Cogn Process (2016) 17:213–223
DOI 10.1007/s10339-015-0748-z

LETTER TO THE EDITOR

# The impact of epistemological beliefs and cognitive ability on recall and critical evaluation of scientific information

Insa Feinkohl[1,3] · Danny Flemming[1] · Ulrike Cress[1,2] · Joachim Kimmerle[1,2]

Received: 3 March 2015 / Accepted: 18 December 2015 / Published online: 9 January 2016


**Abstract** Scientific research findings are frequently picked up by the mainstream media, but it is largely unclear which factors have an impact on laypeople's processing of the presented scientific information. In this study, we investigated the influence of cognitive and metacognitive inter-individual differences on recall and on critical evaluation of new scientific information that was presented in a journalistic article. Sixty-three participants (80 % female; mean age 24.1 ± 3.3 years) read a newspaper article reporting research findings on a recently developed and yet unproven treatment for depression. We found that more sophisticated, domain-specific epistemological beliefs and a higher cognitive ability were independently associated with better recall of content from the article. Additionally, participants with more sophisticated epistemological beliefs displayed a more critical evaluation of the article. Cognitive ability was unrelated to critical evaluation and to epistemological beliefs. There were also no interaction effects of cognitive ability and epistemological beliefs on recall or on critical evaluation. Based on our preliminary findings and previous evidence of epistemological beliefs as a modifiable feature, we discuss this inter-individual characteristic as a potential target for the promotion of better understanding of scientific topics by the general public.

**Keywords** Epistemological beliefs · Knowledge · Cognitive ability · Intelligence · Learning · Critical thinking

## Introduction

The mass media have the potential to function as a tool in the construction of scientific knowledge by the general public. For instance, findings from recent drug trials may be of high personal relevance for laypeople due to possible influences on their own health-related decision-making. Such scientific details are highly complex and are communicated via a language that is characterized by unique terminology, semantics, syntax, and logic (Britt et al. 2014; Yore and Shymansky 1991). However, it is largely unclear to what extent scientific information is understood and later recalled by laypeople. One key aspect of science that is important for laypeople to comprehend is its uncertainty, that is, its fallibility (Sinatra and Chinn 2012): Individual research studies in the science domain are characterized by inconsistencies as well as continuous updating of findings, retractions, and controversies (Friedman et al. 1999; Whitehead 2011). Because journalists are not always successful in their endeavor to provide a balanced summary of these complexities (Moynihan et al. 2000), laypeople are often faced with the task of engaging in critical evaluation of

Handling Editor: Marta Olivetti Belardinelli, Sapienza University of Rome.

Reviewers: Kenneth J. Kurtz, Binghampton University, USA; R.V. Krishnaiah, DRK Institute of Science and Technology, Hyderabad, India.

✉ Insa Feinkohl
ifeinkohl@gmail.com

[1] Knowledge Construction Lab, Leibniz-Institut fuer Wissensmedien, Schleichstr. 6, 72076 Tuebingen, Germany

[2] Department of Psychology, University of Tuebingen, Schleichstr. 4, 72076 Tuebingen, Germany

[3] Max-Delbrueck-Center for Molecular Medicine (MDC), Robert-Roessle-Str. 10, 13092 Berlin, Germany

scientific content on their own. Although the precise definition of critical thinking is diffuse and subject to variation (for a review, see Phan 2010), it certainly involves a number of higher cognitive processes (Maclellan and Soden 2011). These include practices such as the higher-level evaluation of content, reflection, avoidance of myside bias (the preference for information that is consistent with one's own beliefs), recognition of assumptions made by the author, probabilistic and statistical reasoning, and the inference of conclusions (Ku and Ho 2010; Ross et al. 2013; Stanovich and West 2014). Applied to the perception of scientific journalistic content, critical thinking directly manifests in people's ability to grasp the reversionary, fallible, and tentative character of the 'scientific truth' as portrayed by the media (Lederman and O'Malley 1990).

The fact that the detection of tentativeness from scientific data poses a substantial challenge to the general public presumably has a variety of reasons, including a 'bounded understanding of science' in laypeople (for a review, see Bromme and Goldman 2014). Due to a 'widespread lack of scientific literacy,' the public has been assumed to be 'relatively defenseless to the media's influence' (Nisbet et al. 2002, p. 586). This has the potential to contribute to a growing skepticism toward the science media as well as to distrust of scientists (Sinatra and Chinn 2012), and so substantial efforts have been made to ensure balanced (rather than biased or sensational) science communication. At the same time, it is important to investigate the determinants of the ability to engage in critical appraisal of science-related texts presented in the media. In this paper, we initially review the existing evidence of selected interindividual differences that influence learning from texts and appraisal of their content. Among a breadth of potential determinants, we chose to focus on people's 'prior knowledge,' 'epistemological beliefs,' and on their 'cognitive ability.' With this choice, we aimed to ascertain contributions both by potentially modifiable and therefore targetable (i.e., prior knowledge, epistemological beliefs) and by more stable (i.e., cognitive ability) individual differences. We then describe results from our own experimental study on the relationship of these factors in the context of the processing of scientific material, using the successful detection of scientific tentativeness as an example of critical appraisal in the science domain. To date, prior knowledge, epistemological beliefs, and cognitive ability have been investigated largely in isolation despite the fact that they are related to one another (e.g., Bendixen and Rule 2004) and so may well interact with one another in determining recall and critical evaluation of information. We now aim to make a unique contribution to the research field by evaluating the independence versus interrelationships of effects by each of these factors on those outcomes.

## Prior knowledge

By 'prior knowledge,' we refer to prior domain knowledge describing an individual's implicit or explicit, declarative, procedural, and conditional knowledge that is specific to a given subject and collected over time (Alexander et al. 1997). Reports of positive influences of such knowledge on comprehension, achievement, and *learning* overall appear relatively consistent (Dochy et al. 2002; Johnston 1984; Ozuru et al. 2009; Tobias 1994; see also Cordova et al. 2014). Research has found a positive relationship between students' prior topic knowledge and their performance in various subject domains (e.g., Murphy and Alexander 2002). Pieschl et al. (2008) found that students with greater knowledge in biology were better learners of biological content than students of the humanities. Similar observations were made in another study identifying associations between knowledge in the field of social psychology and comprehension of a text from the same domain (Le Bigot and Rouet 2007). Other examples of prior knowledge that have been used in previous research include expertise in the domains of chess or baseball games (e.g., Chase and Simon 1973; Recht and Leslie 1988). Such effects of prior knowledge on learning have been conceptualized in the 'knowledge-is-power' hypothesis (for a review, see Hambrick and Engle 2002). A reason for these findings is that prior knowledge provides students with a basis upon which they can build new information (Rumelhart 1980; see Cordova et al. 2014). That is, the underlying cognitive processes may involve the inclusion of a greater amount of information in each 'chunk' during the encoding stage of information processing, due to the availability of prior knowledge (Chase and Simon 1973). This reasoning is consistent with observations of an inverse relationship between the level of prior knowledge and the time required to read a text stemming from that field (Surber and Schroeder 2007). On the basis of such evidence, we expect that people with prior background knowledge of a scientific topic will learn more content from that topic's domain when it is presented in a journalistic science-related article compared with people who have no prior background knowledge (Hypothesis 1).

Prior knowledge has also been associated with strategies used during the processing of text (e.g., Alexander et al. 1997; Cordova et al. 2014; Dinsmore et al. 2015) and, relatedly, with *critical thinking*. In a study with students, an increase in knowledge in the field of human genetics resulted in an increase in the quality and complexity of participants' arguments in a subsequent reasoning task (Zohar and Nemet 2002). Similar findings were reported in another study which presented high school students with arguments on sociopolitical issues, such as the legalization of marijuana. Here, too, students with greater prior knowledge exhibited a higher performance on a range of reasoning measures (Means and Voss 1996). Similar studies with focus on the scientific domain are needed to supplement the currently sparse evidence. We assume that people with prior background knowledge of a scientific topic will be better able to detect the tentativeness of scientific evidence reported in a journalistic article on the same topic than people with no prior background knowledge (Hypothesis 2).

### Epistemological beliefs

Epistemological beliefs (EBs), that is, people's beliefs and concepts about the nature of knowledge itself, are complex and multidimensional constructs that can be aligned on a continuum spanning simple (i.e., naïve, less developed) to sophisticated (i.e., more elaborated) EBs (Bientzle et al. 2014; Chinn et al. 2011; Roex and Degryse 2007). People with simple EBs tend to consider knowledge as simple and absolute, whereas people with sophisticated EBs regard knowledge as variable and constructed (Hofer and Pintrich 1997; Stahl and Bromme 2007). EBs are inherently difficult to conceptualize and to measure, but as trait characteristics appear to be relatively stable within individuals. They influence a range of aspects of people's lives. For instance, sophisticated EBs appear to predispose high school students to select the natural sciences, medicine, or similar subjects at university level (Trautwein and Lüdtke 2007). They have also been linked to better *learning* outcomes (Bath and Smith 2009; Hofer 2001), for instance in experimental settings involving learning from hypertext (Pieschl et al. 2008). Sophisticated EBs have additionally been shown to predict greater academic success at school (Chen and Pajares 2010) and college level (Schommer 1993; Trautwein and Lüdtke 2007). Observations such as these and reports of a modifiability of EBs even during brief experimental sessions (Kienhues et al. 2008) have led to the recommendation that EB development should be targeted in school curricula (Trautwein and Lüdtke 2007). People with sophisticated EBs could be characterized by an 'epistemic curiosity' (Richter and Schmid 2010) and by efficient self-regulatory processes (Bromme et al. 2010). Overall, the association between EBs and learning outcome appears to be well established in other research fields, and so we expect that the learning of scientific content from a journalistic article will be facilitated by more sophisticated EBs (Hypothesis 3).

Investigations of EB associations with text appraisal and *critical thinking* are rarer. One early study by Stanovich and West (1997) measured students' 'thinking disposition' using a questionnaire which captured EB-like constructs such as 'absolutism.' The researchers found that questionnaire scores predicted participants' ability to critically evaluate arguments presented by a fictitious character. Similar findings were made more recently in a study of children. Here, EBs were associated with the quality of arguments used during the discussion of controversial topics (Mason and Scirica 2006). Another study investigated associations of EBs with ratings of a scientific text's trustworthiness. During rating, it appeared that participants with more sophisticated EBs (relative to those with simple EBs) increasingly made use of their own opinion and, in addition to evaluating the material itself, critically evaluated information on the author of the text as well (Strømsø et al. 2011). In view of this type of evidence, it certainly appears plausible that sophisticated EBs could facilitate people's critical thinking ability in the science domain. An investigation of the relationship of EBs and critical thinking in this domain in particular is warranted, as the ability to engage in appropriate critical appraisal of scientific content concerns any layperson and because EBs, as mentioned above, may be modifiable (Kienhues et al. 2008; Trautwein and Lüdtke 2007). Here, we expect that when reading a journalistic article that describes scientific findings, more sophisticated EBs will aid detection of the tentative nature of these findings (Hypothesis 4).

### Cognitive ability

Individual differences in cognitive ability have been at the focus of psychometrists since the early twentieth century (Binet and Simon 1916; Carroll and Maxwell 1979). Cognitive ability, often referred to as IQ or intelligence, is difficult to capture on psychometric instruments. It describes an underlying latent trait dimension that remains relatively stable across the entire life course (Carroll and Maxwell 1979; Deary 2012; Neisser 1979). Although a higher cognitive ability may hinder implicit learning (Marewski et al. 2010), it is a prerequisite for explicit *learning* (e.g., Pazzaglia and Moè 2013). Consequently, it has been linked to greater academic success (e.g., Deary et al. 2007) as well as to a longer time spent in education, with reports of associations of a medium to large effect size (Kuncel and Beatty 2013; Neisser et al. 1996; Noftle and Robins 2007). Cognitive ability has further been identified as a major determinant of job performance (Hunter and Schmidt 1996; Kuncel and Beatty 2013; Kuncel et al. 2014; Neisser et al. 1996). Although such reports do not necessarily reflect causal, direct (Sternberg and Wagner 1993), and linear relationships (Kuncel and Beatty 2013) and are contrasted with occasional null findings (Britton et al. 1998), associations of cognitive ability with learning are overall undisputed. Consequently, we assume that a higher cognitive ability will facilitate learning of scientific content from a journalistic article (Hypothesis 5).

Cognitive ability is related to the capability to make rational judgments, which includes the capacity to apply *critical thinking*, but both are not identical. For instance, in order to score high on tests of intelligence, people are not usually required to exhibit rational thinking (Stanovich et al. 2013; Stanovich and West 2014), and so relationships between the constructs are of interest. Although an early study had failed to identify cognitive ability relationships with critical thinking aptitude (Furst 1950), more recent investigations have observed such links. In one study by Klaczynski and Gordon (1996), adolescents were confronted with arguments regarding religion that were either consistent or inconsistent with their own beliefs, or were neutrally framed. Participants' cognitive ability was positively related to the ability to engage in reasoning, and this was entirely independent of whether or not arguments were consistent with their own beliefs. The consideration of people's own beliefs in studies such as this is important, because—at least under certain experimental conditions—cognitive ability appears to be related to myside bias (Evans and Over 2010; for a review, see Stanovich and West 2007) which has the potential to confound any relationship of cognitive ability with critical thinking. In another study, a higher cognitive ability was associated with greater critical thinking ability in evaluating arguments about social or political issues that were presented by a fictitious character. A regression analysis used to partial out participants' own beliefs in the subject showed that results were independent of that factor (Stanovich and West 1997). However, the use of such statistical adjustment is not undisputed (Willett 1997), and the application of both belief-consistent and belief-inconsistent arguments with subsequent evaluation of differences between such arguments (Klaczynski and Gordon 1996) may be similarly suboptimal. Using a topic about which laypeople have no personal opinion or associated biases would circumvent those problems altogether. Our hypothesis is consistent with the apparent positive relationships of cognitive ability (Westbrook and Sellers 1967) and academic success (Ross et al. 2013; which may be seen as a proxy of cognitive ability) with critical thinking: We expect that a higher cognitive ability will enable better detection of the tentativeness of scientific findings presented in a journalistic article (Hypothesis 6).

### Present study

The intent of this study was to test associations of prior knowledge that was operationalized as immediate background knowledge of the topic at hand, as well as people's EBs and cognitive ability, with their capability to detect the tentativeness of scientific findings in a journalistic article. In addition, we aimed to test associations of these factors with people's ability to recall the article's content. We also explored potential interaction effects of the three factors on both outcomes, as well as links of EBs with cognitive ability. To the best of our knowledge, the application of individual differences analyses to science-related mass media content as we describe them has not been attempted in previous research.

The newspaper article used in our experiment reported findings from a scientific study on Deep Brain Stimulation (DBS), a brain surgical procedure that has been used experimentally in the treatment of depression (Schlaepfer and Lieb 2005). Thereby, we selected a topic for which the current scientific evidence is particularly tentative both relative to other treatment options for depression and relative to the use of DBS in the treatment of conditions other than depression (Schlaepfer et al. 2014). There is also little knowledge of the procedure in the general population (Kimmerle et al. 2015). This allowed the manipulation of 'immediate background knowledge' during the experimental session and circumvented problems associated with measurement error in the questionnaire-based assessments of participants' prior knowledge of a topic.

## Materials and methods

### Participants

Participants were 68 adults who were recruited from a University-wide panel of volunteers. All were either students or graduates and were reimbursed for their participation. Prior to the start of the session, participants were asked to let the experimenter know whether they had previously heard of DBS, and one indicated that they had. Two further participants identified themselves as non-native speakers. Because the recall test included some rather simple items (see examples below), motivation of two participants who performed exceptionally poorly on this test (score $\leq 2$ out of 14) compared with the remaining sample (of which all participants had scores of $\geq 4$ out of 14; with 25th percentile of scores at 5.5) was questioned. Following the exclusion of those five participants, total sample size was 63. On average, participants were $M = 24.1$ years old ($SD = 3.3$ years, age range 19–35 years). The study had ethical approval from the Institutional Ethics Committee (approval reference: LEK 2014/001). Informed consent was obtained from all individual participants included in the study.

### Research design

We used a cross-sectional study design. Immediate background knowledge of DBS was manipulated through random allocation into one of two experimental groups. EBs specific to the field of psychomotor diseases, as well as vocabulary as a proxy of general cognitive ability, were measured trait variables. Dependent variables were *perceived tentativeness* of the findings described in the newspaper article and participants' *recall* of its content.

### Procedure

In a single session lasting approximately 45 min, demographic information was collected, and participants were initially either provided with information on DBS, or they were provided with unrelated information. The remainder of the testing procedure was identical for both groups. Participants' EBs were measured with a questionnaire. After being informed that a recall test would follow and that note-taking was not permitted, participants read a newspaper article on DBS in their own time. The tentativeness of findings described in the article was then evaluated by the participants. Finally, they completed the recall test and a test of cognitive ability.

### Instruments and material

Demographic information was obtained using a standard self-report questionnaire with items on age, sex, occupation, native language, and final school grade (scale 1–6; 1 meaning best possible grade).

Participants in the 'immediate background knowledge of DBS' group read a textbook section (539 words) on DBS in general and on its use in treating Parkinson's disease (for which it is a well-established form of treatment). Those in the 'no background knowledge of DBS' group received a control text about a different technological advance in the medical field (567 words) which included no information on DBS or on related concepts.

*Epistemological beliefs* were determined using the German version of the 24-item Connotative Aspects of Epistemological Beliefs (CAEB) Questionnaire (Stahl and Bromme 2007). In response to the statement *Medical knowledge of psychiatric and psychomotor diseases and their treatment is…*, participants selected adjectives on seven-point semantic differential scales which allowed for identification of simpler (e.g., *simple*, *objective*, *static*) versus more sophisticated (e.g., *complex*, *subjective*, *dynamic*) EBs. The CAEB questionnaire has previously been shown to have good internal consistency in a student sample (Kimmerle et al. 2015). Sum scores from the 24 items were calculated, with a possible total score range of 0–144 (higher scores indicate more sophisticated EBs).

We used an authentic newspaper article of 848 words describing findings from a single small-scale study that had used DBS to treat patients with major depressive disorder. We slightly modified this journalistic text in order to ensure a sufficient level of salience of tentativeness. Tentativeness of the study's findings was made salient in the article through so-called hedging (Jensen 2008), that is, the use of cautious expressions (e.g., '…cannot be said with certainty').

*Perceived tentativeness* of that study by participants was measured in a questionnaire with six-point Likert scales corresponding to the level of agreement to five statements (sample items: *The findings of the described study are very definitive*; *the study is conclusive*.). Scores were reversed and summed, resulting in a possible score range of 0–25 (higher values indicate higher perceived tentativeness).

*Recall* of information on DBS that participants derived from the journalistic text was measured using nine open-ended questions (sample questions: *What condition was DBS used to treat?*; *What side effects were reported?*). For each question, the maximum score attainable ranged between 1 and 3 points, depending on the complexity of the respective answer (total score range 0–14). Tests were marked according to a pre-set level of expectations by a single rater who was naïve to the study's research question. The delay between text presentation and recall test was around 10 min. The recall test questions corresponded only to the journalistic text and did not correspond to any of the information included in the initial textbook section on DBS, so that participants of the experimental and the control conditions had identical opportunity in terms of scoring.

We used the Mill-Hill Vocabulary Scale (MHVS; Raven et al. 1998) to estimate participants' global crystallized *cognitive ability* (Ibrahimovic and Bulheller 2009). Crystallized ability results from the application of a general cognitive ability to a specific field and includes knowledge of vocabulary which is obtained through passive acquisition (Cattell 1963). Consequently, such tests of vocabulary, including the MHVS, tend to correlate strongly with comprehensive batteries of tests of cognitive ability (Carroll 1993; Ibrahimovic and Bulheller 2009). In the version of the test used in the present study, each of 30 items included one target word typed in bold font with a group of six response options printed underneath. Participants were instructed to identify those words that applied to the target word (e.g., *room* corresponds to the target word *office*). In each case, between one and five options were correct; the scoring procedure was adjusted for guessing (possible score range 0–150). The MHVS has a time limit of 10 min.

## Results

### Missing data, internal consistencies of instruments, sample characteristics, and distributions

Data were complete for perceived tentativeness, recall, and cognitive ability. Four participants chose not to disclose their age and three did not disclose their sex. Missing data on single EBs items for four participants were replaced by the sample mean for the respective item. Missing CAEB data for one participant who completed only half of the questionnaire was treated as missing. Internal consistency of the CAEB was good (Cronbach's $\alpha = .84$); for the perceived tentativeness scale, internal consistency was acceptable following deletion of one item (*Our knowledge of DBS in the treatment of depression is not yet complete*) from the five-item scale (Cronbach's $\alpha = .59$). Overall sample characteristics are shown in Table 1. Of the 60 participants who disclosed their sex, 48 (80 %) were female. Following calculation of sum scores, normal distributions were found for age, school grade, EBs, perceived tentativeness, and recall. Cognitive ability scores were negatively skewed and square root transformed to achieve near-normal distribution. Thirty-two participants had been randomly assigned to the 'immediate background knowledge' group to read a domain-related text and 31 participants were in the 'no background knowledge' group to read an unrelated scientific text. Subsequent to data preparation, two-tailed statistical testing was applied to all exploratory analyses; one-tailed tests were used for analyses testing the hypotheses outlined above.

### Exploratory analyses

Two-tailed *t* tests revealed that male participants on average achieved marginally higher cognitive ability scores ($M_m = 84.73$, $SD = \pm.86$ vs $M_f = 73.76$, $SD = 1.04$, $t(58) = .90$, $p = .062$) and were also significantly more likely to be assigned to the 'no background knowledge' group than females (83.3 vs 41.7 %, $p = .010$). Therefore, sex was selected as an adjustment variable in the hypothesis testing analyses. Two-tailed Pearson correlations showed that participants with higher cognitive ability achieved higher recall scores ($r = .26$, $p = .037$). A positive association between EBs and perceived tentativeness ($r = .23$, $p = .070$), and an association of higher age with lower school grades ($r = .22$, $p = .093$) fell just short of statistical significance. None of the remaining associations among demographic, predictor, and outcome variables reached statistical significance (all $p > .10$). The two outcome variables perceived tentativeness and recall were unrelated ($p = .572$).

### Tests of hypotheses

An analysis of covariance controlling for sex to evaluate Hypothesis 1 revealed no significant difference in mean recall scores between the 'no background knowledge' ($M = 7.13$, $SD = 1.92$) and the 'immediate background knowledge' groups ($M = 7.17$, $SD = 2.33$, $F(1, 57) = .00$, $p = .475$). To test Hypothesis 2, we compared perceived tentativeness between the two groups, and found that they were similar in both ($M = 11.54$, $SD = 3.17$ vs $M = 10.56$, $SD = 3.52$, $F(1, 57) = 1.15$, $p = .144$). Accordingly, these predictor–outcome relationships were not further explored.

Multiple linear regression analyses of recall and perceived tentativeness on EBs and cognitive ability tested Hypotheses 3–6 (see Table 2). More sophisticated EBs were independently associated with greater recall (Hypothesis 3) and greater perceived tentativeness (Hypothesis 4); higher cognitive ability was linked to better recall (Hypothesis 5) but was unrelated to perceived tentativeness (contrasting Hypothesis 6), with EBs accounted for. Findings for EBs were largely unchanged in terms of effect sizes and significance when repeated post hoc with additional adjustment for the experimental manipulation of 'immediate background knowledge' (for recall, standardized $\beta = .23$, $p = .035$; for perceived tentativeness, $\beta = .22$; $p = .045$). The association of cognitive ability with recall increased marginally in this modeling step ($\beta = .31, p = .008$). Adjustment for sex in a final step, too, did not lead to any substantial alterations to our findings (for EBs on recall, standardized $\beta = .22$, $p = .039$; for EBs on perceived tentativeness, $\beta = .21$, $p = .054$; for cognitive ability on recall, $\beta = .36$, $p = .004$).

### Interaction effects

EBs and cognitive ability were entered in two-tailed analyses of variance in order to explore potential interaction effects on the dependent variables. 'Immediate background knowledge' was disregarded in this analysis due to nonsignificant findings on this factor in the initial analyses. No interaction effects of EBs and cognitive ability on recall ($F(1, 54) = .02$, $p = .886$) or on perceived tentativeness ($F(1, 54) = .09$, $p = .767$) were found in unadjusted analyses and so were not further explored.

## Discussion

In this study, we aimed to identify individual differences in characteristics that determine laypeople's ability to recall new scientific information and their ability to engage in its critical evaluation. By using a journalistic article on findings from the field of health research, we investigated the topic of scientific text processing from a perspective that to date has been neglected. As expected, we found evidence that people who believed medical knowledge of psychomotor diseases to be more complex (i.e., people with more sophisticated EBs in that domain) were better able later to recall the scientific content of the article than those

**Table 1** Sample characteristics

| | Mean ± SD, *n* (%), or median (interquartile range) |
|---|---|
| Age (years) | 24.1 ± 3.3 |
| Female | 48 (80 %) |
| School grade (possible range 1–6[a]) | 2.1 ± .6 |
| EBs (CAEB score) (possible range 0–144) | 76.3 ± 14.0 |
| Cognitive ability (MHVS score) (possible range 0–150) | 78 (68–91) |
| Recall (possible range 0–14) | 7.1 ± 2.1 |
| Perceived tentativeness (possible range 0–20) | 11.1 ± 3.3 |

Perceived tentativeness based on four-item scale

*CAEB* Connotative Aspects of Epistemological Beliefs Questionnaire, *EBs* epistemological beliefs, *MHVS* Mill-Hill Vocabulary Scale, *SD* standard deviation

[a] Lower grades mean better performance. $n = 59–63$

**Table 2** Models of recall and perceived tentativeness on EBs and cognitive ability

| | Recall | | Perceived tentativeness | |
|---|---|---|---|---|
| | Standardized $\beta$ (standard error) | *p* value | Standardized $\beta$ (standard error) | *p* value |
| EBs | .21 (.02) | .047 | .23 (.03) | .037 |
| Cognitive ability | .27 (.25) | .015 | −.07 (.41) | .293 |

$n = 62$. Findings from two linear regression models (for recall and for perceived tentativeness, respectively) with both predictor variables entered in single step. EBs measured by CAEB scores. Cognitive ability measured by MHVS scores

Perceived tentativeness based on four-item scale. Total $r^2$ for model of recall = .12. Total $r^2$ for model of perceived tentativeness = .06

*CAEB* Connotative Aspects of Epistemological Beliefs Questionnaire, *EBs* epistemological beliefs, *MHVS* Mill-Hill Vocabulary Scale

with more simple beliefs about medical knowledge. Participants with more sophisticated EBs were also better able to engage in critical evaluation, as evidenced by their recognition of the tentativeness of the findings reported in the article. We further found evidence that greater cognitive ability, as indexed by a measure of vocabulary, facilitated recall of content. Contrasting with our initial assumption, greater cognitive ability was unrelated to critical thinking. All associations reported here for EBs and cognitive ability were independent of one another and were also independent of experimentally induced immediate background knowledge of the topic, which itself was unrelated to either of the two outcomes. Recall and critical evaluation were also unrelated.

Our finding that EBs and cognitive ability were associated with better recall of health-related content from a newspaper article is in line with evidence for the influence of these predictors on learning success in other domains (Kuncel and Beatty 2013; Pieschl et al. 2008). During processing of a science journalistic text, its content is encoded to produce a mental representation of the concept. This is then continuously updated in cycles involving the integration of incoming information into existing representations (Schmalhofer et al. 2002), and our results suggest that sophisticated EBs and a higher cognitive ability may independently of each other enhance that process.

Compared with the recall of information, the ability to apply critical thinking could be argued to be of even greater importance. Encounters with scientific information are extremely frequent in everyday life, and in processing that type of information laypeople are faced with the challenge of scrutinizing the presented information which represents but a single 'piece' of the puzzle of a scientific topic. Thus, compared with the recall outcome, our present contribution on critical thinking arguably has even greater implications.

The facilitative effect of EBs on critical thinking is consistent with previous research that to date has focused on topics such as climate change rather than health (Strømsø et al. 2011). This is the case despite the fact that critical evaluation is particularly important in the context of health, which is highly relevant to laypeople. We have extended the existing evidence by showing that EBs may influence critical evaluation of a health news article and may do so independently of cognitive ability.

For cognitive ability, however, our study provided no evidence that higher-ability people viewed the article in a more critical light than lower-ability people. The finding is at odds with some earlier research, which had identified associations of cognitive ability with critical thinking aptitude (Klaczynski and Gordon 1996; Stanovich and West 1997). This disparity may be due to differences in domains, as previous investigations had focused on sociopolitical rather than health issues. Further studies are needed to evaluate our finding of a lack of associations, which may have implications for shaping future media contributions with specific audiences in mind. For instance, should our findings be confirmed and cognitive ability was indeed unrelated to critical evaluation of health-related content, journalists targeting their articles at well-educated laypeople should perhaps be advised not to assume intact critical thinking ability in their audience, and should therefore receive further guidance to enhance their cues for tentativeness in the text.

Having been provided with immediate background knowledge of DBS did not affect critical thinking or recall. Previous studies have relatively consistently reported links with learning success and critical thinking both in the health domain (Beier and Ackerman 2005) and in other fields (Chase and Simon 1973; Zohar and Nemet 2002). The way in which prior knowledge may facilitate the acquisition of novel information is thought to involve integration of the novel information into previously formed retrieval structures and mental models (Cook 2006; Fincher-Kiefer et al. 1988). As part of that process, mental models are activated and moved from long-term memory storage into working memory in order to deal with the new input (Wetzels et al. 2011). It has further been suggested that prior knowledge may influence perception of and attention to novel material (Cook 2006). On that basis, we would have expected to find an effect of prior knowledge at least on recall. We suspect that our attempt to induce prior knowledge through provision of immediate background knowledge was insufficient or even led to a certain degree of confusion: Participants received two complex texts on DBS in brief succession, and we presume that it was for this reason that those in the 'immediate background knowledge of DBS' condition occasionally recalled content from the textbook section when asked about content from the journalistic article.

Many investigations into determinants of learning and critical thinking in the past have considered single individual difference characteristics, despite the fact that all are likely to be interrelated. For instance, a more intelligent person is likely to develop more sophisticated EBs (Kuhn 1993; Vrugt and Oort 2008) and is also more likely to apply that ability to gain knowledge in a specific domain (Cattell 1963). We therefore deemed an evaluation of the independence of associations versus interactions as imperative. Similar to our finding that EB associations with critical thinking were independent of participants' cognitive ability, one previous study reported that elaborated EBs predicted better ability in reasoning about the causality between HIV and AIDS (Kardash and Scholes 1996). That association, too, was entirely independent of cognitive ability, which was also unrelated to reasoning. EBs have previously been found to be associated with learning, again independent of cognitive ability (Trautwein and Lüdtke 2007), as we also found in our study. We are not familiar with any previous investigation that has linked cognitive ability to learning or to critical thinking and that has considered the independence of associations from EBs.

The independence of the two outcomes of recall and critical thinking from each other was somewhat surprising. It has been previously suggested that learning typically results from the application of critical thinking (Wang et al. 2009), and so the current preliminary evidence of an independence of both variables in a health context warrants further investigation. Considering that simply controlling for prior knowledge in analyses of determinants of learning is thought to be insufficient (Shapiro 2004), the use of a topic with which all participants on study entry were unfamiliar was one strength of our investigation. It allowed investigation in a 'pure' setting which was unaffected by participants' prior concepts. A number of limitations must also be considered, however. Despite the selection of DBS as a topic in order to induce presence versus absence of 'immediate background knowledge' in our sample, it is precisely that manipulation which appears to have been flawed. The knowledge of DBS that resulted from our single-text manipulation was relatively shallow. It was not akin to naturally occurring prior knowledge let alone expert knowledge that has been at the focus of the research literature on prior knowledge (for a review, see Sinatra and Chinn 2012). Provision of a text on an unrelated topic in the 'no background knowledge' control condition, which aimed to ensure that cognitive processing demands were equivalent in both groups, may also have confused participants in this group. Participants possibly looked for connections between the two unrelated texts, which could have affected results. Finally, though ensuring a greater level of experimental control, modifying the texts may have been less ideal compared with using real, unaltered texts from media outlets.

Although we selected EBs and cognitive ability as two personality factors to investigate with respect to the outcome measures, confounding by other factors that we did not consider is possible. For instance, familiarity with clinical research and statistics may well have varied between participants. In addition, our use of a relatively small convenience sample of students was not ideal, as cognitive ability is overall higher in students than in the general public, where people may face an even greater challenge when processing scientific content from the mass media. The present results clearly warrant replication in non-student samples before any well-founded conclusions may be drawn. Further, the 'recall' measure indicative of learning success captured relatively shallow processing of the article and therefore was only a measure of what may be referred to as 'learning for retention' as opposed to 'knowledge understanding' (Mayer 1996). Finally, our statistical analyses of interaction effects were potentially underpowered and the use of one-tailed statistical tests in hypothesis testing may have been suboptimal. The effect sizes of the present findings were relatively small, and so any real-life implications of cognitive ability and EB effects on learning and critical thinking, if confirmed in future investigations, may be relatively limited.

We recently identified individual differences in self-efficacy as another factor predictive of the critical appraisal of journalistic articles on DBS (Flemming et al. 2015). Future research should now consider further modifiable and non-modifiable cognitive, metacognitive, and personality determinants of the ability to process and evaluate journalistic articles. Examples of these could include individual differences in people's 'belief in authority' (Sanders-Reio et al. 2014), their beliefs about intelligence as a fixed or malleable entity (Dweck 2000), as well as their achievement goals and interests (Winne and Nesbit 2010). Instead of attempting to manipulate prior knowledge by providing immediate background information on a topic, studies are advised to make use of naturally occurring individual differences in knowledge of a specific domain.

To conclude, we have provided preliminary evidence that greater cognitive ability and more sophisticated EBs facilitate the recall of health-related content that is presented in a journalistic article. Additionally, sophisticated EBs appear to go along with a critical approach to the evaluation of scientific information. Some previous longitudinal evidence suggests that EB development may be shaped by commencement of a college course (Trautwein and Lüdtke 2007) and by experimental exposure to conflicting information (for a review, see Ferguson et al. 2012). Further observational investigations and intervention studies with longer follow-up periods are needed to evaluate whether such changes in people's epistemology have lasting effects. Together with our findings of associations of more sophisticated EBs with more advanced critical thinking, the evidence at hand, though preliminary at present, points to the possibility that learning and critical thinking may be promoted in laypeople through strategic targeting of their EBs. If enduring modification of EBs were possible, and if our findings were to be replicated in more diverse samples and across domains, then future promotion of EB development could potentially aid the public's understanding and assessment of scientific topics.

**Acknowledgments** The research reported here was funded by a Grant from the German Federal Ministry of Education and Research awarded to Joachim Kimmerle and Ulrike Cress (Grant No. 01GP1306B).

**Compliance with ethical standards**

**Ethical approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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