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FALSE CERTAINTY AS AN UNWANTED SIDE EFFECT OF KNOWLEDGE ACQUISITION IN COMPUTER-BASED ONLINE SEARCH AND CONTENT LEARNING

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Annotation. Previous research has shown that learners' subjective certainty in the assumed correctness of their false answers to a knowledge test increased after online learning. It is unclear, however, 1) whether this False Certainty Effect (FaCE) results from online learning per se, or 2) whether a FaCE results from people confusing their own knowledge with information available on the internet while searching the internet, and 3) whether any topic-directed activity can result in a FaCE, even if it is not obviously topic related. We conducted two computer-based experiments to answer these questions. In Experiment 1, participants (N = 135) were randomly assigned to either an online-search learning condition, a computer-based content-learning condition with preselected learning material, or a computer-based topic-exploration condition with no learning-relevant information. Across all conditions, there was an increase in false certainty after the activity. The FaCE was equally strong in the two learning conditions (online search and content learning) and minimal in the non-learning condition. In Experiment 2 (N = 87), we replicated the FaCE for a learning activity with pre-selected materials but did not find a spill-over effect to an unrelated topic. These results indicate that the FaCE is primarily an unwanted side effect of the knowledge acquisition that arises from brief computer-based learning activities.

Keywords: False certainty Metacognition Online-search Overconfidence Computer-based learning

Introduction

Self-regulated, unsupervised internet search activities with the extrinsic or intrinsic goal to acquire knowledge have come to be known since the mid-2010s as searching as learning. Recent research has demonstrated that learners' subjective certainty in their own correct as well as in their own false answers increases after short (30–45 min) self-regulated SAL-tasks. In such research, participants fill in a knowledge test comprised of multiple-choice questions (MCQs) before and after an SAL task on a given topic. They are also asked for all items in the test to indicate their subjective certainty that their respective answer was correct. The magnitude of the "False Certainty Effect" seems to depend on the knowledge gain during the SAL task: In conditions in which there is only a small knowledge gain or no knowledge gain at all, there is just a comparatively small increase in the false certainty in incorrectly answered questions. Conditions with a substantial knowledge gain, however, are accompanied by a large increase in false certainty, which is comparable in size to the increase in confidence in correct answers. It is an open research question whether the FaCE results from the online learning activities themselves or from people's confusion of their own knowledge with the information available online while using web search for learning. Thus, the research

presented here aims at disentangling these aspects by comparing an online-search learning situation with a computer-based content-learning situation and with a computer-based exploration scenario. Moreover, the question arises as to which subject areas the effect applies. Does the effect only occur directly in the topic that people have dealt with or does the effect extend beyond that topic? Or does it also occur in other, unrelated topics? We conducted two computer-based experiments to answer these questions. In the following section, we discuss the phenomenon of overconfidence and situations in which it tends to occur, and we present the rationale for our empirical procedure.

The phenomenon of overconfidence arises when individuals hold subjective beliefs about their capabilities or knowledge that exceed what they are in fact capable of or know, as judged by an objective criterion. It is well documented in empirical research that people display a general tendency to be overconfident when evaluating their achievements and other socially valued properties. When comparing their capabilities to those of others, some people demonstrate overplacement as shown by Kruger and Dunning (1999): When the researchers asked participants to rate their own knowledge as compared to others, those being in the bottom quartile judged their knowledge to be above average. Apart from that phenomenon, overconfidence also arises when people compare estimates of their achievement to actual test scores. According to a review by Moore and Healy (2008), such measures of overestimation are used in almost two-thirds of all studies on overconfidence. However, skilled participants systematically under- estimate their performance in rather easy tasks. Some research shows yet another way in which people are overconfident, by comparing the precision of participants' estimates to the actual precision of their answers—for example, in the form of confidence intervals, within which the true score is supposed to be found with reasonable certainty.

Since all these concepts are concerned with people's subjective perceptions of their internal states, a generalized way of thinking about overconfidence in metacognition research is by relating people's perceptions of performance to their actual performance. On the operational level, good calibration is achieved if subjective certainty that one's correct answers are correct largely exceeds the certainty of incorrect ones. Metacognition research emphasizes that those accurate and adequate meta-cognitive judgments are paramount for self-regulated learning since—as part of metacognitive monitoring - they affect control of study behavior. Our study differs from the calibration approach in that we focus specifically on measuring participants' subjective certainty that actually false answers would be correct (false certainty).

We argue that the development of false certainty after learning activities as reviewed above is an important point of concern in and of itself from a pedagogical point of view. Metacognitive judgments are used to decide when to terminate a learning task because learners consider a target learning item as known when they experience high certainty in their answer. This means displaying false certainty after learning could impede the ability to identify gaps in one's own knowledge.

In consequence, false certainty can potentially lead to the premature termination of learning processes and to faulty learning strategies. Maybe even worse, false certainty can also be a problem whenever knowledge is applied in practice. Diagnostic failures of medical professionals, for example, are often linked to ineffective metacognitive monitoring. Just imagine physi- cians advising a patient in need of treatment. If they fail to notice what they do not know about the case, the patient's health might be at risk. A recent re-analysis of data from studies in the field of medical education found evidence that a FaCE can very well emerge in the field of medical training as well: A FaCE occurred among medicine and physiotherapy students who watched an online video of a knee surgery as well as among physiotherapy students who learned about gait analysis in a hybrid learning environment. In these studies, the FaCE was also accompanied by an increase in knowledge and an increase in the certainty in correct answers.

The beginner's bubble phenomenon

A potentially related phenomenon to the FaCE has been described by Sanchez and Dunning as the beginner's bubble phenomenon: Participants who had the task to learn to discriminate fictitious zombie diseases in response to a description of symptoms switched after a small number of diagnoses (approximately 5–10) and initial successes from a 'learning mindset' to a 'performance mindset' (Studies 2, 3, and 4). That is, they no longer put their belief to the test and displayed over- confidence by overestimating the correctness of their diagnoses. Their priority was to optimize performance, in the sense of increasing the number of diagnoses per time.

Similar results could be found for the development of subjective and objective financial knowledge of a representative US panel with data across a lifespan: Whereas subjective knowledge initially grew faster than objective knowledge, which led to overconfidence, the difference between the two ratings diminished during later adulthood. In another experiment, Sanchez and Dunning (2017) could replicate their initial findings regarding zombie diseases, applying them also to other types of judgments, such as choosing a more accurate fictitious lie detector (Study 2).

Theoretical rationale for the present studies

von Hoyer, Kimmerle, and Holtz (2022) could rule out in their studies a very simple alternative explanation for the FaCE based on a prediction by the cue-familiarity heuristic approach: Since the initial studies used the same items in the pre- and post-tests, participants should display more certainty in the answers to questions that they had already encountered beforehand, because they would perceive them as more familiar , irrespective of the participants' actual ability to answer the question. This explanation, however, could be ruled out by manipulating item familiarity. Participants who answered a different set of multiple-choice questions on the same topic (Study 2b) showed a comparable FaCE to those who answered the same items (Study 2a).

However, all studies so far have used some form of online search interface in the learning phase. It is very well possible that learners using the internet are particularly prone to overconfidence in general. By experiencing the fast response of a search interface to one's queries, participants could confuse what they truly know with what they could know by 'googling' it. Hence, the questions remain whether using a digital search interface attenuates the FaCE ("online-search hypothesis"), and whether the small increase in false certainty that could be found in conditions where no knowledge acquisition had taken place can be replicated. It is also very well possible that just any topic-related activity—whether learning takes place or not—can lead to a (comparatively small) increase in false certainty. This has been referred to as the "activity hypothesis". One could finally take the activity hypothesis even one step further: What if any learning activity leads to a FaCE, even if a learner is studying material on a completely unrelated topic? In the two experiments reported here, we explored the boundary conditions and pushed the limits of the acquisition of false certainty in SAL tasks.

Method

Participants were recruited via prolific – a participant management platform and online panel provider. As inclusion criteria, we specified first language German and a maximum age of 50. The selected population consisted of 1900 participants.

Table 1

Condition	Activity environment	Activity scenario
Online-search condition	Online search	Learning
Content-learning condition	Preselected content	Learning
Topic-exploration condition	Preselected content	Exploration

In total, 135 responses that had matching ids for t1 and t2 were collected. One participant had to be excluded because his level of diving experience was greater or equal to the level of 'autonomous diver'. This resulted in a total N of 134. Of the participants, 56 were female and 78 were male.

Mean age was M=29.56 (SD=7.11) years old; 64 of the participants were undergraduates, 24 had an academic degree, and 44 were employees without an academic degree.

Materials

We used scuba diving as a learning topic, which contains facts and concepts from subtopics like physics, medicine, diving equipment, and diving behavior. For measuring knowledge before and after the information-search activity, we used a 30-item forced- choice knowledge test that had been developed and refined in two previous studies. We measured RCJs by a Likert-type item with labeled end points (1=not certain at all, 5=very certain) following each knowledge test item. As an exploration topic, we used scuba diving as well, but selected learning-irrelevant content, like reports about diving trips or diving resorts.

This study was conducted as a two-part online experiment. In the first part, participants responded to a survey testing their prior knowledge and then provided demographic information. The second part consisted of an online session of up to 10 participants via the video conference tool Zoom Video Communications. One experimenter supervised the participants who were required to share their screen to ensure everyone followed the instructions. In this part, participants were randomized to one of three experimental conditions. They then completed the respective activity and were subsequently tested for their knowledge again.

As means of increasing motivation, participants were initially told that they had to write a brief text about the topic of scuba diving after the learning phase, which was not the case. Participants were debriefed at the end of the study.

Online-search condition. To compare our results to previous studies, the online-search condition was very similar to von Hoyer, Kimmerle, and Holtz (2022). Participants were instructed to freely search the internet by using Google for 30 min to learn about scuba diving as a preparation for obtaining a diver's license. Study time was controlled by the experimenter.

Content-learning condition. Informed by a previous study where participants freely used the Google search engine to learn about scuba diving, we put together a selection of web pages that were used in this study (see OSF repository above). Participants were given 30 min to learn about scuba diving using those selected resources only. However, they were able to choose order and time spent on each resource. The instructions for the online-search condition were slightly rephrased to be applicable to the selected material of the content-learning condition, but otherwise identical.

Topic-exploration condition. For the topic-exploration condition, we compiled another set of online resources about scuba diving, which was not related to aspects of the knowledge questions (see OSF repository above). For example, we included videos showing cave diving or written diving-trip reports. This collection did not contain information pertaining to concepts and facts about diving which had been included in the previous condition. Participants were instructed to go through this collection of resources by following their curiosity and were not specifically instructed to learn. Their goal was to use what they found in the material to write the outline of a blog post with the headline "Fascination of diving".

Results

To determine whether participants had any knowledge gain after completing their assigned activity, we calculated three paired sample t-tests for the mean percentage of knowledge test items answered correctly at t1 and t2 for all three conditions. As expected, on average, participants displayed a significant knowledge gain in the online-search condition (M_{t1} = 50.0%, SD_{t1} = 13.6%, M_{t2} = 60.0%, SD_{t2} = 12.0%, t_{44} = 6.358, p = <.001, d = 0.77, 95% CIs [0.45, 1.04]) and content-learning condition (M_{t1} = 51.5%, SD_{t1} = 13.0%, M_{t2} = 60.2%, SD_{t2} = 10.4%, t_{44} = 5.334, p = <.001, d = 0.74, 95% CIs [0.42, 1.04]). There was no such effect for the topic-exploration condition (M_{t1} 48.0%, SD_{t1} 12.5%, M_{t2} 48.6%, SD_{t2} 11.8%, t_{43} 0.388, p .700). See Table 2 for means, SDs, and statistical parameters of the t-tests.

Table 2

Means, standard deviations, and statistical parameters of mean participant knowledge separated for the three activity conditions.

Condition	***t1***	***t2***	**p**	**Cohen's d**	**CIs**	**df**	**Nitem**	**Nsubject**
	M (SD)	**M (SD)**						
Online-search condition	0.50 (0.14)	0.60 (0.12)	<.001	0.76	[0.49; 1.04]	44	30	45
Content-learning condition	0.52 (0.13)	0.60 (0.10)	<.001	0.73	[0.42; 1.04]	44	30	45
Topic-exploration condition	0.48 (0.13)	0.49 (0.12)	0.700	0.04	[-0.18; 0.27]	43	30	44

A successful learning activity should not only lead to an increase in correct answers. In an ideal world, such an activity should also make people more aware of what they know and what they don't know, in that they attribute higher certainty to correct answers and lower certainty to incorrect ones. At the very least, learners should not be more certain that their false answers are correct after (successful) learning. However, as in previous studies, we consistently found that the certainty that false answers were correct increased after short, self-regulated learning activities. In the current article, we present the new finding that this effect can also be observed in learning environments with pre-selected learning materials, and not only in SAL tasks that involve searching the internet.

We observed a small FaCE even in an experimental condition in which learning was made impossible, since the provided learning material did not contain any information that was relevant for the knowledge test and no learning instruction was given. This finding becomes even more interesting if compared to the results of von Hoyer, Kim- merle, and Holtz (2022), which show that just being exposed to a knowledge test a second time does not elicit the effect. As investigated in Study 2, we could not find any traces of a 'spillover effect' where learning on a given topic increased the false certainty in answers on an unrelated topic. So, topic congruency might be a boundary condition for the FaCE.

Based on these findings, we conclude that, for the most part, the FaCE is an unwanted consequence of the acquisition of knowledge in (at least partly) self-regulated learning activities: Increasing knowledge, as indicated by the ability to answer more MCQ-items correctly, seems to be accompanied by a certain sense of entitlement with regard to the veracity of one's answers—even when they are factually wrong. It is only natural that gaining competence in a given domain leads to an increased perception of self-efficacy, but does not necessarily lead to an increased awareness of the limits of one's newly acquired knowledge. Such a capacity for self-critical reflection may require, among other things, the experience of failure, which has been shown to be able to trigger productive learning processes in domains such as STEM education.

Future research will have to investigate the question if and how false certainty can also be an issue in more communal and externally controlled learning settings, such as classroom teaching. So far, we have only looked at situations where learners could either freely decide which learning

materials to select from the internet and what to do with them, or where learning materials were provided in advance, but learners could use them in any way they wanted. It is possible that in more traditional learning settings, interactions with teachers and other learners can attenuate the acquisition of false certainty, but at the present time, more research is needed to test this hypothesis.

It should be noted that the duration of such a beginner's bubble apparently can be rather fluid, since it ranged in the studies by Sanchez and Dunning from minutes to several years. It also appears plausible that the duration of such a beginner's bubble can differ widely as a function of the complexity of the learning task at hand. In any case, occasional and rather informal "everyday learning" in the form of brief, self-regulated learning activities has arguably gained in societal importance since the rise of the internet as the primary source of information. Given the potential detrimental con- sequences of false certainty, pedagogical and instructional methods are needed to reduce the FaCE. Future studies could investigate whether using feedback strategies and training to promote general metacognitive awareness could reduce false certainty after brief learning activities.

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