passage. The pattern of physiological response predicted reading

comprehension measured by retelling. That is, better comprehenders were those who, after hearing the instructions, had a reduction, followed by an increase in the "brake" activity, reflecting a state of calm as a function of the self-regulated engagement process (Daley et al., 2014). In a very recent study on reliability judgments of a set of Internet sources in lower secondary school students, basal HRV was measured, that is, their dispositional self-regulation at rest. Results revealed that basal HRV positively predicted source evaluation (Mason, Scrimin, Tornatora, Suitner, & Moè, 2018). It would appear to be worth investigating whether HRV *during* webpage reading also predicts deeper comprehension of multiple texts.

1.3 The present study

Research on multiple-text comprehension has so far overlooked students' emotional arousal and regulation while reading conflicting sources. Yet, for school assignments, students may frequently access webpages that engage them emotionally, to some extent. It is therefore important to understand whether students' emotional response and the way they self-regulate at the psychophysiological level during webpage reading, contribute to multiple-text comprehension on a debated issue, such as the potential health risks associated with the use of mobile phones. In particular, we were interested in the role of emotion-related factors in lower secondary school students for three main reasons: (a) from sixth and seventh grades on they become almost daily "consumers" of online information for their homework, at least in our country; (b) due to their rapid hormonal changes, early adolescents are expected to be particularly sensitive to emotional content during information processing; (c) their emotion regulation at the psychophysiological level is therefore essential when performing cognitively demanding tasks.

To properly examine the role of psychophysiological correlates during webpage reading, some variables that may interfere with processes and outcomes of reading comprehension should be taken into account. In the current study we considered prior topic knowledge and reading comprehension as control variables. Prior topic knowledge was taken into account as it has been largely documented to be related to single (e.g., Mason, Tornatora, & Pluchino, 2015) and multiple-text comprehension (Bråten & Strømsø, 2010; Bråten et al., 2014). More specifically, as concerns the latter, recent research has shown that high school students value author expertise more when the topic is less familiar (Bråten, McCrudden, Stang Lund, Brante, & Strømsø, 2017). On the other hand, research has also indicated that readers use their prior knowledge not only for encoding and understanding new information, but also for monitoring its validity (Richter & Maier, 2017). Thus, it may happen that readers appeal to their preexisting topic knowledge and evaluate new information as less reliable when it is not aligned with what they already know (Richter, 2015).

The reason why single-text reading comprehension ability was also considered as a control variable is that multiple-text comprehension implies, first of all, the comprehension of a set of single texts, especially if students are still at different levels in this ability (Florit, Cain, & Mason, 2017). Research with elementary school children has provided evidence that higher comprehension ability is a resource in evaluating information sources during text comprehension (Macedo-Rouet, Braasch, Britt, & Rouet, 2013).

To fill the gap in current research on multiple-text comprehension, the study was guided by the research question: do HR and HRV while reading multiple webpages differing for reliability and position on a debated topic, predict multiple-text comprehension, after controlling for prior knowledge and reading comprehension?

Our hypotheses were rooted in the few educational studies about reading that used psychophysiological measures reviewed in the previous sections (Daley et al., 2014; Mason et al., 2017, 2018). Based on these studies, we hypothesized that both psychophysiological correlates of webpage reading would predict multiple-text comprehension. In particular, HR would be a negative predictor as a higher emotional response lowers cognitive performance in general (e.g., Valiente et al., 2012) and, more specifically, sourcing when reading divergent accounts (Mason et al., 2017). In contrast, we hypothesized that HRV would be a positive predictor as an increase in the parasympathetic response ("the brake"). This implies greater emotional regulation, thus deeper cognitive effort, which is associated with higher cognitive performance in general (Thayer et al., 2009) and, more specifically, with single-text comprehension (Daley et al., 2014).

However, in order to answer the research question about the role of the two psychophysiological correlates of webpage reading in multiple-text comprehension, we should first analyze whether readers differentiate in their psychophysiological emotional arousal and regulation, as reflected in heart rate (HR) and heart rate variability (HRV), respectively, while reading multiple webpages differing for reliability and position on a debated topic. Reliability refers to the degree of credibility based on source authorativeness and expertise. Position on a debated topic refers to the adoption of a negative firm stance about the issue examined, or a stance appealing to the lack of certain scientific knowledge (see below).

2 Method

2.1 Participants

Forty-seven 7th graders (females = 27, $M_{age} = 12.28$, $SD = 0.53$) attending a lower secondary school were involved on a voluntary basis, with parental consent, after approval of the study by the University Ethics Committee. Initially 51 participants were involved but the data of 4 students were excluded from the analysis for poor registration of physiological measures or incomplete. Of the 47 participants, 43 were native-born Italian with Italian as their first language and 4 came from families where neither parent spoke Italian as their first language (1 from Somalia, 1 from Romania, 1 from Congo, and 1 from Bangladesh). Participants were relatively homogeneous regarding their middle class socioeconomic status.

2.2 Pre-reading measures

Before webpages reading, two control variable that can interfere with multi-text comprehension were measured.

2.2.1 Topic prior knowledge

It was measured using five open-ended questions about electromagnetism and the potential health risks associated with the use of mobile phones, taken from Bråten et al. (2014, p. 67). The answers to these questions were analyzed for content and scored 1 for each correct information unit mentioned (range: 0–3). A random selection of 30 students' responses were scored independently by the third and fourth authors, resulting in a 93% agreement for all answers. Disagreements were resolved through discussion. The same authors collaboratively scored the remaining participants' answers.

2.2.2 Reading comprehension

It was measured using the Italian standardized test for the appropriate grade (Cornoldi & Colpo, 1995). Participants read an informational text and answered 14 multiple-choice questions. Reliability test-retest of this instrument for grade 7 has been reported as = .86. As measured by Cronbach's alpha, reliability = 0.72.

2.2.3 Reading materials

Using ecologically valid materials, participants read four webpages balanced for reliability (low/high) and position on the debated topic (mobile phones are harmful/there is no certain scientific evidence yet), which looked like the original. Each text included the same number of words, taken from real sites; only the language was modified, in some cases, to make it simpler (see Table 1).

Table 1 Overview of the four webpages.

alt-text: Table 1

Type of webpage	Reliability	Author	Content	Words number	Readability score
Personal blog	Low	Unknown Supporter of natural life	States that mobile phones undoubtedly cause many diseases, among them cancer of the brain tissues. Cites a scientific journal (Add a full stop.)	424	48
Science section of a newspaper	High	Scientist from an institute of molecular biology (report from an interview)	Explains that there are no doubts about the biological impact of radiations from cell phones which pose serious risks for brain tissues. Cites scientific works and journals (Add a full stop.)	424	50
Site of an online magazine on mobile phones	Low	Webmaster	States that there is no conclusive answer about health risks associated with the use of mobile phones, and wonders who would give up using the mobile phones if s/he knew that it is definitely harmful. Cites research carried out in UK and Denmark.	424	47
Site of the Italian Society of Pediatrics	High	Pediatrician	Explains that there no conclusive scientific evidence about the health risks associated with the use of mobile phones, especially for children. Recommends many precautions.	424	49

All texts had an emotional charge, to some extent, as they mentioned different types of disease and included emotionally charged words like brain cancer, eye cancer, tumor, and intracranial tumors related to a very salient object in the everyday life of adolescents. Of note is that the two webpages that did not support the certain harmfulness of mobile phones also included emotionally charged words to explain that there is no conclusive answer whether mobile phones cause some diseases. At the beginning of each text, information about the author, credentials, and date of publication was provided. For example, for the high-reliability page presenting information about the harmfulness of mobile phone within the section “Science” of a popular newspaper, included the following: “From an interview with a scientist of the Institute of molecular genetics of the National Research Council in Bologna. Date of publication: 29-09-2013”.

Readability scores of the four texts, computed using the Gulpease index (the only tool available for Italian texts; Lucisano, 1992) ranged from 47 to 50 (100 = very easy). They indicated that the texts were to some extent challenging, so cognitive effort was required to understand the information provided.

The webpages included graphical elements taken from the real sites on the right side. However, these elements were neither related to the content of the pages, nor any affective feature. To avoid possible interference from the order of appearance of the webpages, four different combinations were used in random order. Based on a pilot study, participants were allowed 4 min to read each webpage.

2.3 Psychophysiological correlates

Participants' cardiovascular responses as reflected in HR and HRV both at baseline, that is while at rest watching a 3-min relaxing video of a natural scenario with some ducks on a lake, and while reading the four webpages, were measured in a non-intrusive, standardized way using a computerized recording system (ProComp Infiniti, Thought Technology, Montreal). To obtain both psychophysiological indices, blood volume pulse was recorded by means of a photoplethysmographic detection sensor attached to a fingertip of the participant's non-dominant hand (see the Appendix). Blood volume pulse was used to determine the inter-beat intervals and derive both HR and HRV. Artefacts were controlled for when computing the data about inter-beat intervals using Kubios-HRV 2.2 (Kuopio, Finland) software. Then, HR was calculated as well as HRV through the Root Mean Square of the Successive Differences (RMSSD) of heart periods. Specifically, RMSSD is an index of the variations in the inter-beat intervals between heartbeats, which is sensitive to short-term fast heart period fluctuations. This index specifically reflects the parasympathetic activity through the vagal nerve (the "brake") on the heart (Porges & Byrne, 1992).

As a measure of emotional arousal, for each webpage we computed the difference between HR during reading and HR at baseline. Similarly, as measure of emotional ~~re~~ (self- (self-regulation))-regulation, for each webpage we computed the difference between HRV during reading and HRV at baseline. For each cardiovascular parameter we also computed the mean score across texts.

2.4 Multiple-text comprehension

Deep or intertextual comprehension was measured with an essay task, which is commonly used in this area of research (e.g., Bråten, Braasch, Strømsø, & Ferguson, 2015; Bråten & Strømsø, 2010; Mason, Junyent, & Tornatora, 2014). Participants were asked to write a short essay to judge the health risks of mobile phone use, based on the texts read. Following Bråten et al. (2014) and Mason et al. (2017), the essays were scored for sourcing and argumentation. For sourcing, we first identified all explicit references to the four source texts (e.g., the ministry of health as author). Successively, we identified whether the students also reported the content of the source when they mentioned a specific source. In identifying the source-content links, we also considered implicit references to sources when participants wrote some information about the source that could be easily identified even in the absence of the source name. Two were therefore the source variables: (a) the total number of explicit references to the four source documents regardless of the fact that any content from those sources cold be mentioned or not and (b) the total number of source-content links, that is, explicit and implicit references to the four source documents that also mentioned content from those sources. A composite score was computed for sourcing.

For argumentation, following Mason et al. (2017), the essays were scored 1–3: 1 point was assigned for essays that reported only one position on the debated topic, with no reference to the controversy; 2 points were assigned when the negative position and the "neutral" position appealing to the lack of certain scientific knowledge of the topic were reported, with no reference to the "openness" of the issue; 3 points were assigned when the two positions were reported but also the need for more scientific information.

A random selection of 30 essays were independently scored by the third and fourth authors, resulting in an overall 90% agreement on the essays. Disagreements were resolved through discussion. The same two authors collaboratively scored the rest of participants' essays. Of note is that the participants had the texts of the four webpages available on paper when they were asked to write the short report, to exclude that working memory would play a significant role.

2.5 Procedure

The study included two sessions, both taking place in the morning given the school constraints and availability. In this regard, it is of note that research has documented the influence of time of the day on students' productivity. Specifically, as measured by GPA and state test scores, it has emerged that students' (from sixth to eleventh grade) learning is greater in English and math classes scheduled in the morning compared with later in the school day (Pope, 2016). In the first session, the participants were tested collectively in their classroom for their topic prior knowledge and reading comprehension. This session lasted about 30–35 min. In the second session, each participant was individually tested in a quiet room of the school. First, they watched a 3-min relaxing video presenting a natural scenario with some ducks on a lake, to measure their baseline heart rate and heart rate variability. Second, they read the four webpages while their cardiac activity was registered webpage by webpage. After the reading task and a brief filler task, the participants wrote the essay to measure comprehension at the intertext level. This session took about 50–60 min.

3 Results

3.1 Preliminary analyses

All statistical analyses were performed using IBM® SPSS Statistics Version 24. Data were first tested for skewness, kurtosis, and outliers; all continuous dependent variables were normally distributed. Descriptive statistics of the examined variables and correlations are presented in Table 2. A MANOVA was also carried out to ensure that there were no gender differences for any of the variables of interest. The multivariate analysis of variance revealed no gender difference, Wilks Lambda = 0.87, $F(4, 42) = 1.54$, $p = .206$.

Table 2 Descriptive statistics and zero-order correlations between the examined variables (N = 47).

alt-text: Table 2

	1	2	3	4	5	6
1. Prior knowledge	–					
2. Reading comprehension	.36*	–				
3. Heart rate (HR)[a]	.18	.16	–			
4. Heart rate variability (HRV)[b]	.10	−.06	.05	–		
5. Sourcing	−.03	.10	−.11	−.12	–	
6. Argumentation (multiple-text comprehension)	.32*	.37**	_.28*	.25	.15	–
M	1.10	7.16	3.47	.02	2.82	1.54
SD	1.03	2.72	3.19	20.58	1.38	.76
Min	0	2	−3.17	−47.30	0	1
Max	3	13	13.72	48.30	7	3
Skewness	.48	.22	.64	.31	.38	1.01
Kurtosis	−.94	−.36	.90	.67	.33	−.48

*$p \leq .05$, **$p < .01$.

Note.

[a] Mean score across webpages as the difference between heart rate (HR) while reading and HR at baseline.

[b] Mean score across webpages as the difference between heart rate variability (HRV) while reading and HRV at baseline. HRV was computed as the Root Mean Square of the Successive Differences (RMSSD) of heart periods.

We then carried out two repeated measures analyses of variance to test whether the participants differentiated in their emotional responses while reading multiple webpages differing for reliability and position on the debated topic. One analysis had HR and the other HRV as the dependent variable, considering prior knowledge and reading comprehension as covariates in both. From the first analysis with HR, the effect of webpage did not emerge, $F(3, 42) = 0.40$ (= 0.22), $p = .03$ (= .879). From the second analysis with HRV, the effect did not emerge either, $F(3, 42) = 1.65$, $p = .202$. Of note, in none of the analyses any covariate had an effect on the dependent variable.

These outcomes indicate that readers' cardiac responses while reading did not differentiate as a function of the type of webpage. That is, emotional arousal and self-regulation as psychophysiological responses were substantially similar regardless of the webpage reliability and position on the debated topic (Table 3). Type of webpage was therefore not considered in the subsequent analysis.

Table 3 Adjusted mean scores for HR and HRV as a function of webpage (N = 47).

alt-text: Table 3

	Webpage no. 1 (personal blog) *M (SD)*	Webpage no. 2 (science section of a newspaper: interview with a scientist) *M (SD)*	Webpage no. 3 (Italian Society of Pediatrics) *M (SD)*	Webpage no. 4 (Online magazine on mobile phones) *M (SD)*
HR[a]	3.48 (3.28)	3.50 (4.32)	4.41 (5.75)	4.20 (4.06)
HRV[b]	.019 (20.58)	−1.39 (17.67)	−1.79 (17.41)	1.90 (23.01)

Note.

[a] Difference between heart rate (HR) while reading the webpage and HR at baseline.

[b] Difference between heart rate variability (HRV) while reading the webpage and HRV at baseline. HRV was computed as the Root Mean Square of the Successive Differences (RMSSD) of heart periods.

3.2 Do HR and HRV while reading multiple webpages predict multiple-text comprehension?

To answer our research question, we first took into consideration the correlations among the examined variables. As Table 2 shows, readers' scores for argumentation, as measure of multiple-text comprehension, positively correlated with prior knowledge ($r = 0.32$) and reading comprehension ($r = 0.37$). The negative correlation between HR and argumentation ($r = -0.28$) was also significant at 0.05, while there was only a tendency to significance for the positive correlation between HRV and argumentation ($r = 0.25$, $p = .09$). None of the variables correlated with sourcing, thus this outcome measure was not used in the subsequent statistical analysis.

We then carried out a hierarchical regression analysis with argumentation as the dependent variable of multiple-text comprehension. In the first step of the analysis the control variables of prior knowledge and reading comprehension were entered. In the second step, the psychophysiological indices of HR and HRV were entered. The regression model was significant after entering prior knowledge and reading comprehension, $R^2 = 0.16$, F_{change} (2, 44) = 4.31, $p = .019$. Reading comprehension ($ß = 0.29$) was only a marginally significant predictor of multiple-text comprehension. The addition of the two psychophysiological indices in the second step resulted in a statistical increase in the explained variance, $R^2 = 0.39$, F_{change} (2, 42) = 7.76, $p = .001$. In this step, reading comprehension ($ß = 0.37$), HR ($ß = -0.41$), and HRV ($ß = 0.27$), were significant predictors of argumentation (Table 4). These outcomes indicate that psychophysiological emotional arousal and regulation while reading the four webpages predicted, negatively and positively, respectively, multiple-text comprehension over and above prior knowledge and reading comprehension.

Table 4 Results of hierarchical regression analysis for variables predicting multiple-text comprehension as reflected in argumentation (N = 47).

alt-text: Table 4

Predictor	ΔR²	*B*	*SE*	ß	*t*	*p*
Model 1	16*					
Prior knowledge		.15	.10	.20	1.38	.174
Reading comprehension		.08	.04	.29	1.97	.056
Model 2	39**					
Prior knowledge		.17	.09	.23	1.72	.091
Reading comprehension		.11	.04	.37	2.87	.091
Heart rate (HR)		−.10	.03	−.41	−3.34	.002
Heart rate variability (HRV)[a]		.01	.00	.27	2.23	.031

*$p < .05$, **$p \leq .01$.

Note. (Note "a" SHOULD preceed Note "b", like in the manuscript. Please reverse the order of the two notes. Asterisks with the p values SHOULD be moved after Note b, that is at the end, like in the manuscript)

[b]Mean score across webpages as the difference between heart rate variability (HRV) while reading and HRV at baseline. HRV was computed as the Root Mean Square of the Successive Differences (RMSSD) of heart periods.

[a] Mean score across webpages as the difference between heart rate (HR) while reading and HR at baseline.

4 Discussion

Reading online multiple documents on the same topic for school assignments is a common experience for secondary school students. It appears theoretically and practically relevant to know the individual factors that may underlie what students comprehend when reading conflicting information from different sources. To extend current research, this study addressed the role of affect in multiple-text comprehension, the core construct of the recently proposed Affective Engagement Model (CAEM) of multiple-source use (List &Alexander, 2017). We considered psychophysiological emotional arousal and regulation, as reflected in heart rate and heart rate variability, as objective process data in response to reading webpages that have some emotional content, but differ for reliability and position on the debated topic of the potential health risks associated with the use of mobile phones. Emotional arousal in response to the reading materials was indexed by an increase in HR compared with the baseline (Thayer & Lane, 2000). We also considered heart rate variability as a measure of psychophysiological self-regulation during reading,

which was indexed by higher HRV compared with the baseline (Hansen et al., 2003).

Interestingly, preliminary repeated measures analyses for HR and HRV did not reveal the effect of webpage, that is, readers' emotional response and regulation at the psychophysiological level was substantially similar across webpages. A possible methodological explanation for this outcome is that the content of the four webpages was not different enough to emotionally engage readers at different levels. Another explanation refers to the possibility that emotional responses are related to topic-specific epistemic beliefs, that is beliefs about complexity, uncertainty, source, and justification of knowledge of the examined topic. Recent research with university students has indicated that epistemic beliefs about climate change consistently predicted self-reported emotions, which in turn predicted learning from various texts on the topic (Trevors et al., 2017). In an international study with university students by Muis et al. (2015), self-reported epistemic emotions predicted self-reported learning strategies used to learn the content of four conflicting texts and mediated the relations between topic-specific epistemic beliefs and learning strategies. Considering the age and grade level of the participants, we did not measure topic-specific epistemic beliefs (only topic prior knowledge). However, if appropriately measured, this variable might contribute to a better understanding of the role of psychophysiological emotion-related factors in younger students' multiple-text comprehension.

A third plausible explanation for the lack of effect of the type of webpage on HR and HRV is that the readers may not have evaluated source reliability on the basis of the information provided at the top of each webpage, as they were equally emotionally engaged when reading authoritative and non-authoritative pages. Given the age and grade level of the participants, it is not surprising there may not have been an automatic and routine “validation” of information (Richter & Maier, 2017) through an implicit source evaluation in early reading (Mason, Pluchino, & Ariasi, 2014).

4.1 Role of psychophysiological emotional arousal and regulation in multiple-text comprehension

The research question that guided this study asked whether emotional arousal and regulation at the psychophysiological level were predictors of multiple-text comprehension. As hypothesized, the two psychophysiological correlates predicted participants' argumentation about the diverging positions read on the topic. HR negatively predicted argumentation in the essay task and this result confirms previous investigations that indicated how high emotional arousal may debilitate performance in complex cognitive tasks (e.g., Valiente et al., 2012). In accordance with the resource allocation model (Ellis & Ashbrook, 1988), the explanation for this result is that high emotional arousal reduces the integration of relevant aspects during cognitive processing. This occurs because intense emotional engagement leads to an increase in intrusive, irrelevant thoughts which compete with relevant cognitive activities that are important for the multiple-text comprehension task.

The role of HR in this study is also aligned, at least to some extent, with that of a previous investigation with lower secondary school students in which electrodermal activity was measured as an index of emotional arousal (Mason et al., 2017). In this study, however, emotional arousal was not measured while reading but before, as a response to a negative stimulus unrelated to the text information. Being less emotionally reactive to the stimulus emerged as a positive individual characteristic when considering sourcing, that is, the ability to refer to source information and to link it with content (Mason et al., 2017).

The negative role of HR in our study is associated with argumentation, not sourcing. As was seen in the preliminary analysis, the type of webpage did not affect psychophysiological responses and this may also be due to a poor representation of source information and lack of source evaluation, among other factors. Readers focused on the contrasting positions on the topic regardless of the type of source, thus their emotional arousal only associated with argumentation about the topic. Current data are not able to show whether and to what extent participants paid attention to source information. Future research supplemented by behavioral measures, such as eye fixations, will help understand this issue better. However, it is more likely that a quick, routine source evaluation takes place when young learners are explicitly asked (Mason et al., 2018), or trained (Walraven, Brand-Gruwel, & B~~u~~(o (Boshuizen))shuizen, 2010) to do it during reading. In this regard, it is of note that sourcing and argumentation scores did not correlate. Further investigation is also needed to shed more light on the role of emotional arousal in relation to different degrees of emotionally engaging materials from sources characterized by different levels of authoritativeness and position on a topic.

As hypothesized, HRV positively predicted argumentation as intertextual comprehension of multiple texts. The higher the psychophysiological emotion regulation, the better their ability to represent both perspectives and the need for further scientific information on the controversial topic. This finding indicates that a greater state of psychophysiological calm and concentration is associated with a better performance in a complex cognitive task in the Internet era. This outcome regarding HRV as a correlate of multiple-text comprehension is an illustrative example of the functional framework that integrates affective regulation, attentional regulation, and heart rate variability (Thayer & Lane, 2000), since variations in cardiac activity are linked to emotional response and regulation, and also cognitive processes (Porges, 2007).

The positive role of HRV is aligned with previous research showing that the parasympathetic “brake” during reading relates to better comprehension of a single text (Daley et al., 2014). Research on HRV, both at rest as a dispositional ability to self-regulate in emotionally and/or cognitively challenging situations, and in response to demanding activities, has also documented that HRV is positively linked to performance in various academic tasks in students at different educational levels. A greater ability to regulate emotional responses, and to reach a calm state, is in fact conducive to cognitive effort and sustaining a better performance (Mason et al., 2018; Minkley, Ringeisen, Josek, & Kärner, 2017; Scrimin, Patron, Florit, Palomba, & Mason, 2017).

In sum, the study provides empirical evidence that the affective component should also be taken into account when examining multiple-source processing and comprehension, as proposed by the Cognitive and Affective

Engagement Model (CAEM; List & Alexander, 2017)(2017a (List & Alexander, 2017a).). What emerges is the importance of a regulated emotional response for performing well cognitively. Engagement can be investigated from various perspectives, one of which is the physiological, which has been adopted innovatively in this study. Following this thread, future mixed-methods research will shed more light on the dynamics of emotional and cognitive engagement while reading multiple conflicting texts.

Implications for practitioners concern the importance of emotion regulation, since it is evident that the ability to successfully regulate one's emotions makes a difference in terms of learning and achievement (Goetz & Bieg, 2016). In the course of schooling, students can be sustained in developing elaborated self-regulatory strategies, which represent a crucial resource for their academic functioning. Especially when experiencing negative affective states, students need to be able to regulate them so that they are not debilitated in their high-demanding cognitive performances. Anxiety, anger, and shame, for example, are negative achievement emotions that may accompany school activities. If students learn how to cope with them in the school context, they are less likely to be diverted from a task at hand and to waste cognitive resources that could be allocated to performing well cognitively. Classroom interventions on emotion regulation can start with teaching students general knowledge of emotions and how they influence learning processes and achievement. Then, students can be taught to recognize and reflect on their own, and others' emotions. Examples of strategies can subsequently be presented to effectively model students' emotion regulation (Goetz & Bieg, 2016).

Moreover, since the role of psychophysiological emotion regulation has emerged in relation to online multiple-text comprehension, implications for practitioners also regard webpage reading and Internet-based learning, both crucial in the digital era. Students need to be aware that the affective state they are experiencing matters when they search the Web for information and interpret conflicting information. Young adolescents must be supported in developing critical thinking skills in order to be able to follow up reliable sources only. To this aim, they need awareness that high emotional engagement may be detrimental to processing information, in particular when its quality in terms of truth and veracity should be evaluated, as well as its relevance and usefulness (Brand-Gruwel & Stadtler, 2011).

4.2 Limitations

The current study has some limitations. First, the sample was small. A larger number of participants will lead to more solid data. Second, we considered only one topic and this reduces the generalizability of the findings. The salience of the mobile phone for young adolescents, who have started using it intensively, may have influenced the outcomes. Future research may follow an experimental design by comparing topics that differ for emotional engagement which would allow for an in-depth examination of the role of affect in multiple-text comprehension. Third, we took into account only psychophysiological indices to examine emotional response and regulation during reading. A combination of psychophysiological measures with self-reports will make it possible to examine both arousal and valence of emotional experience in further studies. Fourth, given the sample size, we carried out relatively simple statistical analyses. For further investigations with larger samples, more complex statistical methods (e.g., multilevel modelling, or growth curve modelling) may be adopted for further advancement of knowledge in the field.

4.3 Conclusions

Despite these limitations, the present study contributes uniquely to research on multiple-text comprehension by indicating the role of its psychophysiological correlates. From the theoretical perspective, it is the first study to indicate that emotional arousal (as reflected in HR) in response to webpage reading negatively contributes to the construction of meaning from various texts on the same debated topic, whereas emotional regulation (as reflected in HRV) positively contributes to multiple-text comprehension. From the methodological perspective, the study shows that cardiac activity can be measured in a non-intrusive way in school settings to derive objective indicators of emotional arousal and self-regulation. From the practical perspective, our results point to the importance of considering that both emotional and cognitive factors may underlie students' performance in a common task in the Internet era. Teachers and educators may start indirectly contributing to the improvement of their students' reading performance by making them aware that high emotional involvement and low self-regulation do not help understand multiple conflicting texts on the same topic.

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Appendix

The non-invasive technique of photoplethysmography for detecting blood volume pulse.

The sensor that was used works by detecting the heart beat by measuring the pulse in a finger tip. Specifically, with every beat, the heart pushes a volume of blood through the body's arteries and veins, causing a wave which travels from the heart to the peripheral regions of the body (arms and legs) and eventually returns to the heart. The body's circulation system distributes the oxygen-rich blood through the tissues through a finer and finer series of

arteries, arterioles, and capillaries. It then gathers up deoxygenated blood via the capillaries, venules and veins. As the blood reaches a specific area of the skin, the pulse wave causes a sudden increase in engorgement in the tissues, which is followed rapidly by the return to normal tissue perfusion. The blood volume pulse (BVP) sensor detects this process by shining infrared light through the tip of a finger and measuring how much light is reflected (blood is red because it reflects the red frequencies of the light spectrum.) As the amount of blood increases, more light is reflected, creating an increase in the signal. As the surge of blood dissipates, the signal diminishes. This waveform is slightly complicated by the fact that the direct pulse wave caused by the systolic contraction is bounced back from the lower body and causes a secondary “reflected” wave, which appears as a secondary rise in the signal. The gap between the direct and reflected waves is called the dicrotic notch. Once this pulse is registered, in order to obtain the inter-beat interval (IBI) and the HR indexes, one needs to know the temporal locations of the heart beats as identified by the maxima of the BVP series. In general, such maxima are not easy to spot because the BVP series is not a regular periodic function of time, e.g. it may have more than one maxima within a time of 0.0–0.4 s, the period of the function may change, etc. To find such maxima, BVP series are smoothed through polynomial splines of degree equal to either two or three. Then the first and the second derivatives of the BVP function with respect to time is considered. All the time points for which the first derivative is equal to zero and the second derivative is negative are identified as potential maxima. To control for artefacts, if two or more time points that satisfy the latter condition are found to be too close, i.e., within 0.0–0.4 s, then only the one with the highest BVP is considered. The IBI series for each individual is computed as the distance in time (e.g., msec) between consecutive maxima.

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Highlights

- Seventh graders' psychophysiological responses while reading conflicting webpages were examined.
- Emotional arousal was measured by heart rate (HR).
- Emotional regulation was measured by heart rate variability (HRV).
- HR was a negative predictor of multiple-text comprehension.
- HRV was a positive predictor of multiple-text comprehension.

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