



## Differential impact of web habits and active navigation on adolescents' online learning<sup>☆</sup>

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### ABSTRACT

In this study we investigated how 14- to 17-year-olds ( $n = 48$ ) search the web for information about unsettled scientific dilemmas. In particular, we addressed to what extent adolescents' capability to appraise accurate web sources, learn, and mold informed opinions is influenced by the quality of their online search strategies, the control they exert over the online search experience, and the experience they have while searching the web for relevant factual information. Our results show that adolescents' learning resulting from independent online search was not influenced by their search strategies and was generally quite poor, although they did identify and consult the most relevant and informative web sources. Interestingly, we found that having active control over the search process enhanced participants' learning and retention of factual information, but following the search process more passively increased their capability to reflect on, process, and elaborate on the information found on the web. This latter aspect was also positively influenced by having greater experience searching the web to perform school assignments. Taken together, these findings can inform educational practices, supporting the development and implementation of more effective interventions to empower the conscientious use and successful mastery of the pseudo-infinite information available on the web.

### 1. Introduction

It is crucial for us—humans of the information age—to be able to critically reflect on the insights and opinions we gather, or often just get bombarded with, from our social and digital environment: A friend might share a post on Facebook warning us not to use deodorants anymore because they allegedly contain carcinogenic aluminum compounds, or we may come across an advertisement trying to convince us to buy this new kind of mineral water that contains a lower concentration of carcinogenic substances, such as nitrates.

Whether information comes from real-world encounters, social media feeds, the news on TV, or Google, we are constantly faced with the challenge of evaluating its accuracy. In this sense, the web is an extremely powerful resource; searching it allows us to understand, learn, and form opinions about health, scientific, political, or social issues we know little or even nothing about (Corley, Kim, & Scheufele, 2011). The increasing involvement of institutions and scientists on all kinds of web

and media platforms (e.g., Facebook and YouTube) contributes to this empowerment by facilitating the spread and accessibility of complex findings to a general audience and enabling people to be actively engaged by commenting and sharing opinions (Brossard, 2013).

Because of the ease, immediacy, and success with which one can obtain information, searching the web has become a daily routine to gain knowledge on a variety of topics, ranging from food safety (Bouzembrak, Klüche, Gavai, & Marvin, 2019) to science (National Science Board., 2012). Seven out of ten European aged 16- to 29 ranked *searching for information* among the most pursued activities on the web, together with emailing, video browsing, and using social networks (Eurostat, 2020). At least 80% of web users claim to prefer this method to alternative offline sources (Jiménez-Pernett, de Labry-Lima, Bermúdez-Tamayo, García-Gutiérrez, & del Carmen Salcedo-Sánchez, 2010), and a large majority of Americans (81%) report they rely on their own web research over friends and family (43%) or professional experts (31%) when gathering information before making an important decision

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(Rainie, Keeter, & Perrin, 2019).

The web represents an appealing learning resource especially for adolescents. First, they are generally more responsive than adults to interactive and innovative approaches to knowledge acquisition (Skopelja, Whipple, & Richwine, 2008). Second, adolescence is a major stage of development characterized by a strong desire for autonomy and self-determination (Shifflet-Chila, Harold, Fitton, & Ahmedani, 2016). In this context, the internet represents a powerful tool that allows adolescents to explore freely and independently, searching for information they might be too embarrassed to ask their peers or parents to supply, and to experiment with different roles to achieve a sense of occupational and sexual identity. Indeed, a survey by the EU Kids Online Network indicated that 81% of 15- to 17-year-old students go online daily after school, surfing on average for 3 h (Smahel et al., 2020), and according to a survey by the Pew Internet and American Life Project, 83% of children of the same age believe that the internet has enormous potential to improve their study habits and schoolwork, as it helps them quickly find answers, communicate with friends, and satisfy their curiosity (Lenhart, Madden, Rankin Macgill, & Smith, 2007).

Yet, having every kind of information available at our fingertips does not necessarily make information acquisition simpler. Indeed, although the web constitutes an invaluable resource, the abundance, richness, and often contradictory nature of the data available can easily be overwhelming. To acquire new information efficiently and successfully, one has to be able to search, filter, critically evaluate, and compare a virtually infinite list of results and sources, which are not all equally reliable, or reliable at all. This ability to effectively navigate the web, to read and interpret information coming from the media, and to evaluate and apply the knowledge gained from digital environments (often referred to as *information literacy*) has been described as the most important skill for the 21st-century learner (Eisenberg, 2003; Saunders, Severyn, & Caron, 2017). Information literacy is critical to transition from the *information* society we are living in, which is primarily concerned with collecting and disseminating data, to a *knowledge* society that transforms the available data and information into resources to empower people and improve the human condition (Alkali & Amichai-Hamburger, 2004; Aviram & Eshet-Alkalai, 2006; B. Jones & Flannigan, 2006). In this study we investigated *how* adolescents search and filter the web for information about unsettled scientific dilemmas, addressing to what extent their capability to appraise web sources for accuracy, learn, and mold informed opinions is influenced by the control they exert over the online search experience, by the efficiency of their search strategies, and by the experience they have with searching the web for relevant factual information.

### 1.1. State of the art

As information literacy becomes increasingly relevant for nearly every academic and nonacademic endeavor, research has been conducted from a variety of disciplinary perspectives, from psychology, human-computer interaction and education, to marketing and design, often with diverging goals and distinct methodologies (Livingstone, 2004). Consequently, there is quite some blurriness and ambiguity in the literature, with different terms (e.g., *computer literacy*, *digital literacy*) often used interchangeably despite their overlapping but still fairly distinct definitions (Bawden, 2008, chap. 1; Porat, Blau, & Barak, 2018). Overall, prior work has mostly focused on assessing the efficiency and effectiveness of students' online search behavior, and on their ability to identify and target reliable sources of information. Throughout this manuscript we consider information literacy as encompassing both the above-mentioned competences.

#### 1.1.1. Efficiency in adolescents' online search strategies

Previous research evaluating students' efficiency when browsing and filtering the web for information (see Covelto & Lei, 2010, for a review) focused on different measurements, using questionnaires and

self-reports (e.g., Gui & Argentin, 2011; Ng, 2012; Porat et al., 2018; see Hargittai, 2010, for a comparative study of self-reports' efficacy), search engines' transaction logs (e.g., Toms & Latter, 2007; Walhout et al., 2015), verbal protocols (e.g., Greene, Copeland, Deekens, & Seung, 2018; Greene, Seung, & Copeland, 2014; Kammerer & Gerjets, 2014), and video analyses of search patterns in tailored (e.g., modified results' page: Gwizdka & Bilal, 2017) or realistic (e.g., Google: Bilal & Gwizdka, 2018; Rennis, McNamara, Seidel, & Shneyderman, 2015) search engines. Notwithstanding these differences, this work converges to suggest that adolescents often do not implement optimal search strategies when navigating the web. For instance, they frequently utilize search engines rather than going straight to websites, often trusting the engines' query suggestions blindly (Gossen, Low, & Nürnberg, 2011). Although this approach might circumvent their lack of relevant knowledge and general difficulty in formulating correct queries on their own, following the algorithm's predictions may lead to results that are popular and trending but not necessarily the most relevant or accurate. This risk becomes even more significant given the evidence suggesting that teenagers heavily rely on the search engines' rankings, tending to select the very first results obtained and rarely looking beyond the first page of results (Gwizdka & Bilal, 2017; Kammerer & Gerjets, 2014). When compared to adults, 10- to 16-year-olds are more likely to click on higher ranked results, spend less time on each web address (i.e., URL), but nevertheless take longer to reach a solution to the task at hand (Duarte Torres & Weber, 2011), which is likely because of a stronger tendency to repeat the same queries and revisit the same result pages and websites (i.e., *loopy browsing*, Gossen, Höbel, & Nürnberg, 2014). Moreover, when formulating queries to be used on search engines, they seem to prefer natural language to keywords (Bilal & Gwizdka, 2018; Duarte Torres & Weber, 2011), which would lead to more targeted and refined results.

#### 1.1.2. Efficiency in identifying appropriate sources of information

From a strictly developmental and cognitive standpoint, adolescents should be generally pretty good at telling good from bad sources of information, as children as young as 4 years can already successfully identify which informant to trust and rely on (see Mills, 2013; David M. Sobel and Kushnir, 2013; for reviews). However, several studies suggested that they often do not take into account or are not able to evaluate the reliability and credibility of the sources of the information they are presented with online (Hautala et al., 2018). For instance, Maitz et al. (2020) found that more than 90% of the web pages visited by 14-year-olds during a health search task (i.e., suggest whether to get rid of a hairy mole) were judged poor or unreliable by independent raters. In particular, adolescents seem to fail to consider those aspects of the websites that would be relevant to appraise their reliability, such as the presence of advertisements (Gossen et al., 2011; McGrew, Breakstone, Ortega, Smith, & Wineburg, 2018), and do not take into account the website's sponsors or political and industry affiliations (McGrew et al., 2018). Instead, they often focus on more superficial cues, such as the vaunted expertise of the person providing information (e.g., the source of health-related information claiming to be a doctor, Maitz et al., 2020), or the website appearance (Freeman, Caldwell, Bennett, & Scott, 2018). In this respect, a meta-analysis by Dresang (2005) indicated that young people tend to discard the information coming from text-only websites, preferring more interactive pages, rich with video and visual content. This tendency might make them especially susceptible to false or biased information (Britt & Aglinskas, 2002). For example, McGrew et al. (2018) found that 52% of high-school students wrongfully believed that a grainy video claiming to document ballot stuffing in the 2016 Democratic primaries constituted strong evidence of voter fraud, although the video was actually shot in Russia.

#### 1.1.3. The impact of information literacy on learning outcomes

Previous literature rarely offers insights on the impact of information literacy on learning outcomes that transcend the boundaries of academic achievements on higher education's specific subjects (e.g., Christ, 2004;

Johnston & Webber, 2003; Storksdieck, 2016), with some exceptions. For instance, using verbal protocol analysis, Greene et al. (2018) found that the extent to which university students checked the consistency between different claims found on the web was positively related to their knowledge and comprehension of the topic at hand, although this relationship was not found to be statistically significant. Along these lines, undergraduate students were found to be better at justifying their opinions about unsettled scientific topics (e.g., whether using mobile phones can be a health hazard: Mason, Boldrin, & Ariasi, 2010) when they had reflected on the extent to which the consulted websites provided actual scientific evidence (see also Çoklar, Yaman, & Yurdakul, 2017; Kammerer, Gottschling, & Bräten, 2021; Zlatkin-Troitschanskaia et al., 2020 for similar work with university students). Moreover, Tu, Shih, and Tsai (2008a) analyzed video captures of 14-year-olds' web searches about nuclear energy. In their task, participants were asked to search for answers to both "open-ended" (i.e., among all of the energy resources, what do you think is the best energy resource? Why?) and "close-ended" (i.e., What are the currently used energy resources in Taiwan?) questions. Coding of the video captures focused on several quality indicators such as number of keywords, visited pages, maximum depth of exploration, refinement of keywords, and number of words used in the first query. Their results indicate that some of these parameters (e.g., number of keywords used), along with participants' general web experience, predicted the accuracy of participants' answers, but only when they were searching answers to close-ended questions. Analyzing similar query patterns, Bilal (2000) found a positive correlation between the quality of the search strategies implemented by 12- to 13-year-old students and their success in solving fact-finding tasks (i.e., how long do alligators live in the wild vs. captivity?). In particular, they found that successful children had navigated and examined a higher percentage of hyperlinks and homepages, and looped searches and hyperlinks less frequently than unsuccessful children. However, more recently, Walhout, Oomen, Jarodzka, and Brand-Gruwel (2017) measured 14-year-olds' perceptual search processes using a combination of log files, eye-tracking data, surveys, and think-aloud protocols when they were asked to complete three tasks of differing complexity (i.e., fact-finding, cause-effect, and a controversial topic task). Their results showed that an increase in task complexity resulted in poorer task performance but in increased interaction with the search engine. In particular, when completing the controversial task (i.e., Does radiation from mobile phones have consequences?), participants made more search queries and used more keywords, longer formulation time, and considered a greater amount of search results (but still higher ranked in the results' page).

#### 1.1.4. Assessing and boosting students' information literacy in educational settings

Results from the comparative International Computer and Information Literacy Study (Fraillon, Ainley, Schulz, Friedman, & Duckworth, 2020), conducted in 2013 and 2018 among teachers and students from 2,200 schools across 14 countries, suggest that although in this time frame schools had been increasingly equipped with digital tools such as computers and tablets, this was often not accompanied by the actual implementation of such tools in the educational curricula. For example, ILCIS 2018 consisted of a battery of tasks developed to measure students' ability to use computers to collect, manage, produce, and exchange information (computer information literacy). Participants' scores indicated that in most Western countries (e.g., Germany, Finland, and the United States), the majority of students were at Level 2 of 4, indicating they "needed support." Italian students reached an average score of 461 (of 746), corresponding to the "basic skills" Level 1. Furthermore, only 18% of the Italian students reported regularly using computers during their classes on information technology, programming, and computer science, which is a lower percentage compared to students from other European countries such as Denmark (75%) and Portugal (67%; Fraillon et al., 2020). These findings are in line with

other survey studies showing that only 5% of the students credit school for teaching them how to search and process online information (Strom, Strom, Wing, & Beckert, 2009).

In light of the research reviewed above, it seems evident that there is a considerable gap between the ever-rising awareness of the need to provide students with the opportunity to become information literate and the poor implementation of this process in school curricula. Indeed, although a variety of tools and interventions—games, tutorials, guidelines, workshops—have been developed over the last few years, their actual efficacy and potential is unclear and hard to assess, as they often stem from different perspectives and focus on diverse methods, outcomes, and goals (see Munn & Small, 2017, for a review). The efficacy of some of these interventions has been proven in higher education settings by introducing information literacy training within school curricula to boost students' ability to search scientific literature from specific databases, generally showing quite good and long-term success (e.g., Hegarty & Carbery, 2010; Kavsek, Peklaj, & Zigelj, 2016; Wallace, Shorten, & Crookes, 2000; Wegener, 2018). However, the evidence of successful interventions targeting younger students is generally scarce, if not absent. In this respect, the Joint Research Center of the European Commission published a support guide for stakeholders (DigComp; Kluzer & Priego, 2018), including case studies and interventions developed within the European Union with the aim of enabling people to acquire the digital skills they need to be successful in the workplace, at school, or simply as citizens. In the educational domain, most case studies suggested that interventions and tools were mostly successful when focusing on making students aware of their digital competences rather than boosting them (e.g., see the Task Project's tool).

#### 1.1.5. Factors influencing computer and information literacy

Studies have addressed the impact of different personal, social, and motivational factors underlying individual differences in information literacy skills (see also Lewandowski & Kammerer, 2020 for a review of factors influencing viewing behavior on search engine results pages). Evidence from the comparative ILCIS study (Fraillon et al., 2020) suggests that factors such as parental education, socioeconomic background, and students' expectations of attaining a university education were significant predictors of computer and information literacy across countries. A similar trend was found for participants' gender, with female participants scoring on average 11 points higher than male participants. Gender differences were also found in adolescents' online search efficiency, but generally pointing in the opposite direction, suggesting that boys may be more efficient searchers than girls (e.g., Large, Beheshti, & Rahman, 2002). For instance, Roy and Chi (2003) found that 13-year-old boys filtered information at an early stage in the search process, using a predominantly horizontal search pattern, which consists of opening multiple tabs simultaneously to check the veracity of different sources of information. Same-aged girls, on the other hand, were found to implement more vertical, linear search moves and to be generally more thorough than boys. The kind of task presented also has an impact on learning efficiency (e.g., Walhout et al., 2017). For instance, Bilal (2002) found that 12- to 13-year-olds solved fact-finding tasks with greater ease compared to more research-oriented assignments, where participants were asked to learn and report about more complex topics, such as the depletion of the ozone layer (Bilal, 2002).

Not too surprisingly, general experience and time spent in navigating web environments also has been found to have a solid impact on adults' navigational style (e.g., Palmquist & Kim, 2000; Thatcher, 2008) and on children's performance on tasks related to computer and information literacy (e.g., Bilal, 2000; Tu, Shih, & Tsai, 2008b). Even the frequency of use of information and communications technology applications in the classroom, along with the perception of having learned about computer and information technologies, was found to predict children's information literacy (Fraillon et al., 2020). Perceived self-efficacy (Hatlevik, Throndsen, Loi, & Gudmundsdottir, 2018), self-regulated inquiries (Lai, Hwang, & Tu, 2018), as well as epistemological beliefs

and previous knowledge about the topics one searches about (e.g., Corredor, 2006; Tu et al., 2008b), also seems to affect students' efficiency in searching, retrieving, and interpreting information from the web.

## 1.2. The current study

Contributing to the rapidly growing literature reviewed above, the present study explored how 14- to 17-year-olds navigate the web when they were tasked with making an informed suggestion about controversial topics (i.e., whether using deodorants containing aluminum compounds or drinking mineral water containing nitrates increase the risk of developing cancer). In addition to evaluating participants' overall search patterns, the factual knowledge they acquired, the accuracy of their suggestions, the completeness and clarity of their explanations, and interactions between these outcomes, we were interested in exploring the factors driving individual differences in search efficiency and learning outcomes. In particular, we have addressed the novel hypothesis that having control over the online search experience, along with having experience with searching the web specifically to obtain relevant factual information, may influence the overall quality of adolescents' online search efficiency and learning. We detail each hypothesis below.

### 1.2.1. Volitional control over the search process

As mentioned above, efficiently controlling the online search process is quite complex and demanding to: One has to know what to type in the search box, filter a pseudo-infinite list of results, evaluate the sources providing the information and the accuracy of the information provided, and finally decide when enough information has been collected and stop querying. Previous work suggests that the online search process taps into several cognitive skills, such as reasoning, working memory, attention, and perceptual speed (Sharit, Hernández, Czaja, & Piroli, 2008), as well as as vocabulary and cognitive flexibility (Dommes, Chevalier, & Lia, 2011). However, the media landscape also offers a constant stream of information that one does not control—TV news, YouTube channels, video bloggers, and social media feeds collecting and assembling information for consumption, presenting well-packaged stories that one can only absorb, endure, and later try to process, filter, and make sense of. Even though this process might be less costly from a cognitive perspective (Brossard, 2013) compared to situations in which one has to search actively, it may be even more demanding and taxing to evaluate and integrate information one has not put together oneself.

Indeed, active, self-directed learning has proven to be beneficial in educational settings across a variety of domains and subjects, contributing to the widespread idea that giving students some degree of control over the learning experience supports and boosts learning. In particular, recent experimental work indicates that even minimal forms of volitional control, such as allowing the learner to control the pace and order of the materials to be studied, enhance memory retention in both adults (e.g., ChangHong Liu, Ward, and Markall, 2007; D. Markant, DuBrow, Davachi, & Gureckis, 2014; Plancher, Barra, Orriols, & Piolino, 2013; Voss et al., 2011) and children (e.g., Fantasia, Markant, Valeri, Perri, & Ruggeri, 2020; D. Markant, Ruggeri, Gureckis, & Xu, 2016; Partridge, McGovern, Yung, & Kidd, 2015; Ruggeri, Markant, Gureckis, Bretzke, & Xu, 2019) compared to situations in which the learner is merely exposed (i.e., *yoked*) to other participants' study choices. By matching the content experienced during study across conditions, yoked designs isolate the effects of active control on learning. These benefits were proven to persist a week after the initial study session and were robust across different types of tasks and populations (D. Markant et al., 2016). Self-directed information sampling has been also linked to learning advantages in causal reasoning, where adult participants were asked to intervene—actively or by replicating actions made by someone else—on an unknown system to figure out which sensors turned on which lights (e.g., David M Sobel and Kushnir, 2006; Steyvers, Tenenbaum, Wagenmakers, & Blum, 2003). In their review, Gureckis and Markant (2012)

argued that besides the different valences of attention and motivation, just the act of making decisions about the timing, spacing, and order of information that active learners experience can enhance deeper processing. Additionally, because self-directed learners may gather data to specifically test a hypothesis they have in mind, in line with their existing knowledge, their mental state may simply not be matched to the yoked partners' search strategy. In this sense, the advantage of self-directed sampling would emerge only in cases where learners have a proper representation of the information space and are able to successfully monitor their own knowledge gap and uncertainty, sparing them the effort to allocate cognitive resources to redundant information (D. Markant & Gureckis, 2014). Indeed, self-directed sampling does not always lead to more efficient and successful learning, particularly on very complex tasks (Schwartz, 1966). For example, Enkvist, Newell, Juslin, and Olsson (2006) found that participants who actively experimented on a multiple-cue inference task to predict the binary criterion on which a bug would be considered deadly produced poorer judgments about the criterion values. Along these lines, self-directed sampling can also result in bias-driven strategies in which learners tend to confirm their initial (and potentially wrong) hypothesis (e.g., Denrell, 2005) and perceive illusory correlations (e.g., Fiedler, 2000), which may result in overconfidence about the efficacy of their sampling capabilities (e.g., Juslin, Winman, & Hansson, 2007).

Thus, this study expands previous work by exploring whether having volitional control over the online search experience impacts the accuracy and quality of the search process and of the knowledge acquired. For this purpose, we manipulated within participants whether they were free to search and navigate the web to collect the information they needed to form an opinion and make a suggestion (active condition) or could merely observe and follow another participant's search process (yoked condition).

### 1.2.2. Experience in searching relevant information

Evidence from Lenhart et al. (2007) indicates that the majority of 13- to 17-year-old adolescents use the web most often to visit social media platforms (71%), to check websites about movies, TV shows, music groups, or sports stars (81%), but also to look up news and current events (77%). Some studies suggested that older teens (15- to 18-year-olds) also use the web to look up health-related information (66%), particularly about sensitive topics that can cause embarrassment when discussed with other people (e.g., sex or mental health; Robards et al., 2017; Skinner, Biscope, Poland, & Goldberg, 2003; or see Freeman et al., 2018, for a comprehensive review). However, it is unclear whether and how different kinds of web experience and habits relate to adolescents' search efficiency and learning success. Previous studies suggested that the general experience of using computers (e.g., 5 days a week) was positively associated with students' information literacy (Fraillon et al., 2020). Yet, it seems improbable that using computers to play video games, to chat with friends, or to watch movies would make one a more efficient and conscious web user.

In this study, we contribute to the existing literature by investigating whether the frequency with which adolescents specifically search for factual information on the web (e.g., related to subjects covered in school, current events, or news stories), compared to other kinds of web experience, has a positive impact on their ability to search, filter, and consciously learn from the web.

## 2. Methods

### 2.1. Participants

Fifty 14- to 17-year-old high school students were recruited from one public secondary school in Livorno, Italy. Our agreement with the school prevented us from collecting participants' SES information. However, note that the city of Livorno does not offer any private schools: All children attend public schools, which are completely free of charge and

are therefore attended by students from all economic backgrounds. Two participants were excluded from the analyses due to a certified intellectual disability ( $n = 1$ ) and missing data ( $n = 1$ ). Thus, the final sample included 48 participants (13 female;  $M_{age} = 15.2$  years,  $SD = 1.03$ ). Participants were mostly white Europeans, native Italian speakers or fluent in Italian. The study was advertised through leaflets handed out by teachers. Institutional Review Board approval was obtained before we began recruiting participants from the Ethics Committee of the Max Planck Institute for Human Development in Berlin (protocol: "WISE"), and parents gave informed consent for their children to participate before testing took place.

## 2.2. Materials

We developed a testing battery which was implemented on Qualtrics (Qualtrics, 2005). All the items included in the battery are detailed below, mirroring the order in which they were presented to participants.

### 2.2.1. Previous knowledge

A closed question (yes/no) was used to assess participants' previous knowledge about the topic(s) they were presented with in the dilemma scenarios detailed below (i.e., "Do you know anything about nitrates in water/Do you know anything about aluminum in deodorants?").

### 2.2.2. Dilemma scenarios and web pages

The next page showed a brief text describing a dilemma scenario in which a fictitious character expressed uncertainty about whether to use products containing one of two substances (counterbalanced across blocks; see Procedure below) that have recently received controversial media coverage because of their potential carcinogenic effect: aluminum (A) in deodorants and nitrates (N) in water.

The text included four "target" keywords (i.e., cancer, scientific evidence, aluminum/nitrates, deodorants/water), not made explicit as such to participants, which if searched on Google (as required by the active search task; see procedure below) would have led to the most reliable (*target*) website being shown as a snippet (i.e., a box on top of the results page containing a summary of the main content of a website relevant to the user's search).<sup>1</sup> The target website belonged to a national association for cancer research (a nongovernmental organization [NGO]) and presented transparent and clear information about the connection of both substances to cancer.<sup>2</sup> The text concluded with the fictitious character explicitly asking participants whether the use of products containing those substances was safe and whether there was actual scientific evidence supporting their connection to cancer (see Section A in the Appendix for the complete procedure). The two pages were comparable in terms of reading time (5 min), and contained all the information needed to make an informed suggestion in reply to the character's question, and to answer knowledge assessment questions correctly (see below). That is, the Italian Association for Cancer Research (AIRC) has reassured the public that it is safe to use both of these products, as there is no evidence supporting the alleged risks. In particular, epidemiological studies have not shown significant relationships between deodorant use and the occurrence of any cancer, and specific studies on aluminum have not found any relationship between its effect on estrogen receptors and breast cancer. However, studies on nitrates have shown that, when ingested, about 20% of these compounds can be transformed into *nitrosamines*, which can be considered carcinogenic if introduced directly and at high doses. Therefore, according to the World Health Organization and the Italian law, nitrates in tap and bottled water must not exceed 50 mg/L.

<sup>1</sup> Note that omitting the keyword "scientific evidence" would have still resulted in the "target" website being listed first, but not as a snippet.

<sup>2</sup> Link Aluminium; Link Nitrates.

### 2.2.3. Suggestion and justification

A close yes-no question was used to ask participants to come up with a suggestion to the fictitious character (i.e., to avoid/not avoid deodorants containing aluminum; to avoid/not avoid drinking water containing nitrates), whereas an open ended question (where to type in maximum 150 words) was used to ask them to justify their suggestion.

### 2.2.4. Source reliability

Participants were then administered an open-ended question in which they had to provide a link to the *most reliable* and the *least reliable* source encountered while researching, and were then asked to select the reason for their choice from an eight-item multiple-choice list (see Table A1).

### 2.2.5. Factual knowledge

Three multiple-choice questions were administered to assess the knowledge that participants gained in the researched topic (see Table A3).

### 2.2.6. Information search habits

After having completed the active block, participants were asked which search engines they preferred (open-ended question), and the frequency with which they searched the web for various purposes (listed in Table 1), on a continuous Likert scale, ranging from 0 (*never*) to 10 (*every day*), and 5 (*once a month*) as a middle value.

## 2.3. Procedure

Students were tested in groups of 10–14 in the computer room at their school. Each of them was sitting in front of a 20" monitor connected to Windows 11 computers, distributed across two rows of 7 computer each. The testing battery was made accessible through a direct link placed on each desktop. Participants were asked to start simultaneously after the teacher made sure that all of them had typed in their anonymous code in the survey. Each participant completed a battery consisting of two identically structured blocks (i.e., active and yoked), each including the items described above, in the same order. The only difference between blocks was that, after being presented with the dilemma scenario about usage of one the substances mentioned above (A or N), they were given 10-min to search the web (active block) or instead watched a 10-min video of another participant searching the web (yoked block). The scenarios were pseudo-randomly assigned, so that participants sitting side by side on the same row would have been exposed to scenarios with alternating topics (see Figure A1). During the active block participants were explicitly asked to use Google for their research, and before starting, they were prompted to be as exhaustive and accurate as possible in order to being able complete the tasks that would have followed (i.e., make an informed suggestion and answer questions). Importantly, they were instructed to record their screen during the search phase, save this recording on the desktop, and name it as their anonymous code. A window popped up on the screen 10 min later to remind participants that time to research was over, and they had to move on with the survey. After completing the active block participants were given a short break, during which the teacher made sure that all

**Table 1**

Mean frequency (0 = never; 10 = on a daily basis) of participants' information search activities on the web and percentage of participants who ranked each search activity as the most pursued on the web.

Activity	Mean	SD	Ranked 1st by
Entertainment	8.54	2.23	37.5%
Interesting facts	7.85	1.84	33.3%
School-related content	6.56	2.34	8.3%
Products to purchase	6.52	3.26	12.5%
Daily news	4.31	3.03	2.2%
News about celebrities	4.58	3.33	6.2%

screen recordings had been saved on the desktop and named correctly. This was also done to ensure that they could have accessed the screen recordings which were needed to complete the next (yoked) block. At this point participants were asked to stand up and switch places with the participants sitting in the opposite row. As a result, half of the participants started with Topic A in the active block and proceeded to Topic N in the yoked block, whereas the other half started with Topic N in the active block and proceeded to Topic A in the yoked block.

In this  $2 \times 2$  within-subject design, the test blocks (2 levels: Active and yoked) and the topic (2 levels: Aluminum and nitrates) were the independent variables. However, as we found no effect of topic (A or N) on any of the outcomes considered in the study, we excluded this variable for the following analyses. The measures described above were considered as both dependent and independent variables, depending on the hypothesis considered.

We detail these hypothesis and corresponding statistical analysis below (please note that the full data set and script is available on the OSF platform at this link <https://osf.io/vykb6>).

### 2.3.1. Data coding

Three chemistry experts blind to the research questions rated the accuracy and completeness of the justifications on a scale of 0 (lowest possible score) to 10 (highest possible score). We assessed raters' agreement by computing the intraclass correlation coefficient (ICC) with a one-way random effect model and average unit:  $ICC = 0.881$ ; 95% confidence interval (CI) [0.83, 0.91];  $F(86,174) = 8.39$ ;  $p < .001$ . As the raters' agreement was very good, an average score was calculated for each participant.

The links participants provided as most/least reliable sources of information were then coded into different categories: NGO websites, official international governmental organization (IGO) websites, commercial websites, personal blogs, and Wikipedia pages.

Video captures of participants' search during the active blocks were coded by a blind and independent observer using the Datavyu video-coding software (Datavyu-Team, 2014). Five video captures were missing because of technical problems, leaving  $n = 43$  participants for the following analyses. The coding focused on two main aspects: the characteristics of the websites consulted and those of the inquiry process that have been previously identified as indicators of web search efficiency (e.g., Tu et al., 2008b). As those concerning source reliability, the websites participants consulted were coded by type.

### 2.3.2. Analytic strategies

We first calculated descriptive statistics of the learning outcomes considered (previous knowledge, accuracy of the suggestion and quality of the justification provided, sources selected as most/least reliable) merged across conditions, as well as of participants' web habits and search patterns in the active blocks.

Additionally we ran three mixed-effects regression models to examine potential interactions between the above-mentioned outcomes and the two conditions,<sup>3</sup> as well as three models predicting each learning outcome by the probability of providing a fully informative link, that is, a link that contained at least two of the three pieces of information needed to answer the knowledge assessment questions correctly.

We then performed the analyses of the factors we hypothesized might contribute to participants' performance. To do so, we used nine

<sup>3</sup> All generalized linear mixed models were run using the *lme4* package, version v1.1-23, inserting a random intercept for subjects. Effect sizes and 95% confidence intervals (CIs) for significant effects of logistic regressions are reported in terms of relative odds ratios (OR), which indicate the multiplicative change in the odds of providing a positive suggestion (binomial) or a fully informative link (binomial), which is associated with a unit change in the given predictor.

generalized mixed-effects models. Four models were fit to predict each learning outcome (i.e., knowledge assessment, justification score, suggestion, and provision of a fully informative link) with fixed effects of condition (i.e., active and yoked), and their interactions. Five additional models predicted each of the learning outcomes (as above), and search efficiency by participants' previous knowledge (factor: Yes/No) and their interactions with learning condition (not with search efficiency, as this was only active).

Finally we explored whether web information search habits also had an impact on participants' learning outcomes and search efficiency. For this purpose we ran several additional regression models, predicting each of the learning outcomes by the overall frequency of online information search, by the habit of searching the web for factual information (factor: Yes/No), and by search activity (i.e., by the characteristics of the inquiry process and of the websites consulted).

## 3. Results

### 3.1. Descriptive

#### 3.1.1. Previous knowledge: Had participants heard about these topics before?

Overall, 12.5% of the students indicated that they had heard about one of the presented topics before (Topic A:  $n = 6/48$ ; Topic N:  $n = 6/48$ ), whereas only two of 48 students had heard about both topics, and 70.8% ( $n = 34/48$ ) had heard about neither.

#### 3.1.2. Suggestion and justification

In total, 58.3% of participants ( $n = 28$ ) gave positive suggestions concerning both products; that is, they thought that the characters could safely continue using deodorants containing aluminum and continue drinking water containing nitrates, whereas 10.4% had the opposite opinion, that is, that the characters should stop using both products ( $n = 5/48$ ). Thirty-one percent of the participants gave a positive suggestion to the fictitious character concerning at least one of the allegedly carcinogenic products (Topic A:  $n = 7/48$ ; Topic N:  $n = 8/48$ ). Participants were also asked to justify the given suggestions with a short text. On average, the justification score obtained by participants was  $-4.59$  (Min = 1, Max = 9,  $SD = 2.38$ ).

#### 3.1.3. Source reliability

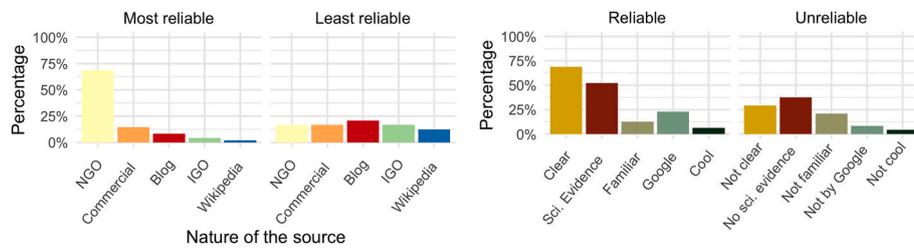
Descriptive statistic of the links participants provided as most/least reliable sources is reported in Table A2). As illustrated in Fig. 1a, 68.8% of participants deemed NGO websites as the most reliable (94.5% of the NGO links provided were the target website). Overall, 72.9% of the websites participants indicated as most reliable provided at least two of the three pieces of information required to correctly answer the knowledge assessment questions. Interestingly, we found no systematic trend in attributing unreliability to any of the source types (see Fig. 1b). Sixty-nine percent of participants perceived sources as reliable because they were clear and provided scientific evidence (52%), but no reason stood out when indicating why the provided sources were the least reliable.

#### 3.1.4. Knowledge assessment

Participants' answers to the three multiple-choice questions were coded as "1" when they were correct and "0" otherwise. On average, participants answered correctly about half of the questions ( $M = 0.45$ ,  $SD = 0.29$ ).

#### 3.1.5. Online information search habits

As can be seen in Table 1, adolescents reported they most often searched the web for entertainment content (e.g., video and games). Indeed, this was ranked as the most frequent activity by 37.5% of participants. In total, the percentage of participants who ranked factual information search (i.e., searching for interesting facts, school-related



**Fig. 1.** Percentage of the websites indicated by participants as most and least reliable, coded by source type (Panel a) and the reasons why participants had selected those links as most or least reliable (Panel b). IGO = International governmental organization; NGO = nongovernmental organization; sci = scientific. (a) Which source was the most or least reliable? (b) Why was the source the most or least reliable?.

content, or daily news) as the most pursued online research activity amounted to 43.8%.

3.1.6. Information search patterns in the active blocks

Table 2 provides an overview of the percentage of pages consulted and the average time spent on pages by source type, whereas in Table 3 we report the coding results concerning all the characteristics of the inquiry process. As participants were explicitly instructed to use the Google search engine, we did not include “search engine” among the indicators. Also, note that none of the participants used hyperlinks or typed in a specific link directly.

Overall, only 39.54% (17 of 43) of participants used a keyword-based query, that is, did not use any unnecessary conjunctions or specifications as one would do using natural language. Among them, 5.90% used none of the four target keywords, 11.76% used just one, 58.82% used two, and 23.52% used three. Interestingly, none of the participants used the cue “scientific evidence,” although this was explicitly mentioned in the text as the main goal of the research task.

3.2. Interactions between learning outcomes

We found that neither the proportion of correct answers participants gave in the factual knowledge assessment ( $p = .27$ ), nor the suggestions given ( $p = .52$ ) predicted the justifications’ scores. However, the alternative models revealed that participants who provided fully informative links were slightly more likely to answer more questions correctly (OR = 0.65, 95% CI [0.23, 1.78],  $p = .05$ ) but not to give different suggestions ( $p = .47$ ) or to get higher justification scores ( $p = .28$ ).

**Table 2**

Summary of the sources consulted during the active research blocks: Proportion of participants who visited each source type at least once, average percentage of page visits of the total of all pages consulted by source type, and average time spent on each source type across all queries.

Source type	Visited at least once	Total pages visited	Time spent on page (s)	
	Percentage (participants)	Percentage (source type)	Mean	SD
NGO	93.02%	52.2%	273.12	162.99
Commercial	65.12%	29.8%	85.6	126.85
Blog	18.60%	4.4%	11.21	34.75
IGO	16.28%	3.4%	16.72	57.63
Magazine	16.28%	6.4%	6.42	20.39
Wikipedia	11.63%	2.6%	11.81	36.53
Scientific journal	2.33%	1.2%	2.28	14.94

Note. NGO = nongovernmental organization; IGO = international governmental organization.

**Table 3**

Summary of the characteristics of the inquiry process: The average of each of the actions listed has been calculated across queries, unless indicated otherwise. Time excludes time spent taking notes.

Inquiry characteristic	Average	SD
Queries	2.18	1.36
Keywords	0.53	0.80
Keywords/query	2.49	0.76
Natural language	1.65	1.11
Reformulations	0.16	0.43
Pages consulted	3.25	2.18
Pages/query	1.86	1.28
Position rank	3.36	1.72
Lowest position rank (of 10)	4.67	3.67
Time (s)	407.16	145.23
Time/page (s)	185.05	146.40

3.3. Factors contributing to participants’ performance

3.3.1. Active versus yoked: Does volitional control over the search process impact learning outcomes?

The models show that participants in the yoked condition were less likely to answer the knowledge questions correctly ( $\beta = -0.38$ , 95% CI [-0.75, -0.01],  $p = .04$ ) but more likely to get higher justification ratings ( $\beta = 0.42$ , 95% CI [0.00, 0.83],  $p = .05$ ). Learning condition did not have an effect on the suggestions they gave to the fictitious character ( $p = .44$ ), or on the likelihood of providing a fully informative link ( $p = .08$ ).

As illustrated in Fig. 2, a paired Wilcoxon signed-rank test confirmed that the average of correct answers was significantly higher for the active blocks ( $Z = -8.48$ ,  $p < .001$ ,  $r = 1.22$ ). Yet participants received on average higher ratings for their justifications in the yoked condition ( $Z = -7.74$ ,  $p < .001$ ,  $r = 1.11$ ).

3.3.2. Does previous knowledge predict learning outcomes and search efficiency?

Not too surprisingly, previous knowledge about the topics to be researched significantly predicted learning outcomes. The models revealed that participants who stated at the beginning of the test that they had heard about the topic(s) before were more likely to answer the multiple-choice questions correctly ( $\beta = 0.98$ , 95% CI [0.29, 1.67],  $p < .01$ ) and to get higher justification ratings ( $\beta = 0.77$ , 95% CI [0.06, 1.47],  $p = .03$ ). Interestingly though, knowing about the topics had a negative interaction effect in the yoked condition, indicating that when participants did not exert control over the search process, they were less likely to answer the knowledge questions correctly even if they knew something about the subject before actually gaining the (new) information ( $\beta = -0.98$ , 95% CI [-2.00, 0.04],  $p = .05$ ). On the other hand, previous knowledge did not affect participants’ suggestions to the fictitious character in any learning condition ( $p = .08$ ), nor the likelihood of consulting a fully informative link ( $p = .09$ ), nor any characteristic of the inquiry process ( $ps > .11$ ).

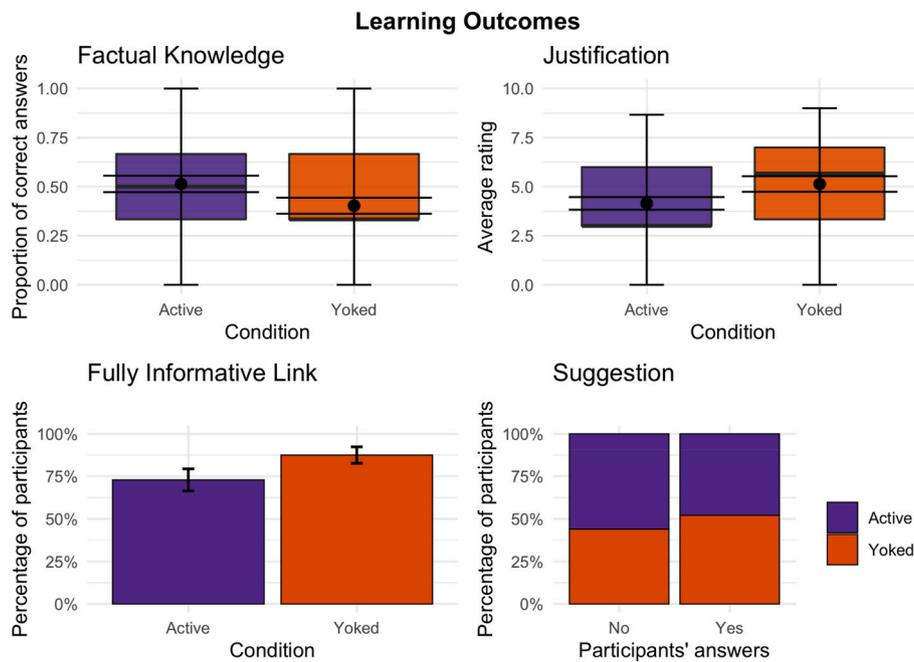


Fig. 2. Outcome measures used in the study: Knowledge assessment, justification rating, provision of a fully informative link, and suggestion. Bars represent 95% bootstrapped confidence intervals.

### 3.3.3. Do web information search habits predict learning outcomes and search efficiency?

The first model showed that neither the overall frequency of online information search ( $p > .12$ ) nor the habit of searching the web for factual information ( $p = .59$ ) predict any of the learning outcomes considered. However, by looking at each activity separately, the third model revealed that participants who more frequently searched the web to perform school-related assignments were more likely to achieve higher justification ratings ( $\beta = 0.49$ , 95% CI [0.17, 0.82],  $p < .01$ ). No further predictors were found to be significant in this case; nor were these predictive of any other learning outcome. Finally, the models predicting different characteristics of the inquiry process by participants' information search habits revealed no significant results ( $p > .14$ ).

### 3.3.4. Does online search efficiency impact learning outcomes?

The models revealed that participants who visited IGO websites were more likely to answer more questions correctly ( $\beta = 0.42$ , 95% CI [-0.01, 0.84],  $p = .05$ ). The number of reformulations negatively predicted the quality of the justification provided (OR = -0.31, 95% CI [-0.62, -0.01],  $p = .04$ ). In contrast, participants who spent more time reading blogs ( $\beta = 0.36$ , 95% CI [0.06, 0.67],  $p = .01$ ) and NGO websites ( $\beta = 0.43$ , 95% CI [0.02, 0.84],  $p = .03$ ) were more likely to obtain higher justification ratings. Moreover, participants who visited NGO websites were more likely to suggest the fictitious character continue using the products (OR = 0.27, 95% CI [0.02, 1.15],  $p = .04$ ). Somewhat surprisingly, no other aspects of the inquiry process significantly predicted learning outcomes.

## 4. Discussion

In this project we examined how adolescents search and filter information on the web when they are tasked with making and justifying an informed suggestion about unsettled scientific issues. Beyond assessing the effect of factors that have already been identified as potential influences on adolescents' information literacy (i.e., previous knowledge and search efficiency), we were particularly interested in exploring the possibility that having control over the online search

experience, along with having experience with searching the web to obtain factual information, would positively contribute to the quality and informativeness with which opinions, such as whether using a certain product might be a health hazard, are formed. Generally, we found that participants' learning performance was rather poor, although a vast majority had indeed identified informative and accurate web sources and provided the right suggestion (i.e., it is indeed safe to use the controversial products).

### 4.1. Volitional control over the search process

To our knowledge, our study was the first to compare active and yoked information acquisition on the web, within participants, and in a naturalistic Google environment. Notably, our results indicate that having or lacking volitional control over the search process had a differential impact on the learning outcomes considered. In particular, our results suggest that having control over the information flow in the active blocks (i.e., being able to decide what to search, which keywords to use, which source to consult, and for how long) supported participants' retention of specific factual information, as measured by the knowledge assessment task. This is in line with the previous studies with adults and developmental work reviewed in the Introduction, robustly showing that even minimal forms of volitional control tend to result in memory improvements across a variety of tasks when compared to situations in which one lacks this possibility (Liu, [ChangHong], Ward, & Markall, 2007; D. Markant et al., 2014; D. Markant et al., 2016; Murty, DuBrow, & Davachi, 2015; Partridge et al., 2015; Pezzulo, Carboni, Rigoli, Pio-Lopez, & Friston, 2016; Ruggeri et al., 2019; Voss et al., 2011). However, our results also indicate that being a passive observer of the search process, in the yoked blocks, resulted in more accurate and elaborate justifications. This apparently contradictory finding can be potentially explained by taking into account the different nature of this task, compared to the knowledge assessment task. Indeed, similar trends have been found in spatial and spatial navigation tasks. For example, Plancher et al. (2013) compared active drivers and yoked passengers in a virtual driving experiment. Active participants were assigned to one of two conditions: an interaction condition, in which they drove a car along a route dictated by the experimenter, and a planning condition, in which

they decided which direction to turn at each intersection and their choices were carried out by the experimenter. Compared to a yoked condition in which participants simply watched a video of the driving experience generated by active participants, both active conditions led to better memory for the layout of the virtual environment and the route taken. Moreover, performance in the planning condition was higher than in the interaction condition, suggesting that deciding how to explore enhanced memory independent of the physical act of exploring itself. This is in line with a number of studies showing that certain forms of spatial memory (e.g., memory for the distances between landmarks) are enhanced by active navigation of the environment (see [Chrastil & Warren, 2012](#), for a review). Interestingly, however, just like in our work, the same study found the opposite pattern in recognition memory for objects encountered along the route, with passive observers showing better recognition relative to both active conditions (see also [Brooks, 1999](#)).

Similarly, some studies found that participants who were given volitional control when exploring immersive and complex virtual environments or 3D objects had equal ([Foreman, Sandamas, & Newson, 2004](#); [Keehner, Hegarty, Cohen, Khooshabeh, & Montello, 2008](#); [Paul N Wilson, 1999](#)) or even worse route and survey knowledge (i.e., configural information to take novel shortcuts and detours between locations) than participants who were passively exposed to the same content ([Attree et al., 1996](#); [Marchak & Zulager, 1992](#); [Richardson, Wuillemin, & MacKintosh, 1981](#)). For instance, [Paul N. Wilson and Peruch, 2002](#) showed that young adults who explored a virtual environment through a prerecorded tour of similar experiences were significantly more accurate in their judgments of orientation and paths to the target object than active explorers. Generally, in a review of these findings, [Chrastil & Warren, 2012](#) proposed that encoding certain aspects of the environment, such as full route and survey knowledge, requires mental manipulation of such properties but also the allocation of attention and encoding in working memory, which in turn may be constrained when participants are also actively involved in the decision-making process. In this sense, it is plausible that in the current study, saving participants the cognitive effort of deciding how to navigate the web allowed them to pay more attention and focus on the quality of the information provided, allowing them later to formulate more rigorous and conclusive arguments. Yet, why would they fail at the knowledge assessment task? On the one hand, it may be that while the yoked exposure promoted a broader view of the problem considered, enabling participants to allocate their attention in weighting counter-evidence and critically evaluate the information to which they were exposed, the effort of putting together such information somehow hindered the encoding of specific factual information. On the other hand, it is worth considering that this effect could also just be a result of always having participants complete the yoked block after the active block. In particular, this may have affected our results in two ways. First, completing the questionnaires following the active block might have unconsciously prompted participants to focus their attention on different aspects of the video they watched, for instance, on the reliability of the sources and the information. Second, although participants already knew about the justification task at the beginning of both research phases, they might have realized what was really required to succeed at this task only after having done it for the first time. Yet, it is unlikely that such awareness would have affected the knowledge assessment task, as it was practically impossible for participants to predict the specific facts the multiple-choice questions addressed. In support of this interpretation, previous work suggests that providing participants with specific instructions about what to pay attention to might mitigate the differences found within subjects' performance in active and yoked exploration of complex virtual environments ([Taylor, Naylor, & Chechile, 1999](#); [Paul N. Wilson & Peruch, 2002](#)).

#### 4.2. Previous knowledge

Not too surprisingly, and in line with previous work, we found that already being familiar with the topic(s) to be researched helped and supported subsequent retention of factual knowledge, resulting in more accurate and evidence-based judgments ([Hailikari, Katajavuori, & Lindblom-Ylänne, 2008](#); [Hembroke, Granka, Gay, & Liddy, 2005](#)). Interestingly, our results suggest that this advantage was absent in the yoked condition. Thus, when participants did not exert control over the search process, they were less likely to answer the questions correctly even if they knew something about the subject before actually gaining novel information. As discussed by [Gureckis and Markant \(2012\)](#), it is likely that in this study context, participants' previous knowledge about the topics may not have been matched in the yoked partners' search, hindering their chance to directly test their intuitions and eventually confirm their hypotheses and resulting in a potentially frustrating experience.

Contrary to what has been found in previous work ([Kelly & Cool, 2002](#); [White, Dumais, & Teevan, 2009](#); [Wildemuth, 2004](#)), previous knowledge did not seem to impact the efficiency of participants' inquiry strategies (e.g., keywords used, reformulations, websites consulted, etc.). However, this inconsistency may also be attributable to the different definition of *familiarity* adopted in the studies mentioned above, where the benefit of having previous knowledge was assessed by comparing search effectiveness of users identified as experts and non-experts within different domains (e.g., medical doctor vs. nonmedical doctor searching for health-related information).

#### 4.3. Inferences about web sources

Notably, our findings show that the majority of participants endorsed the reliability of nonprofit NGO websites, such as the National Association for Cancer Research, which in our case also represented the best source of information needed to succeed on the learning tasks. This finding is consistent with the many studies showing that adolescents deem NGO or IGO websites (i.e., the National Health Service in the United Kingdom: [Gray, Klein, Noyce, Sesselberg, & Cantrill, 2005](#), or the Mayo Clinic in the United States: [Malbon, Ojong, & Nucci-Sack, 2012](#)) as the most reliable for health-related information ([Gray, Klein, Cantrill, & Noyce, 2002](#); [R. K. Jones & Biddlecom, 2011a, 2011b](#)). In this respect, more than the half of our participants indicated they attributed trust and reliability to web sources based on the quality of the information provided, such as its clarity ([Selkie, Benson, & Moreno, 2011](#)) and the degree to which it provided scientific evidence. However, even if to a lesser extent, participants also inferred reliability from other, less content-related aspects of the web source, such as its familiarity (i.e., whether they had heard of it before) and its position in Google's list of results ([Gossen et al., 2014](#)). Surprisingly, participants did not seem to agree on what kind of websites are least reliable, and they did not systematically distrust Wikipedia and similar sources, as found in previous studies (e.g., [Henderson, Keogh, Rosser, & Eccleston, 2013](#)). This lack of expectations should be further investigated, especially in relation to adolescents' critical-thinking competence and more specifically to their ability to detect fake news.

#### 4.4. Search efficiency

Generally, the characteristics of the inquiry process observed in this study resembled the general trends found with adolescents in similar web-research-oriented tasks. For instance, participants in our study formulated queries using natural language rather than keywords, did not use hyperlinks ([Bilal & Gwizdka, 2018](#)) and never went beyond the first page of Google results ([Druin et al., 2009](#); [Gossen et al., 2011](#); [Walhout et al., 2017](#)). They consulted predominantly the first three web pages in the list of results ([Kammerer & Gerjets, 2014](#)) and spent a relatively short time (i.e., about 3 min) on each page ([Duarte Torres & Weber,](#)

2011). All participants used the Google search function rather than typing in a specific website (Gossen et al., 2011; Kobayashi, Misue, Shizuki, & Tanaka, 2006). Crucially, however, our results suggest that only a few characteristics of the inquiry process were predictive of the quality of the learning outcomes. In particular, spending more time reading information provided by NGO websites resulted in greater—though not *great*—performance on the knowledge assessment task. Moreover, more frequent use of reformulations led participants to provide lower rated justification; in contrast, Tu et al. (2008b) showed that refinement of keywords predicted the accuracy of participants' answers. Yet this effect was found only when participants were tasked with searching for answers to close-ended questions, like in other studies reporting a relationship between the quality of students' learning and their information search strategies (e.g., Bilal, 2000; Greene et al., 2014; Greene et al., 2018). Taken together, these results suggest that understanding such effects on research-oriented tasks might necessitate more sophisticated classification of the inquiry's characteristics (e.g., Bilal & Gwizdka, 2018; Chang Liu, Gwizdka, Liu, Xu, and Belkin, 2010), which may better reflect the complexity and amplitude of tasks such as the one used in this study.

#### 4.5. Implications for educational settings

Importantly, we found that having the habit, that is, having more experience in searching the web to complete school assignments, helped students reflect on the information found on the web, resulting in higher rated justifications for their opinions. This is an encouraging result from the educational point of view, as it seems to suggest that training students to independently perform research tasks may indirectly support the development of critical reasoning, even about topics that are not directly relevant to their academic achievements. Future endeavors should address this possibility more directly, by evaluating the efficacy of such a simple, yet potentially effective training. For the same purpose, research should further systematically analyze other factors that may potentially contribute to adolescents' ability to search, filter, and learn from the web, addressing, for instance, the impact of cognitive factors (e.g., meta cognitive skills, working memory, attention) and academic achievement, generally focusing more on individual differences, for example, by implementing longitudinal designs.

#### 4.6. Research limitations

This work presents some limitations, partly due to its exploratory nature. First, the complexity of our study procedure (i.e., the need to run two within-participants testing sessions and create a chain of active and yoked conditions counterbalancing the topics), our desire to run the study in a public, free-of-charge school while ensuring testing rigour, forced us to settle for a rather small sample of participants. Second, we acknowledge that our sample may not be fully representative of the general population (e.g., we could not balance participation by gender,

nor collect information about participants' SES), thus potentially impacting the generalizability of our results. We are looking forward to address these limitations in future, larger scale studies.

## 5. Conclusion

To conclude, this paper contributes to the rapidly growing literature on children's and adolescents' information and digital literacy. In particular, we laid the groundwork for future research to investigate how active involvement in the search process may have a differential impact on learning outcomes, suggesting that the cognitive effort of having to search and filter the vast and infinite space of web information may support adolescents' ability to acquire knowledge, while being spared such effort may help them critically reflect on the quality of the information found, provided that the information sources to which they are exposed are reliable. This study also raises the uplifting possibility that training web-search abilities for school-related activities can support online learning outcomes beyond the boundaries of pure academic achievements.

In the digital era, where there is the ever-increasing power to shape political and social discourse with just one click, the ability to search, filter, evaluate, and integrate online information is becoming the necessary foundation for conscientious citizenship. Our findings highlight the crucial need to know more about the factors impacting adolescents' online search efficiency and success, with the goal of developing more effective tools to boost their critical thinking and societal participation.

### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### Data availability

Anonymised dataset is available on OSF at this link <https://osf.io/vykb6/>.

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## Appendix

### Complete study procedures

#### A.1. Instructions

Instructions given to participants before the active and yoked research phase on each topic. Target keywords are written in bold.

##### 1) Read the following text carefully:

(Nitrates). "I am Sue, and I am 22 years old. I was at the grocery store yesterday and I noticed that on some drinking water bottles it is specified in capital letters that they contain low levels of nitrates. I have asked around and apparently, many people seem to think that the **nitrates** contained in some **water** can cause **cancer**. I am really confused because I wasn't aware of this risk before, and I wonder whether there is reliable **scientific**

evidence confirming this claim. Should I stop drinking mineral water containing nitrates or is this not really harmful?"

(Aluminum). "I am Bea, and I am 22 years old. I was at the drugstore yesterday and I noticed that on many deodorants it is specified in capital letters that they do not contain aluminum. I have asked around and apparently, many people seem to think that using **deodorants** containing **aluminum** can cause breast **cancer**. I am really confused because I was not aware of this risk before, and I wonder whether there is reliable **scientific evidence** confirming this claim. Should I stop using deodorants containing aluminum or is this not really harmful?"

## 2) Now follow the instructions below:

You have 10 min to search [active condition] — You will watch a video of the previous participant searching [yoked condition] — for accurate information about this topic on Google in order to give an informed suggestion to Sue/Bea. You can take notes. Your goal is to come up with a suggestion and a justification for this suggestion, and then answer some questions about this topic. Try to be as exhaustive and accurate as possible. An expert in the field will judge the accuracy and completeness of all justifications and will choose the most accurate. The best justification will be rewarded with a 25-euro Amazon voucher.

### A.2. Assessments

**Table A1**

*Source reliability.* English translation of the answers presented on the 5-item multiple-choice questionnaire used to assess participants' intuitions about the characteristics that make a website reliable or unreliable. Participants could select multiple items

Why was this source reliable?	Why was this source unreliable?
It was clear	It was not clear
It provided scientific evidence	It provided no scientific evidence
It was familiar	It was not familiar
It was suggested by Google	It was not suggested by Google
It was cool	It was not cool

**Table A2**

*Source reliability.* Original links to web pages provided by participants for the source reliability assessment, categorized by source type.

Source type	Link
NGO	altroconsumo.it
IGO	salute.gov.it
Commercial	nivea.it
Blog	naturalmentemamma.it
Wikipedia	wikipedia.it
Magazine	tio.ch
Scientific journal	academic.oup.com

*Note.* NGO = nongovernmental organization; IGO = international governmental organization.

Magazines and scientific journals were never provided as the most reliable web sources found but were visited by two participants during the active search.

**Table A3**

*Factual knowledge.* English translations of the forced-choice questionnaire used to assess participants' factual knowledge about each substance (nitrates and aluminum) and their relatedness to cancer. Correct answers are written in italics.

Nitrates
<b>Do all types of water contain nitrates?</b>
1) Yes, both tap and bottled water contain nitrates
2) No, only bottled still water contains nitrates
3) No, only bottled sparkling water contains nitrates
<b>Why have some scientists hypothesized that nitrates in drinking water might cause cancer?</b>
1) Because nitrites (NO <sub>2</sub> <sup>-</sup> ) can be converted into nitrates (NO <sub>3</sub> <sup>-</sup> ) within our organism and can act as precursors of N-nitroso compounds, which are considered extremely carcinogenic
2) <i>Because nitrates (NO<sub>3</sub><sup>-</sup>) react within our organism to form N-nitroso compounds, which are able to modify the molecular structure of the cell and thus cause abnormal cell growth</i>
3) Because nitrates (NO <sub>3</sub> <sup>-</sup> ) can be converted into nitrites (NO <sub>2</sub> <sup>-</sup> ) within our organism and can act as precursors of N-nitroso compounds, which are considered extremely carcinogenic
<b>According to Italian law, the amount of nitrates in drinking water must be below ...</b>
1) 40 mg/L
2) 50 mg/L
3) 40 mg/L

(continued on next page)

Table A3 (continued)

Aluminum
Aluminum
<b>Do all deodorants contain aluminum?</b>
1) Every commercial deodorant contains aluminum
2) Aluminum is contained only in the spray kind of deodorant and not in roll-ons
3) <i>Only antiperspirant deodorants contain aluminum</i>
<b>Why have some scientists assumed that aluminum-containing deodorants can cause breast cancer?</b>
1) Because aluminum is absorbed by the skin and could have estrogen-like effects, thus promoting breast cancer
2) Because aluminum contains estrogen, which when absorbed by the skin can promote carcinogenic cells' growth
3) Because when aluminum is absorbed by the skin it can release some toxins that can promote breast cancer
<b>Why do some deodorants contain aluminum?</b>
1) Because it covers the stinky chemicals excreted by sweat
2) <i>Because it can plug up sweat glands, thus stopping us from sweating</i>
3) Because it kills the bacteria producing the stinky chemicals

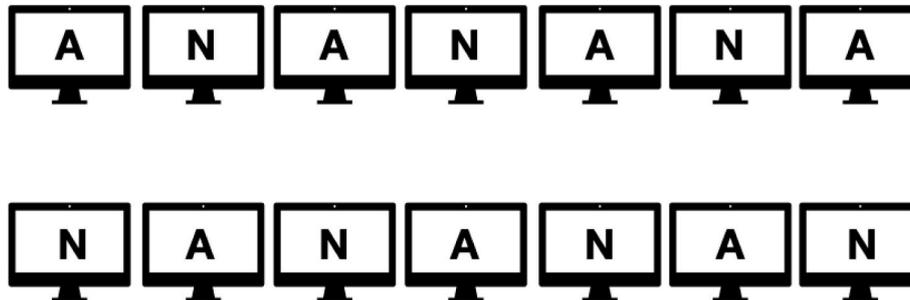


Fig. A1. Layout of the computer room. Participants were seated across two rows of 7 computer each. Participants sitting side by side on the same were assigned to scenarios with alternating topics (A = Aluminum; N = Nitrates).

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