



Effects of critical thinking on multiple-document comprehension

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Abstract

The purpose of this study was to test the relationships between critical thinking, prior topic knowledge and beliefs, and multiple-document comprehension through a path analysis approach. The participants were 281 Italian undergraduate students. Participants first completed a rational-experiential inventory, a critical thinking skills test, a prior topic knowledge test, and a prior topic beliefs test. Then, they were asked to read six documents on the topic of flu vaccination. After reading the texts, students were asked to write an argumentative essay on the topic as a measure of multiple-document comprehension. The hypothesized model fit the data well. Results confirmed that argumentation quality after reading six documents with different perspectives on the topic is associated with different critical thinking skills in stronger- versus weaker-belief readers. In weaker-belief readers, multiple-document comprehension was associated with deduction skills, whereas in stronger-belief readers, multiple-document comprehension was associated with hypothesis-testing skills. Both theoretical and educational implications of the results are discussed.

Keywords Critical thinking · Multiple-document comprehension · Need for cognition · Intuitive thinking · Prior topic beliefs

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Introduction

In the present-day knowledge society, to make decisions on relevant everyday-life issues and participate in the democratic discourse, people need to critically comprehend information across multiple sources that express diverse and contradictory viewpoints. However, the effortful processing of multiple documents is not always effective, even among adults, as it depends on readers' skills and dispositions (Bråten et al. 2014a; 2011a). Readers often struggle in integrating information from alternative perspectives, fail in evaluating the plausibility of arguments, and construct one-sided representations (Richter and Maier 2017). Prior topic beliefs appear to play a dominant role in guiding readers' engagement with controversial issues, with belief-consistent information having a processing advantage over belief-inconsistent information in terms of comprehension and memory (e.g., Maier and Richter 2012; Wiley 2005). From an educational perspective, comprehending and critically analyzing school texts are essential for academic success and lifelong learning (Li et al. 2016; National Assessment Governing Board 2013). Critical thinking can be improved through appropriate interventions and its effect transferred to contexts in which students learn from various sources (Halpern 1999, 2014). In turn, critical thinking coupled with inquiry activities based on multiple sources may lead to well grounded, long lasting, and transferable knowledge (Bailin 2002).

In the last decade, research on multiple-document comprehension has examined the role of several cognitive factors, like prior knowledge (e.g., Strømsø et al. 2010) and epistemic beliefs (Bråten et al. 2013b), as well as the role of motivational characteristics, like individual interest (e.g., Bråten et al. 2014a) and theories of intelligence (e.g., Braasch et al. 2014). Very recently, the role of emotions has also been explored (Mason et al. 2017). To advance current research on multiple-document comprehension, in this study we focused on the contribution of a neglected factor, critical thinking, as it is involved in dealing with information about ill-defined problems that lack a clear resolution path (Angeli and Valanides 2009). Critical thinking is considered as a fundamental twenty-first century skill, thus a primary educational goal (Kettler 2014). Moreover, while research has advanced our understanding of how single factors may or may not affect multiple-document comprehension, less clear is how these factors interact. Thus, in this study, we will analyze the moderating role of prior topic beliefs on the relationship between critical thinking and multiple-document comprehension. Results will shed light on whether readers with different levels of strength in prior topic beliefs approach multiple documents about a controversial topic with a different pattern of critical thinking skills and dispositions.

Multiple-document comprehension

Multiple-document comprehension involves the “building of a coherent mental representation of an issue from the contents of multiple documents that deal with the same issue from different perspectives” (Bråten et al. 2013a, pp. 322-23). The most prominent framework for analyzing this complex task is the Documents Model (Britt et al. 1999; Perfetti et al. 1999). This is an extension of Kintsch's (1998) construction-integration model of single-text comprehension. It assumes that four types of representation are required when comprehending multiple documents: A textbase model and a situation model for each text, plus an intertext model and an integrated (situations) model (Britt and Rouet 2012). Readers need to represent

the internal meaning of each text (i.e., textbase) and to link it to relevant prior knowledge (i.e., situation model). Then, readers need to include a “node” for each text that incorporates relevant information about the source: Who wrote it and why, what type of text it is, what audience it was written for, when it was written, where it was published, and the like. Source nodes are connected to the text content and interconnected to each other through supporting or opposing links (i.e., intertext model). Readers need to create an internal representation that integrates content across documents, including agreements and discrepancies in the accounts they read (i.e., situations model or integrated mental model).

Reader's prior topic beliefs and multiple-document comprehension

In the pertinent literature, the most prominent model explaining the role of prior topic beliefs is the two-step model of processing conflicting information in multiple documents (Richter and Maier 2017). The model suggests that readers routinely monitor if incoming information is consistent or not with their prior belief (validation). According to the model, in the first step of routine validation, readers detect text-belief inconsistencies and evaluate the validity of text content in light of their prior topic beliefs. Validation processes are based on previous information read, prior topic knowledge and beliefs, if currently active while reading. The use of validation processes while reading belief-inconsistent information is higher when readers are following an argument task, rather than a memorization task (Maier and Richter 2016). The validation step can induce the reader to reject belief-inconsistent information as it is considered invalid, unless the reader is highly motivated. In this case, in the second step, the reader engages in strategic, resource-intensive elaboration of belief-inconsistent information, which leads to the construction of an integrated mental model of the controversial issue (Richter and Maier 2017).

Past studies provide some support to the idea that students with stronger prior topic beliefs might address the task of reading multiple documents with a different approach than students with weaker prior topic beliefs do. Maier and Richter (2014) analyzed readers' tendency to construct a one-sided mental representation that is biased towards information consistent with prior beliefs (i.e., text-belief consistency effect). University students were asked to read one belief-consistent and one belief-inconsistent text in four conditions: (i) control group (no knowledge about metacognitive strategies provided); (ii) providing students with knowledge about metacognitive strategies without feedback; (iii) providing students with knowledge about metacognitive strategies with negative feedback; and (iv) providing students with knowledge about metacognitive strategies with positive feedback. The three experimental conditions (no feedback, positive feedback, and negative feedback) were introduced to manipulate motivation. According to the results, the metacognitive strategies were effective in reducing a text-belief consistency effect only when students were motivated to use these strategies after positive performance feedback. Moreover, research has documented that students who reason independently of their own prior topic beliefs (i.e., with little or no myside bias) are more reflective in evaluating arguments than students who do not reason independently of their beliefs (McCrudden and Barnes 2016). Both studies suggest that students with stronger prior topic beliefs may activate different processes when elaborating belief-inconsistent texts than students with weaker prior topic beliefs would.

Research also indicates that the text-belief consistency effect is influenced by task variables and is stronger when multiple-document comprehension is measured through an

argumentative essay (Richter and Maier 2017), as this task might strengthen reading goals directed at bolstering prior topic beliefs. Arguably, the influence of task characteristics (e.g., outcome measure) on the strength of text-belief consistency effects may be attributed to the reader's different cognitive and dispositional approach to the task itself.

Critical thinking

Critical thinking is considered as a necessary component of a twenty-first century active citizenship that participates in a pluralistic and democratic society (Angeli and Valanides 2009). Critical thinking includes two components: *Skills* and *dispositions* (Ennis 1989). Critical thinking is a type of reflective thinking, focused on deciding what we should believe or do (Ennis 1993). A critical thinker needs the skills to identify what is implicit in the reasoning and to judge if the basis of an inference is solid or not. It is possible to decide what to believe through different processes, namely induction, deduction, and value judgment (Ennis 1989). Each of these processes taps on several critical thinking skills. Induction refers to the skill to judge whether the information contained in a claim supports or invalidates the conclusion or does not match with the argumentation. Induction processes can be enacted through hypothesis-testing and planning experiment skills (Facione 1990). Critical thinkers should be able to query evidence, that is, determine whether a certain claim is acceptable or plausible based on information available (e.g., data). Moreover, critical thinkers should be able to plan experiments that provide data to support or refute a certain claim.

Deduction regards the skill to judge whether a given conclusion necessarily follows from the premises or contradicts, or does not match any of the components included in an argumentation. Deduction also includes the ability to identify the assumptions on the basis of which a certain argumentation is built. Finally, close attention to the linguistic aspects of the argument is required to a person who deals with various types of inference and their underlying bases. Deduction processes can be enacted through semantic interpretation and definition skills: A critical thinker needs to be able to interpret a reasoning also in relation to how language is used as a persuasive mean, the way a specific keyword is used, and what is the best definition that should be associated to its use in a specific context (Millman et al. 2005).

Value judging can be enacted through source evaluation skills: Critical thinkers should be able to assess the credibility of statements or other representations in light of the degree of credibility to ascribe to a source of information or opinion (Facione 1990).

The second component of critical thinking, dispositions, also includes a variety of aspects, like truth-seeking, open-mindedness, cognitive effort, and maturity (Facione 2000). In this study, we investigated the tendency to engage with pleasure in activities that require cognitive effort, namely rational-analytic thinking (Epstein et al. 1996) or need for cognition (Cacioppo and Petty 1982), and the tendency to rely on our own experiences to reason and make decisions, namely experiential-intuitive thinking (Epstein et al. 1996).

Relationship between critical thinking and multiple-document comprehension

Critical thinking and multiple-document comprehension are theoretically related constructs, as the former may play an important role at several levels of the latter one. Critical thinking may

intervene before reading, when readers scan the documents for validation purposes, to decide which document is trustworthy and which is not (see McCrudden and Sparks 2014, who found that reading goals enhancing critical thinking reduced the text-belief consistency effect). Value judging skills (i.e., source evaluation skills) may be involved in this step and in the construction of an intertext model. Deduction and induction skills are theoretically required when readers construct the integrated mental model of the documents that they are reading. Deduction skills may come into play to identify which are the authors' premises that lead to the conclusions discussed in each document. Through deduction, divergent conclusions are not directly compared, but put in relation to what the intentions of authors are. Moreover, deduction skills are useful to detect when authors use emotional language to manipulate readers' reasoning. Finally, deduction skills must be involved to understand if diverging opinions on a topic are based or not on a shared understanding of key concepts.

Induction skills may come into play to judge if inferences made in the documents are solid or not, based on the logic of the reasoning or the data. As concerns critical thinking disposition, since the processing is an effortful and demanding endeavor, the tendency to engage with pleasure in activities that require cognitive effort seems fundamental. Critical thinking is thought to influence multiple-document comprehension also through the activation of sophisticated epistemic beliefs. For instance, readers believing that knowledge should be justified through reason (i.e., critical thinking) rather than personal opinion are more likely to process documents with deep strategic processing (Bråten et al. 2011a). Most argumentative texts have a persuasive goal and readers' critical thinking may play a fundamental role in reducing the detrimental effect of prior beliefs, especially when they are engaged with multiple texts reporting different stances on a topic.

To the best of our knowledge, no prior research has compared the contribution of different critical thinking skills and dispositions to multiple-document comprehension. The lack of investigations on the link between critical thinking and comprehension of multiple documents on the same issue is surprising (except for source evaluation skills), given the relevance and popularity of both constructs in academic, work, and social environments. Some indications for multiple-document comprehension can be derived from prior studies focused on the contribution of constructs that are comparable to critical thinking, such as argumentative reasoning (Mason et al. 2011) or scientific thinking (Kuhn 2010), on comparable outcomes, like web-based search or evaluation of socio-scientific issues.

Critical thinking skills

Induction skills (i.e., theory-evidence coordination skills) have been investigated in the context of scientific thinking (Kuhn 2010). Yang (2004) examined high-school students' use of theory and evidence in evaluating a socio-scientific issue. Students were first provided with basic scientific knowledge on the use of underground water through a course, and then tested in reasoning behaviors. Results suggested that students did not have an adequate sense that a theory or hypothesis needs to be supported by evidence, even though they made progresses in knowledge achievement relative to the basic scientific information. Lawson et al. (2000) investigated levels of induction skills (i.e., testing hypotheses about observable causal agents and testing hypotheses involving unobservable entities) in college students and found a predictive relationship between the level of hypothesis-testing skills and course performance. Taken together, these results show that induction skills are still developing among older students but results on their relationship with scientific thinking and learning are mixed.

Moreover, the contribution of induction skills on multiple-document comprehension has never been investigated.

As concerns deduction skills, few studies have emphasized the link between readers' skills to analyze argumentations verbally and semantically and multiple-document comprehension, a construct comparable to semantic interpretation skills. Braasch, McCabe, and Daniel (2016) revealed that semantically congruent texts lead to worse recall and memory of sources performances than semantically distinct texts, a result that may extend to multiple-document comprehension too. Thus, available results suggest an inability to distinguish sources when two accounts on an issue are expressed in similar terms, that is, an effect that may be reduced by readers' critical skill to interpret a reasoning in relation to linguistic aspects.

In addition, Jucks and Paus (2012) analyzed different lexical encodings of the same underlying concept across documents in dyads. Results showed that dyads in the different-terminology condition were more aware of the overall differences across texts, which led to perceive more controversies across texts and resolve them by conceptual elaboration. This finding suggests the importance of analyzing the definition of words in order to identify and interpret differences in viewpoints across texts (i.e., critical-thinking skill to assess the best definition of a word in a context).

Certainly, multiple-document comprehension taps on value judgment skills. In this regard, since the seminal work by Wineburg (1991), the importance of source evaluation skills for multiple-document comprehension has been well documented. Source evaluation skills are connected to domain expertise (Bråten et al. 2011b). Strømsø et al. (2010) focused on source memory, rather than source evaluation skills, and found that this variable contributed equally to both intertextual and intratextual comprehension. Moreover, the effectiveness of an intervention to provide students with essential declarative knowledge on what to consider when evaluating the authoritative nature of Web sources has been documented. Readers' skills to detect informal reasoning fallacies played a minor role when readers know what to consider in evaluating whether a Web source is trustworthy (Mason et al. 2014). This result seems to suggest that deduction and induction skills might compete with value judgment skills in contributing to multiple-document comprehension.

Critical thinking dispositions

Scholars from the field of personality and social psychology proposed two fundamentally different modes of processing information: (a) An analytical, rational, deliberative, effortful, intentional, and systematic mode and (b) an intuitive, natural, automatic, heuristic, and experiential mode (Epstein et al. 1996). The rational mode was substantially referred to the construct of need for cognition (Cacioppo et al. 1996; Epstein et al. 1996). This construct signals a domain-general tendency to work with persistence, commitment, and reflection on cognitively demanding task (Bråten et al. 2014a). When applied to reading comprehension, need for cognition describes a disposition to engage in deep understanding of the text, which leads to the construction of a situational model (Dai and Wang 2007). Several investigations have confirmed its association with the use of critical thinking skills (Macpherson and Stanovich 2007), the processing of controversial information (Mason et al. 2010) and multiple-document comprehension (Bråten et al. 2014a). Specifically, Bråten et al.'s study (2014a) showed that readers' need for cognition had an indirect effect on multiple-document comprehension performance, mediated by deeper-level strategies, whereas its direct effect was more restricted than expected.

A low need for cognition can mean that a person is not motivated to engage in complex cognitive activities, or alternatively, that a person is more confident in his/her intuition when engaged in complex issues. However, no prior research has explored the effect of the intuitive-experiential mode of thinking on multiple-document comprehension. A few indications can be derived from the literature on normative and heuristic judgments. For instance, Shiloh et al. (2002) found that high scores in intuition were associated with a tendency to make heuristic judgments, whereas high scores in need for cognition were associated with normative judgments. This result suggests that intuition might disengage the use of critical thinking skills when processing information, with a tendency to process it automatically, based on prior experiences.

The present study: research questions and hypotheses

To extend current research, the aim of the study was to investigate the role of both critical thinking skills and dispositions in multiple-document comprehension—as revealed in an argumentative task—in relation to prior topic beliefs. Specifically, the study was guided by two research questions:

1. Are critical thinking dispositions and skills associated with multiple-document comprehension?
2. Do weaker and stronger prior topic beliefs interact with different critical thinking skills and dispositions in contributing to multiple-document comprehension?

Based on the available literature, for research question 1, we hypothesized critical thinking dispositions to be related to critical thinking skills and multiple-document comprehension. Specifically, we hypothesized rational-analytic disposition to be positively associated with critical thinking skills and have a positive effect on multiple-document comprehension. Prior studies have supported a positive link between rational-analytic thinking—a measure derived from the need for cognition construct—critical thinking (Macpherson and Stanovich 2007), reading behavior (Mason et al. 2010), and multiple-document comprehension (Bråten et al. 2014a). In contrast, we hypothesized intuitive-experiential disposition to be negatively associated with critical thinking skills and have a negative effect on multiple-document comprehension. The role of intuitive-experiential disposition has been scarcely investigated, but the very few studies suggest a negative link with critical thinking (Shiloh et al. 2002). Thus, we also expected a negative contribution of this thinking disposition to the comprehension of various documents on the same topic. As concerns the various critical thinking skills, we could not formulate a specific hypothesis based on the literature, as no empirical studies have investigated their role in single or multiple-text comprehension, except for source evaluation skills (e.g., Wineburg 1991). However, as an integrated representation of conflicting documents on the same topic involves complex cognitive activities, we expected that deduction and induction skills, besides source evaluation skills, would play a role (Mason et al. 2014).

Based on the available literature, for research question 2, we hypothesized that students with weaker prior topic beliefs would approach a multiple-document comprehension task in a way different from that of students with stronger prior topic beliefs. Specifically, we hypothesized the former to apply a wider range of critical thinking than the latter in comprehending conflicting documents. This would occur because less entrenched beliefs about a topic more likely lead to a deeper elaboration of the reading materials and a more independent reasoning on a debated issue (Maier and Richter 2012, 2014; McCrudden and Barnes 2016; Wiley 2005).

In other words, readers with weaker prior topic beliefs would be less vulnerable to belief bias and more inclined to effortful processing of conflicting information than readers with stronger prior topic beliefs.

It is worth noting that we also considered prior topic knowledge in the statistical analyses as previous studies have revealed the role of this variable in the construction of an integrated representation of a controversial topic (Bråten et al. 2014a; Strømsø et al. 2010).

Method

Participants

Participants were students from a University located in central Italy. They were enrolled in the second year of a developmental and educational psychology program and voluntarily participated in the study. Out of 302 students who initially expressed their interest in participating, 281 (226 females, men age = 20.98 ± 2.72) signed the consent form and took part in the study. The ratio between males and females in this study is representative of the actual ratio of the population of developmental and educational psychology students in Italian universities. All participants were Italian and spoke Italian as their primary language. The sample was relatively homogeneous (i.e., middle class) regarding socioeconomic status, as assessed through parents' occupation. The study followed all the indications of the Declaration of Helsinki (World Medical Association 2013) and the guidelines of the University Ethics Committee.

Procedure

The procedure included three steps. First, students were administered the tests measuring critical thinking dispositions and skills, prior topic beliefs, and prior topic knowledge. Then, students were assigned six texts to read, with the following instructions: "A 55-year-old lady with prior cardiac problems, comes to you to ask for an advice. She is deciding whether she should get the flu vaccine or not. She looked for information on the Internet and found six documents. She would like you to read them and give her an advice based on scientific facts." After reading the instructions, the participants read the texts on the computer. They were shown a Google-like page with six links, one for each document, in which texts were presented in fixed-order (see Fig. 1). They could read the documents in any order they wanted, for how many times and how long as they wanted.

The six documents differed for position about the topic and trustworthiness. Their length varied between 442 and 573 words and readability varied between 34 and 48, as calculated by the Gulpease index (Lucisano and Piemontese 1988) (see [Supplementary material A](#) for a description of the documents). Overall, the texts presented two stances towards flu vaccination, pro and against it. The encyclopedia presented data about flu vaccination in a neutral way, declaring vaccination as the most prominent defense against flu, but also including data about the low efficacy of vaccination. The health ministry report only presented the pro-vaccination stance. The magazine article and the news agency release reported data about suspect deaths after flu vaccination, but also concluded that the two events cannot be related. The personal blog and the newspaper article reported the against-vaccination stance.

Finally, students were asked to write the answer to the lady through an argumentative essay, with the following instructions: "We ask you to write a short report in which you give an

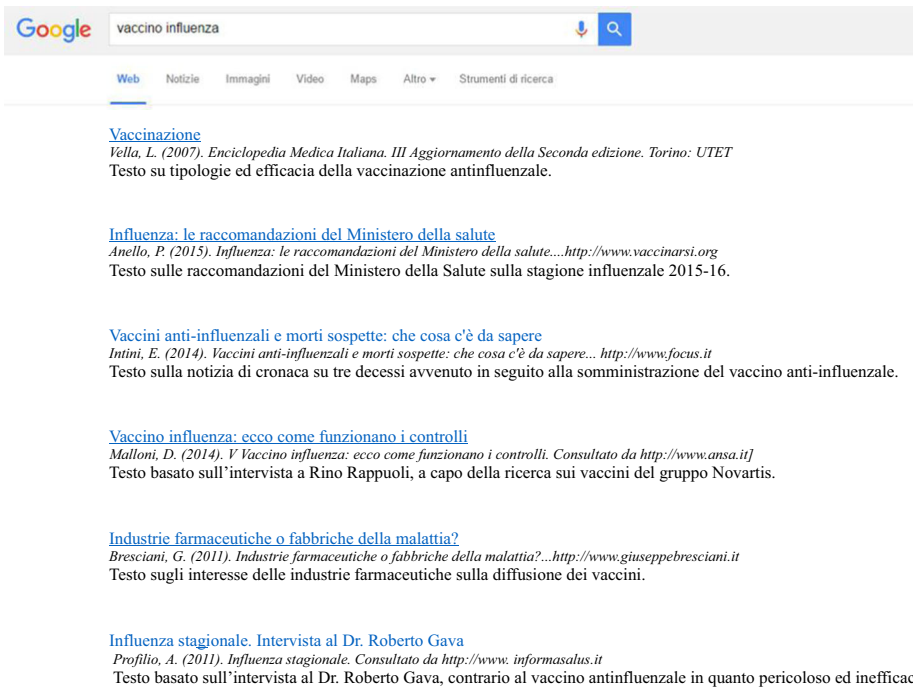


Fig. 1 Google-like page with links to the documents

advice to the lady on whether she should get the flu vaccine or not. Base your report on the information included in the documents that you have just read. Try to explain your point of view in your own words, in a clear and argumentative way. Try also to justify your conclusions by referring explicitly to the documents read.”

Measures

Critical thinking skills

They were measured through the Cornell Critical Thinking Test, Level Z (CCTT, Millman et al. 2005). The instrument includes 52 multiple-choice items. It is a scenario-based multi-aspect test as it assesses more than one aspect of critical thinking (in parenthesis we report the original name of the scales in the instrument and the number of items included in the scale; in the [supplementary material B](#) we report examples for each scale):

Induction skills: Hypothesis testing (i.e., judging whether the information contained in the items supports the conclusion, invalidates it, or does not match any of the two possibilities, 13 items) and Planning experiments (i.e., assessing the best prediction based on the results of an experiment, 4 items).

Deduction skills: Deduction (i.e., judging whether a given conclusion necessarily follows from the premises, contradicts, or does not match any of the two possibilities, 10 items); Meaning and fallacies (i.e., explaining a faulty reasoning in relation to linguistic aspects, 11 items); Definition (i.e., assessing the best definition of a word in a context, 4 items); and Assumption identification (i.e., identifying what is implicit in a reasoning, 6 items).

Value judging skills: Evaluation of source credibility (i.e., judging the credibility of statements, 4 items).

One point was assigned for each correct answer (among three alternatives). Students were asked to base their answers on the information given. Very limited content-area knowledge was necessary for students to answer the questions. The instrument was translated from English to Italian and then back-translated for control.

Before responding to the research questions, we investigated the factorial structure of the critical thinking test on another sample of students from the same cohort as the participants in this study ($n = 299$), using a confirmatory factorial analysis (CFA) in MPlus (Muthen and Muthen 2002). Results of CFA revealed that the presumed seven-factor model showed poor goodness-of-fit indices ($\chi^2 = 1340.601$, $p = .006$; RMSEA = .019; CFI = .558). The analysis was repeated after excluding the factors with non-significant factor loadings (i.e., evaluation of source credibility, planning experiments, and definition skills). The four-factor model showed good goodness-of-fit indices ($\chi^2 = 199.844$, $p = .187$; RMSEA = .018; CFI = .935; see Fig. 2). The four-factor model was tested in the same sample of the present study, also showing good goodness-of-fit indices ($\chi^2 = 150.878$, $p = .374$; RMSEA = .013; CFI = .982).

The reliability of each subtest was: $\omega = .58$ for deduction skills, $\omega = .53$ for meaning and fallacies identification skills, $\omega = .57$ for hypothesis-testing skills, and $\omega = .51$ for assumption identification skills. While these reliability scores are certainly lower than desirable, they may still be considered within the acceptable range for measures developed and used for research purposes only (Hair et al. 2006; Kerlinger and Lee 2000).

Critical thinking dispositions

They were measured through the rational-experiential inventory (Epstein et al. 1996). It consists of two unipolar scales, one measuring rational thinking (derived by the need for cognition scale, 20 items; e.g., “I would prefer complex to simple problems”) and the other measuring experiential thinking (faith in intuition, 20 items; e.g., “My initial impressions of people are almost always right”). Participants scored each item on a 5-point Likert scale (from 1 = completely false to 5 = completely true). The instrument was translated from English to Italian and then back-translated for control. Scores could range between 20 and 100 for each subscale. The reliability of the instrument was $\omega = .83$ for the rational thinking scale and $\omega = .91$ for the experiential thinking scale.

Prior topic beliefs

The instrument was adapted from Maier and Richter (2012). Prior topic beliefs were measured through a 10-item questionnaire on a 6-point Likert scale on the topic of vaccination (e.g., “I think vaccination is the most important and effective method against infective diseases”). Scores could range from 10 to 60. The reliability of the instrument was $\omega = .90$.

Prior topic knowledge

It was measured through a 12-multiple-choice test with four alternatives for each item. Questions were previously validated by an expert in Biology and Medicine. Students were asked questions about flu and vaccination (e.g., “Vaccines are available for these diseases,

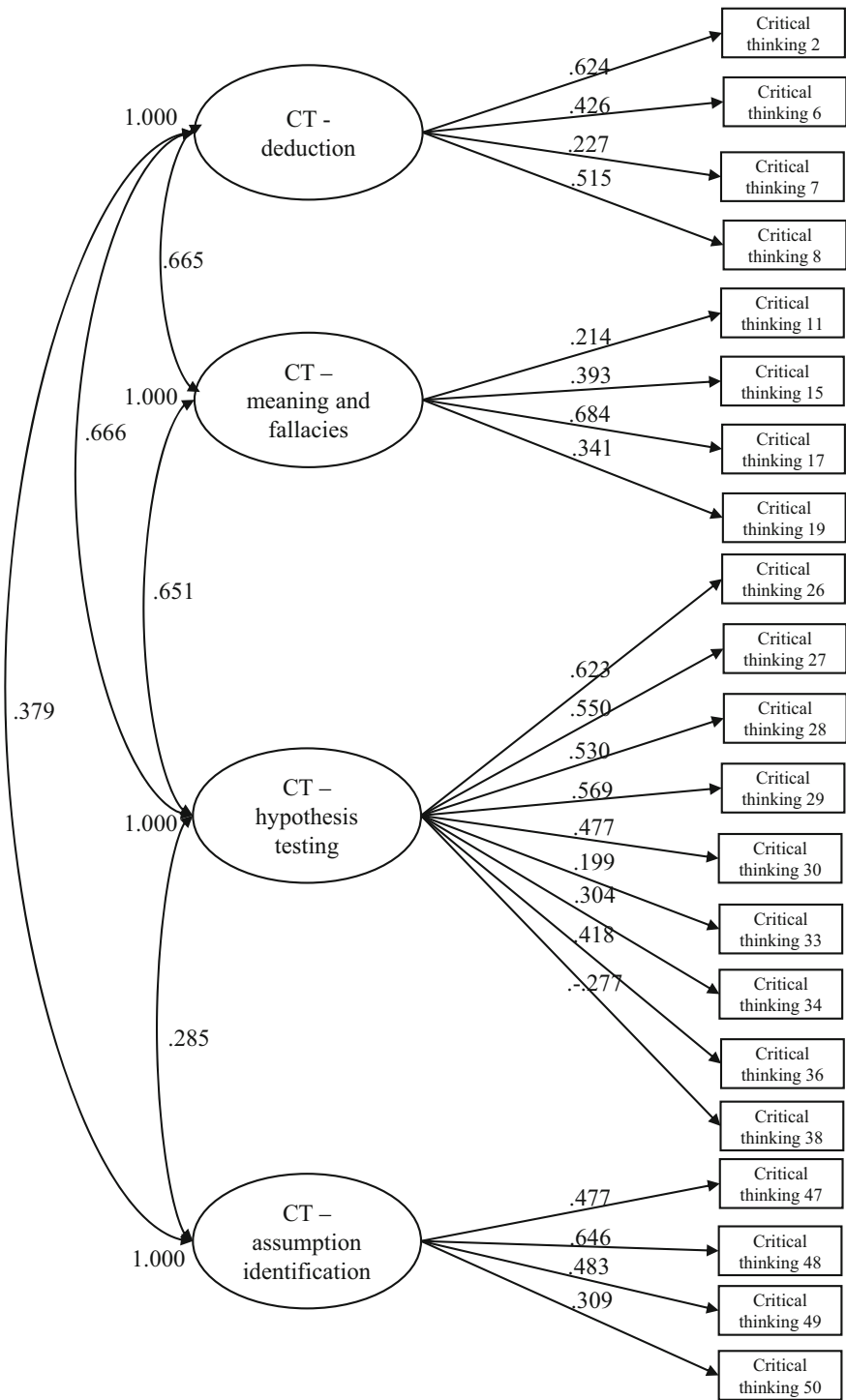


Fig. 2 Confirmatory factorial analysis of Cornell Critical Thinking Test scores

except for: A. Tetanus; B. Hepatitis C; C. Flu”). Scores could range between 0 and 12. The reliability of the instrument was $\omega = .68$.

Multiple-document comprehension

It was measured through an argumentative essay. The coding system was developed by Bråten et al. (2014b), originally adapted from Reznitskaya et al. (2009). The coding system was used to rate the overall quality of written argumentation on a 7-point scale. The procedure included four steps. In the first step, participants' position on the topic was identified: Pro flu vaccination (e.g., “I would recommend vaccination to prevent flu”), against flu vaccination (e.g., “I believe that the side effects are far higher than the advantages of vaccination”), or considered the issue unsettled (e.g., “It is difficult to give an advice, since I am not an expert, thus I would recommend consulting the family doctor”). In the second step, the number of reasons used to support the position taken in the essay was counted. In the third step, we focused on information about opposing perspective(s) and the unsettled nature of the issue was identified, specifically analyzing whether it was just mentioned (e.g., “Of course, there are some side effects”), or discussed and elaborated (e.g., “Side effects of vaccination should be taken into account especially for elderly people, or people who already suffer from other disease, as they might further debilitate them”). In the last step, the overall structure and quality of the essays was examined, specifically whether they included the five fundamental argument components: positions, supporting reasons, opposing reasons, elaborations, and rebuttals. After these steps, the essays were assigned the following scores (see Bråten et al. 2014b for the full description): 1 point to underdeveloped essays, in which the position was unclear; 2 points to essays containing a position on the issue supported by fewer than four reasons; 3 points to essays containing a position on the issue supported by four or more distinct or elaborated reasons; 4 points to essays containing a position on the issue supported by four or more distinct or elaborated reasons, with the alternative perspective mentioned but not discussed; 5 points to essays stating a clear position on the issue supported by elaborated reasons, and including the alternative stance, but without trying to reconcile the two perspectives; 6 points to essays stating a clear position on the issue supported by elaborated reasons, with a consistent discussion of the opposing perspective; and 7 points to well-structured and focused essays, containing the five argument components.

Two independent raters, who had received a specific training, coded all the material, achieving a good score of agreement ($k = .88$). In case of disagreement, a third coder coded the essays independently, and her code was taken if it was identical to the code assigned by one of the two coders. There was no case in which the three coders assigned three different scores.

Data analysis

Basic descriptive statistics were carried out. After controlling skewness and kurtosis indices, all variables resulted to be normally distributed. From the initial sample of 281 students, the data of 18 students were excluded from the analysis because they did not participate in the third part of the study, in which the outcome variable was assessed. The final sample included 263 students. To answer the two research questions a multiple-group analysis was performed, using the MPlus 7.0 software (Muthen and Muthen 2002). As suggested by Hu and Bentler (1999), the fit of the model was estimated by several indices: the chi-square, the root mean square error of approximation (RMSEA) and the comparative fit index (CFI). Missing data

ranged between 1% and 5% and were missing completely at random (Little's MCAR test was not significant, $\chi^2 = 146.97$, $df = 1160$, $p = .087$). Consequently, the path analysis model was estimated using full information maximum likelihood (FIML) estimation to correct distortions caused by MCAR data. Prior topic knowledge and the number of essay words were included in the path analysis model as control variables for argumentation quality.

Results

Descriptive statistics and correlational scores are reported in Tables 1 and 2. Students were not knowledgeable about the topic of vaccination (less than half of the answers in the prior topic knowledge test were correct) and displayed overall pro-vaccination prior topic beliefs. Students' argumentative essays were characterized by ample variability in the number of words. Almost half of the students (42.4%) only reported and discussed one position in their essays and an additional 24% simply mentioned the existence of an alternative position, without elaborating on it. Only 33.6% of the students discussed the two positions on flu vaccination, with only 18.1% writing a well-structured argumentative essay. The mean number of words in the argumentative essays was only around 200 and some argumentative essays were less than 100 words long.

The analysis of the frequencies of prior topic beliefs scores showed that participants had mostly strong pro-vaccination beliefs or weak prior topic beliefs, but only a very small percentage of students had strong against-vaccination beliefs. Indeed, only 6.05% completely or almost disagreed with pro-vaccination items (level 1 and 2 of the Likert scale). 62.27% of the participants displayed a moderate attitude towards the topic (level 3 and 4 of the Likert scale). 31.68% of the students displayed a strong pro-vaccination attitude (level 5 and 6 of the Likert scale). Thus, we decided to proceed by excluding the students with strong against-vaccination beliefs ($n = 17$) and dichotomizing prior topic beliefs of the remaining sample ($n = 265$) through a median-split (median = 46.00). One group was characterized by stronger pro-vaccination scores (mean = 51.92 ± 4.18), whereas the second group was characterized by weaker beliefs (mean = 51.92 ± 4.12). The difference between the two groups for prior topic beliefs was statistically significant, $t = -24.08$, $p < .001$, 95%CI = $-13.32; -11.31$.

Following we proceeded to investigate both research questions by analyzing the goodness of fit of a multi-group model with prior topic beliefs group (stronger- versus weaker pro-vaccination beliefs) included as a moderator and using the factorial scores of critical thinking skills (see Fig. 3 for the hypothesized model).

Table 1 Descriptive statistics of the examined variables

	Range	Min	Max	M \pm SD
Critical thinking dispositions				
Rational-analytic	20–100	44.00	85.00	66.91 \pm 8.43
Intuitive-experiential	20–100	39.00	94.00	67.92 \pm 10.81
Prior topic beliefs	10–60	17	60	44.65 \pm 9.10
Prior topic knowledge	0–12	2.00	9.00	4.93 \pm 1.48
Essay words		24	496	209.51 \pm 98.69
Argumentation	1–7	1	7	4.03 \pm 1.86

Table 2 Intercorrelations between the examined variables ($N = 263$)

		1	2	3	4	5	6	7	8	9	10
1	CTd_Rational_analytic	1									
2	CTd_Intuitive_experiential	-.01	1								
3	CTs_deduction	.06	-.13*	1							
4	CTs_meaning	.09	-.13*	.89**	1						
5	CTs_hypothesis testing	.13*	-.11	.87**	.87**	1					
6	CTs_assumption identification	.06	-.12	.57**	.48**	.46**	1				
7	Prior topic beliefs	-.03	-.06	.06	.03	.08	.05	1			
8	Prior topic knowledge	.13*	-.02	.03	.03	.08	-.04	.09	1		
9	Essay words	.07	-.10	.11	.12*	.10	.03	-.05	.15*	1	
10	Argumentation	-.02	-.08	.12*	.09	.11	.04	.05	.04	.41**	1

* $p < .05$, ** $p < .01$. *CTd*, critical thinking dispositions; *CTS*, critical thinking skills

Firstly, we tested the goodness-of-fit of the multi-group model in which the parameters of the paths to argument quality were constrained to be equal across the two groups. The hypothesized model fit the data well, $\chi^2(32) = 44.894, p = .065$; RMSEA = .055; CFI = .986. Secondly, we tested the goodness-of-fit of the multi-group model with no constraints for the parameters to be equal across groups. The hypothesized model fit the data well, $\chi^2(24) = 28.234, p = .250$; RMSEA = .037; CFI = .996. Thirdly, we compared the goodness-of-fit of the two models with a chi-square test of nested comparison and found that the second model was a significantly better fit, $\chi^2_{diff}(8) = 16.570, p = .039$. A significant p value indicates that the solution with more factors (model with free parameters) is a significantly better fit. This result suggests that critical thinking was associated with multiple-document comprehension differently depending on the strength of readers' prior topic beliefs.

The chi-square contribution of the weaker prior topic beliefs group ($\chi^2 = 16.654$) was higher than that of the stronger prior topic beliefs group ($\chi^2 = 11.580$), showing a poorer fit of the model for the former group. Moreover, the set of variables included in the path analysis

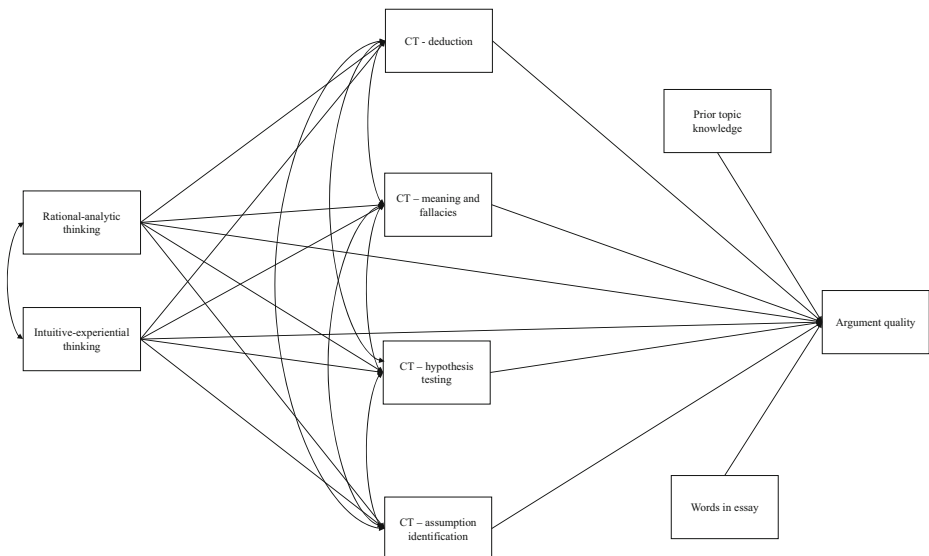


Fig. 3 Hypothesized model

explained a slightly larger portion of variance in the stronger prior belief group (24%) than it did in the weaker prior belief group (20%) (see Table 3).

Prior topic beliefs moderated the effect of critical thinking skills on argumentation (see Table 4). In the stronger prior topic beliefs group (see Fig. 4), only hypothesis-testing skills had a direct effect on argumentation quality. In the weaker prior topic beliefs group (see Fig. 5), only deduction skills had a direct effect on argumentation quality. Neither critical thinking dispositions nor prior topic knowledge were associated with argumentation quality. The number of essay words was significantly related to the argumentation quality in both prior topic beliefs groups.

Critical thinking dispositions were not associated with any other variable in the stronger belief group. Conversely, in the weak belief group, rational-analytic thinking was significantly associated with assumption identification skills.

As concerns covariances, all critical thinking skills were associated with each other in both groups. In the stronger prior topic beliefs group deduction skills were associated with meaning and fallacies identification skills, hypothesis-testing skills, and assumption identification skills. Meaning and fallacies identification skills were associated with hypothesis-testing skills and assumption identification skills. Hypothesis-testing skills were associated with assumption identification skills.

In the weaker prior topic beliefs group deduction skills were associated with meaning and fallacies identification skills, hypothesis-testing skills, and assumption identification skills. Meaning and fallacies identification skills were associated with hypothesis-testing skills and assumption identification skills. Hypothesis-testing skills were associated with assumption identification skills.

In sum, different critical thinking skills were involved in the two prior topic beliefs groups when considering multiple-document comprehension. Argumentation quality was associated with hypothesis-testing skills in the stronger prior topic beliefs group and to deduction skills in the weaker prior topic beliefs group.

Discussion

The study sought to extend current research on multiple-document comprehension in three ways. First, we explored the relationship between critical thinking skills and the construction of an integrated representation of contrasting information on the same topic. Second, we examined the impact of the rational-analytic and intuitive-experiential modes of thinking on

Table 3 R^2 estimates for the observed variables in the path model

Variable	Weaker prior beliefs			Stronger prior beliefs		
	R^2	SE	p	R^2	SE	p
CT_deduction	.028	.030	.360	.013	.019	.502
CT_meaning and fallacies	.030	.032	.338	.014	.020	.483
CT_hypothesis testing	.021	.026	.429	.027	.027	.323
CT_assumption identification	.058	.043	.175	.014	.020	.482
Argument quality	.202	.064	.002	.236	.062	< .001

CT, critical thinking

Table 4 Standardized coefficients of estimated paths for weaker and stronger prior belief groups

Paths	Weaker prior beliefs				Stronger prior beliefs			
	β	SE	<i>p</i>	95%CI	β	SE	<i>p</i>	95%CI
CT_deduction ON								
Rational-analytic thinking	.022	.092	.815	-.159, .202	.040	.086	.645	-.129, .209
Intuitive-experiential thinking	-.167	.091	.067	-.347, .012	-.101	.085	.234	-.267, .065
CT_meaning and fallacies ON								
Rational-analytic thinking	.096	.092	.296	-.084, .276	.035	.086	.528	-.115, .224
Intuitive-experiential thinking	-.153	.091	.092	-.331, .025	-.098	.085	.248	-.264, .068
CT_hypothesis testing ON								
Rational-analytic thinking	.080	.091	.379	-.099, .259	.095	.084	.261	-.071, .260
Intuitive-experiential thinking	-.127	.092	.167	-.307, .053	-.122	.084	.146	-.287, .042
CT_assumption identification ON								
Rational-analytic thinking	.214	.089	.017	.039, .390	-.038	.085	.659	-.205, .130
Intuitive-experiential thinking	-.128	.089	.151	-.302, .047	-.117	.085	.168	-.282, .049
Argument quality ON								
Rational-analytic thinking	.056	.086	.515	-.112, .224	-.131	.076	.087	-.280, .019
Intuitive-experiential thinking	.095	.084	.258	-.070, .260	-.130	.075	.082	-.276, .017
Topic knowledge	.057	.085	.505	-.110, .223	-.071	.076	.352	-.220, .078
CT_deduction	.590	.209	.005	.181, .999	-.142	.189	.451	-.512, .228
CT_meaning and fallacies	-.159	.181	.380	-.514, .196	-.256	.189	.177	-.627, .115
CT_hypothesis testing	-.214	.185	.247	-.576, .148	.398	.163	.014	.080, .717
CT_assumption identification	-.172	.103	.094	-.373, .029	.068	.094	.469	-.117, .254
Essay words	.349	.080	<.001	.192, .505	.413	.069	<.001	.278, .547
Rational-analytic thinking WITH Intuitive-experiential thinking	.080	.093	.387	-.101, .262	-.123	.083	.140	-.286, .040
CT_deduction WITH CT_meaning and fallacies	.875	.021	<.001	.833, .917	.886	.018	<.001	.850, .922
CT_deduction WITH CT_hypothesis testing	.879	.021	<.001	.838, .920	.847	.024	<.001	.800, .894
CT_deduction WITH CT_assumption identification	.564	.062	<.001	.442, .686	.589	.056	<.001	.480, .699
CT_meaning and fallacies WITH CT_hypothesis testing	.838	.027	<.001	.785, .892	.874	.020	<.001	.834, .914
CT_meaning and fallacies WITH CT_assumption identification	.501	.068	<.001	.367, .635	.467	.067	<.001	.336, .598
CT_hypothesis testing WITH CT_assumption identification	.481	.070	<.001	.344, .619	.453	.068	<.001	.320, .586

CT: critical thinking

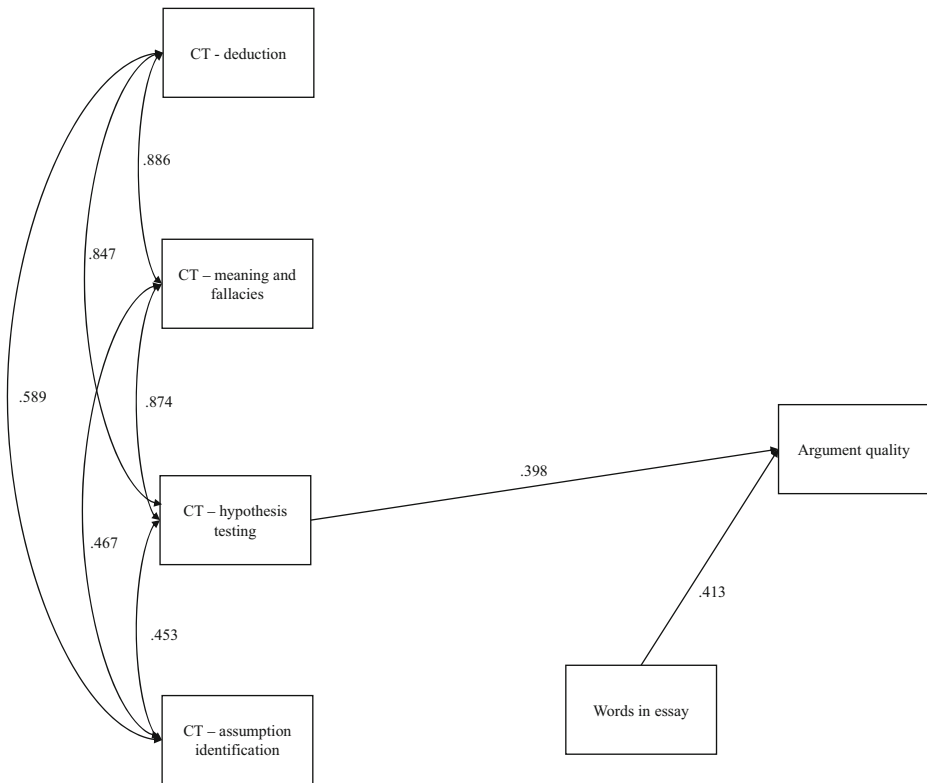


Fig. 4 Path analysis model with significant standardized path coefficients for stronger belief students

multiple-document comprehension, which was not taken into account previously, besides the rational-analytic mode of thinking. Third, we investigated the effect of the interaction between prior topic beliefs and critical thinking skills and dispositions on multiple-document comprehension. Prior topic knowledge was also considered in the statistical analyses.

Of note is that only 18.1% of the participants wrote a well-structured argumentative essay, which included the five fundamental argument components: positions, supporting reasons, opposing reasons, elaborations, and rebuttals. Participants in this study wrote very brief writing samples, which brings up the question of whether argumentation quality was influenced by fatigue, lack of effort, or lack of motivation. The low-stakes experimental context in which the multiple-documents comprehension task was administered may have played a role, and hindered participants' motivation to write a long essay.

This result confirms the idea that the effortful processing of multiple documents is not always effective and leads readers to create one-sided representations of the issue explored (Bråten et al. 2014a; Bråten et al. 2011a). Motivated and effortful processing of multiple documents is typically found among readers with certain epistemic beliefs, thinking dispositions, theory of intelligence, and prior knowledge (Alexander and DRLRL 2012; Rouet and Britt 2011). Thus, there are several reasons why readers struggle in creating two-sided representations of a topic. They may lack the skills to process the information included in the documents (e.g., sourcing skills or integration skills). Or they may not recognize the need for effortful processing of all documents and consider valid only information consistent with

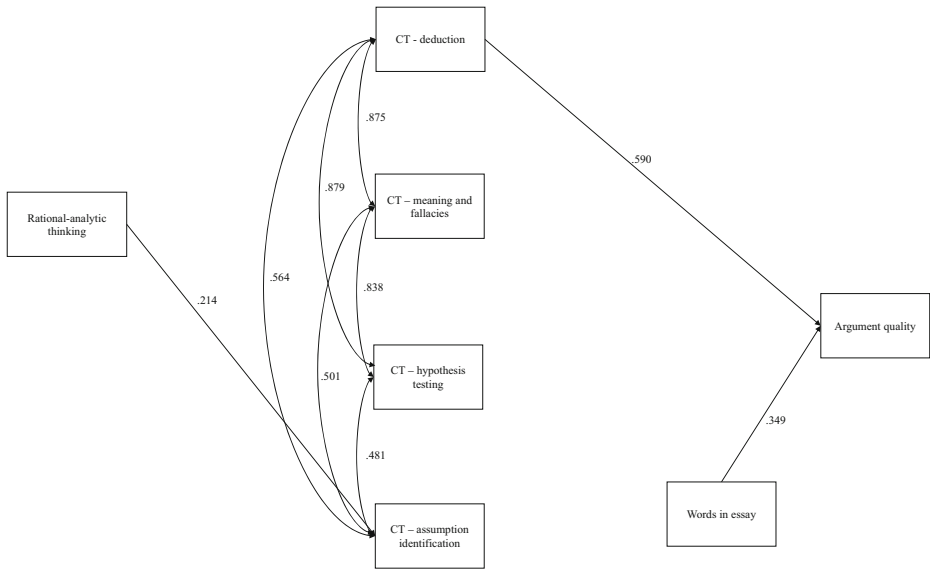


Fig. 5 Path analysis model with significant standardized path coefficients for weaker belief students

their prior beliefs (belief consistency effect, Maier and Richter 2016). Source evaluation may also be ineffective because of the use of (poor) prior knowledge to judge the believability of arguments (belief-bias, see Macpherson and Stanovich 2007; Richter and Maier 2017).

Results of the present study contribute to the measurability of critical thinking skills via the Cornell Critical Thinking Test (CCTT, Millman et al. 2005). The confirmatory factorial analysis and reliability indices suggest a rather poor construct validity of the original theoretical model. Although the CCTT is a widely used instrument that utilizes single multiple-choice response format (Ku 2009), prior studies have challenged and questioned the validity and factorial structure of this instrument and other similar instruments assessing critical thinking skills. Overall, for the sample of this study, the CFA confirms the existence of a four-factor model, which includes deduction skills, skills to explain faulty reasoning in relation to linguistic aspects, hypothesis-testing skills, and assumption identification skills.

Notwithstanding the shortcomings due to the validity and reliability of the CCTT, we were able to answer the research questions taking into account four critical thinking skills, along with two critical thinking dispositions, namely rational-analytic and intuitive-experiential thinking. With this respect, our hypothesis for the first research question was only partially confirmed as critical thinking dispositions were not related to multiple-document comprehension. This result is not aligned with prior studies that found the need for cognition (from which the rational scale is derived) to be related to the processing of controversial information (Mason et al. 2010) and multiple-document comprehension (Bråten et al. 2014a).

A plausible explanation for this finding is that the effect of rational-analytic disposition on multiple-document comprehension disappeared once we included critical thinking skills in the path analysis, that is, a set of variables that are correlated with critical thinking dispositions (Ennis 1989). Of note is that in Bråten et al.'s study (2014a) the direct effect of need for cognition was more restricted than the authors expected, probably because part of its effect was absorbed by the indirect path to multiple-document comprehension via strategic processing. An alternative explanation is that the rational-analytic disposition was not associated with multiple-

document comprehension because of the low scores in prior topic knowledge. Previous research has shown that the relationship between dispositions and multiple-document comprehension may be moderated by prior topic knowledge (Bråten et al. 2011b). Thus, low-knowledge readers might be less motivated to engage in deep text processing.

As concerns the second research question, overall, the results substantially confirmed our hypothesis that after reading six documents with different perspectives on a topic, argumentation quality is associated with different critical thinking skills according to the strength of readers' prior topic beliefs. In weaker-belief readers, multiple-document comprehension was associated with deduction skills, whereas in stronger-belief readers multiple-document comprehension was associated with hypothesis-testing skills. Weaker-belief readers may rely on deduction to judge whether conclusions achieved by each source (e.g., vaccination is useless and dangerous, or vaccination is the most effective method to defeat illnesses) are actually supported or not by the reasons discussed.

Conversely, stronger-belief readers may rely on hypothesis-testing skills as they may approach sources with a specific idea in mind (pro-vaccination in the case of this study) and process the readings in terms of supporting evidence pro or against their beliefs. Past studies indicated that readers with strong prior topic beliefs tend to construct a one-sided mental representation of texts, mainly biased towards belief-consistent information (Maier and Richter 2014). Results of this study suggest that the belief consistency effect may be reduced if competence in hypothesis-testing skills is high.

Although only two critical thinking skills were directly associated with the outcome variable, critical thinking skills were inter-related to each other in both groups, suggesting a rather complex pattern in this construct. As already reported, critical thinking dispositions did not contribute to multiple-document comprehension in a statistically significant way. Even if in the weak belief group only, the rational-analytic disposition was associated with assumption identification skills, this pattern was not associated with the comprehension of the six documents.

A surprising result was the lack of a significant association between prior topic knowledge and multiple-document comprehension. This result may be explained by our participants' low levels of knowledge about flu and vaccination. Majority of the students (84%) answered only half of the prior topic knowledge questions, or less. Low level of prior topic knowledge may also explain why certain critical thinking skills were not associated with multiple-document comprehension. For instance, previous studies indicated that source evaluation skills are related to both, intratextual and intertextual comprehension (Strømsø et al. 2010). However, source evaluation skills are connected to domain expertise, as only high knowledge in a content area provides readers with the epistemic criteria to judge the trustworthiness of documents (Bråten et al. 2011b). It is worth noting that these studies adopted different measures of multiple-document comprehension (i.e., sentence verification task and trustworthiness judgments), thus their results cannot be straightforwardly compared to results of the present study.

The lack of a significant relation between the prior topic knowledge and the dependent variable, as well as the weak association of critical thinking skills with the dependent variable, might be considered in the light of the distinction of logical versus epistemological conceptions of critical thinking. Some scholars considered (and taught) critical thinking as an ability to think critically independently of subject-specific knowledge and skills (i.e., logical conception of critical thinking, Paul 1991, 1993; Siegel 1988). However, evidence from embedded approaches demonstrated that teaching critical thinking within subject-matter domains is more successful in improving students' problem-solving skills than general approaches are (i.e., epistemological conception of critical thinking, McPeck 1981, 1985).

The epistemological approach to critical thinking provides an explanation for the results of this study, suggesting that students' low topic knowledge may be associated with low awareness of the criteria for assessing reasons offered by the documents (McPeck 1981, 1985). Thus, this implies a difficulty to critically evaluate arguments as displayed by the weak association between critical thinking and argument quality of the students' essays. This interpretation is supported by intervention studies suggesting that critical thinking is more effective if coupled with domain-specific knowledge (Abrami et al. 2008). Conversely, Paul (1991) suggested that students may be able to acquire and apply general critical thinking skills to several situations in which reasoning is involved. However, the problem is that critical thinking is often taught as a set of atomic technical skills regardless of prior beliefs, making students unable to decouple their critical thinking from prior beliefs. According to Paul (1991), prior beliefs, rather than prior knowledge, limit the effect of critical thinking on multiple-document comprehension, and students should be helped to reason in those areas where they are most likely to have biases.

Limitations

When interpreting the findings of the current study, some limitations should be taken into account. First, the results are limited to the topic (i.e., flu vaccination) and the outcome variable of multiple-document comprehension (i.e., argumentative essay) adopted in this study. The use of other topics, for instance, issues participants are more familiar with, might reveal a different interplay of the examined variables. Multiple-document comprehension has been studied through different outcome variables, such as intertextual inference verification task (Strømsø et al. 2010), memory for sources (Braasch et al. 2016), or trustworthiness evaluations (Bråten et al. 2011b). The associations between critical thinking and multiple-document comprehension might change as a function of the outcome variable.

Second, the results of this study are limited to the population involved, that is, mostly female Italian undergraduate students. In this regard, it should be pointed out, however, that prior research has not revealed gender differences for multiple-document comprehension (Strømsø et al. 2010). Future studies may shed more light on the current results by involving not only more male participants but also younger students, among which critical thinking skills are still emerging.

Finally, the test used to assess students' critical thinking skills was characterized by a different factorial structure as compared to the original version, and sub-scales confirmed by the CFA had a rather low reliability. These set of results might depend on the translation of the test, or on the characteristics of participants, however it must be noted that some concerns have been raised up on the Cornell Critical Thinking Test and other standardized measure of critical thinking skills (Ku 2009). Further research is needed to identify a valid and reliable measure of this fundamental twenty-first century skill.

Theoretical and practical significance

Despite the limitations, the present study contributes to the literature on multiple-document comprehension. It validates a four-factor model for the CCTT for Italian university students, which could be used in further investigations about the role of critical thinking skills. The study also documents the contribution of readers' critical thinking skills and dispositions on multiple-document comprehension as a function of prior topic beliefs.

On a theoretical level, this study includes hypothesis-testing and deduction skills as a component of multiple-document comprehension and supports the idea that students with different strength of prior topic beliefs approach the reading task in a different way, as different critical thinking skills were important for multiple-document comprehension in the two groups. Moreover, this study confirms that more research is needed to achieve a valid and reliable measurement of critical thinking skills. The weak effect of critical thinking on multiple-document comprehension seems to depend on low prior knowledge scores, which are theoretically associated with a difficulty in using appropriate criteria to evaluate the trustworthiness of documents and integrate content based on the source-source links. On the other side, this result may reflect a difficulty in overriding the effect of reasoning biases and preventing judgments to be guided only by prior beliefs.

On a practical level, a very small number of students were capable to perform on the highest level on the argumentative essay. While our knowledge of the variables involved in multiple-document comprehension is increasing, less clear is how to improve students' approach to the task of reading about a controversial topic. Results of the present study suggest that instructions aimed at scaffolding readers in constructing an integrated mental model should include attention to specific critical thinking skills in relation to the strength of topic beliefs. In turn, scaffolding targeted critical thinking skills should foster a rational decision-making process in students and improve their awareness of how to critically approach a reading task even when they have entrenched convictions on a debated topic or issue.

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Current themes of research:

Comprehension. Critical thinking. Reading and spelling acquisition. Learning disorders. Conceptualization of Physics. Intercultural sensitivity.

Most relevant publications in the field of Psychology of Education:

- Pinto, G., Tarchi, C. & Bigozzi, L. (2019). Promoting narrative competence in kindergarten: An intervention study. *Early Childhood Research Quarterly, 47*, 20-29. DOI: 1016/j.ecresq.2018.09.003
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- Pinto, G., Bigozzi, L., Tarchi, C., & Camilloni, M. (2018). Improving conceptual knowledge of the Italian writing system in kindergarten: a cluster randomized trial *Frontiers in Psychology, 9*:1396. doi: 10.3389/fpsyg.2018.01396
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Current themes of research:

Cognitive and emotional individual differences in source evaluation skills when searching the Web for information on controversial topics and in comprehension of multiple digital texts. Interplay of text and reader characteristics in knowledge revision processes as well as in multimedia learning.

Most relevant publications in the field of Psychology of Education:

- Mason, L. (2018). Multiplicity in the digital era: Processing and learning from multiple sources and modalities of instructional presentations. *Learning and Instruction*, 57, 66-81. doi:10.1016/j.learninstruc.2018.03.004
- Scrimin, S., Moscardino, U., & Mason, L. (2018). First graders' allocation of attentional resources in an emotional stroop task: The role of heart period variability and classroom climate. *British Journal of Educational Psychology*. Advance online publication. doi:10.1111/bjep.12228
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