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Temporal Patterns of Scientific Information-Seeking on *Google* and *Wikipedia*

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Abstract

In response to the news coverage of scientific events and to science education, people increasingly go online to get more information. This study investigates how patterns of science and technology (S&T) information seeking on *Google* and *Wikipedia* change over time, in ways that differ between "ad hoc" terms that correspond to news coverage, and "cyclic" terms that correspond to the academic period.

Findings show that the S&T activity in *Google* and *Wikipedia* was significantly associated with ad hoc and cyclic patterns. While the peak activity in *Google* and *Wikipedia* largely overlapped for ad hoc terms, it mismatched for cyclic terms. The findings indicate the importance of external cues such as news media and education, but also of the online engagement process, and particularly the crucial but different role played by *Google* and *Wikipedia* in gaining S&T knowledge. Educators and policy makers could benefit from taking into account those different patterns.

Keywords: public interest in science, engagement, information seeking behavior, *Google*, *Wikipedia*

Temporal Patterns of Scientific Information-Seeking on *Google* and *Wikipedia*

Science and Technology (S&T) play an increasingly central role in everyday life, and depend on public understanding and support to further develop. In the US and Europe, after formal schooling ends, most of the public's exposure to S&T comes from news coverage of scientific topics. However, not much is known about the relationship between educational and news media cues and the online engagement in S&T. Specifically, some important open questions are: What does the public want to know about S&T, how do people acquire this knowledge online, and to what extent are these processes related to news coverage and the educational cues? Addressing these questions could provide insights into the public's authentic information needs and desires. In turn, these insights could prove useful for drafting sound policies in science communication, science education, and other fields, which could benefit S&T and society at large by allowing stakeholders to cater to those needs and desires.

New technological affordances allow us to investigate public attention to S&T by exploring datasets recording searches, web traffic patterns, and other types of evidence of information-seeking behavior. This approach has been successfully applied in diverse fields such as health, politics, economics, and S&T. The present study attempts to answer some of these open questions by analyzing and comparing publicly available data on S&T related activity in *Google* and *Wikipedia*. In what follows we discuss the importance of two main cues: The *news coverage* of S&T and *science education*, and their respective *ad hoc* and *cyclic* information seeking patterns online.

News media and public interest in S&T

When attempting to identify the most prominent information sources for S&T, scholars stress the significance of the top-down educational and media institutions (Segev & Baram-Tsabari, 2012). While young people are exposed to information from educational institutions, news media is often related to adults' perceptions of S&T (Nisbet et al., 2002). The link between media and public attention has been broadly studied in the context of the agenda-setting theory. According to this theory, media exposure influences what people consider as the most important themes on the public agenda and how to make sense of these themes (McCombs & Shaw, 1972; Takeshita, 2006). Specifically, we can expect that news coverage of S&T issues would serve as a primary information source on these issues and shape related public perceptions.

The link between news coverage of S&T and public interest has been typically established through content analyses and surveys. For example, a comprehensive content analysis of BBC's television channels, radio stations, and websites between 2009 and 2010 revealed that approximately 4.6% of items were scientific, and most frequently concerning medical S&T. Surveys often use this data to construct questionnaires, in which respondents rated general topics of interest from closed lists of news topics, such as "space exploration" and "new medical discoveries" (Mellor, Webster, & Bell, 2011).

Most respondents to these surveys in the US and Europe usually indicate that they are at least moderately interested in S&T and related topics. For example, in 2012, 85% of US respondents said they were very or moderately interested in S&T news about new inventions, technologies, and health related discoveries (National Science Board, 2014). European figures were similar, where 79% of respondents reported to be very or moderately interested in scientific discoveries and technological

developments (European Commission, 2010). Yet these surveys were limited to predefined topics (such as medical discoveries, biology and biotechnology, or the environment), and focused on print or broadcast media in Western countries, although S&T information becomes increasingly available and accessible online all over the world (Schäfer, 2012).

Online engagement in S&T

There is no doubt that much of the public engagement in S&T occurs online. Various surveys conducted in the last decades revealed that the internet has become the primary source to acquire information on S&T (42%, up from 35% in 2010) (Horrigan, 2006; National Science Board, 2016; Smith, Marsden, & Hout, 2015). Following the agenda-setting theory, it would be reasonable to expect that *news coverage* of S&T would increase the likelihood of people to seek for information on frequently covered topics. In health contexts, for example, cancer news coverage correlated with seeking information about cancer mostly among people who had paid close attention to health news, and those with a family history of cancer (Niederdeppe, Frosch, & Hornik, 2008). Similarly, college students in the US reported that they had sought health information after exposure to media coverage of health issues, such as a celebrity's illness (Myrick, Willoughby, & Verghese, 2015).

Educational cues provide another trigger for searching S&T information online (Segev & Baram-Tsabari, 2012). Although it has been often discussed in relation to its possible benefits and outcomes (Lee et al., 2011), little is known about the extent of use, and the particular information sources that are involved in this process. In a comparison of 12 education systems worldwide in 2006, 53% of mathematics teachers and 72% of science teachers reported organizing teaching activities that involved

searching for related online information (Law, 2009). By contrast, although the potential of blogs, social networking websites, and *Wikipedia* as teaching tools has been recognized in academic circles, implementation in school systems seems to have lagged behind. In 2009, only 16% of U.S. public school teachers reported using blogs or wikis sometimes or often (Gray, Thomas, & Lewis, 2010; Konieczny, 2012).

Using *Google* and *Wikipedia* for S&T information

Although survey findings provide plenty of useful data on public interests and possible engagement in S&T, their top-down approach, their reliance on self-reports, their low frequency, and their low resolution preclude a more specific analysis of information needs and interests, and the ways they change over time. A bottom-up approach, in which researchers study online user activity related to S&T, such as in search engines, could address this limitation.

Ginsberg et al. (2009), for example, showed a correlation between searches for flu-related search terms and actual doctor visits. Although these searches might not accurately predict doctor visits (Butler, 2013), they certainly provide an initial indication for the spread of the disease. Similarly, monthly *Google* searches for nanotechnology-related keywords indicated that the public was mostly interested in future directions and applications of nanotechnology, but was less interested in its policy and regulatory aspects (Anderson, Brossard, & Scheufele, 2010). A study focusing on prominent media events related to climate change found a decline in global and US search volume on this topic between 2007 and 2013, including transient peaks of searches such as "global warming hoax" that could indicate a growing skepticism (Anderegg & Goldsmith, 2014).

Previous work has also shown that changes in search volumes over time can take one of at least two patterns, depending on the source of the cue that presumably motivated the searches: For well-established school science terms, such as "genetics", search volumes strongly correlated with the *academic calendar*, whereas the search volumes for science terms extracted from news outlets, such as "Mars Rover" and "Big Bang", were significantly correlated with the *news coverage* of those topics (Segev & Baram-Tsabari, 2012). Further research into public searches prompted by scientific events in media, specifically the Nobel prize announcements, revealed that search volume for the laureates' names typically declines below 50% of the maximal volume in about one week, while news coverage lasts slightly longer (Baram-Tsabari & Segev, 2013).

Together with *Google* search, previous studies have shown that *Wikipedia* is the prime source for students looking for information on S&T (Head, 2007; Thornton, 2010). Both *Google* and *Wikipedia* were further found to be used as the first step of students' search process (Judd & Kennedy, 2011). However, unlike search engine data, visits to *Wikipedia* were hardly utilized so far in order to learn about public interest in science (Generous, Fairchild, Deshpande, Del Valle, & Priedhorsky, 2014).

Few studies used log-files, which offer statistics on visits to specific *Wikipedia* entries, to characterize health and illness-related information seeking behavior. This includes the estimation of the rate of occurrences of influenza-like illnesses in the USA (McIver & Brownstein, 2014), and forecasting occurrences of other global diseases, such as Ebola in central Africa and cholera in Haiti (Generous et al., 2014).

Ad hoc and cyclic patterns in *Google* and *Wikipedia*

While both *Google* and *Wikipedia* are popular sources for acquiring S&T information, they fulfill different roles: *Google* is a general search engine and therefore provides diverse results, including links to commercial sites, news sites, *Wikipedia* entries, social media sites, blogs, or governmental information. *Wikipedia*, on the other hand, is an online encyclopedia, and therefore serves a more specific role in providing information on certain S&T topics (Jansen, Booth, & Spink, 2008). Additionally, the platform design, algorithm, and content production in *Google* and *Wikipedia* have different biases.

When looking at searches for the natural disaster in Pakistan, Weltevrede, Helmond, & Gerlitz (2014) found that *Google*'s PageRank algorithm adapts results by the freshness or "hotness" of a topic. As *Google* includes in its index news and blog updates, it would fit better for acquiring information about real-time or ad-hoc events (Gillespie, 2010; Ladwig, Anderson, Brossard, Scheufele, & Shaw, 2010). Similarly, differences were found between the content of top and lower ranked results in *Google* search for nanotechnology (Li, Anderson, Brossard, & Scheufele, 2014). Top ranked results featured more popular themes on media agenda such as the technical, environmental, and risk-related aspects of nanotechnology. Search rankings were also influenced by the way news websites, blogs, interest groups, and others tag the content (Nisbet, 2011). These effects would further increase the affiliation between *Google* searches and the news coverage of ad hoc S&T topics.

Different from the automatic ranking algorithm of *Google*, *Wikipedia* organizes information based on human contribution and a continuous negotiation among editors (Borra et al., 2014). It would therefore be very instrumental website to deepen one's knowledge on cyclic S&T topics such as those triggered by educational

cues. On the other hand, traffic to *Wikipedia* is very often related to its ranking in *Google* search results. When seeking for health information, Laurent and Vickers (2009) found that *Wikipedia* was ranked among the first ten results in *Google*. Not only that users who started their search in *Google* were referred to *Wikipedia*, but also the traffic in *Wikipedia* increased with ad hoc events such as news on emerging health concerns. Thus, it could certainly be that *Wikipedia* visits to some hoc terms would correspond to their *Google* searches. Yet, to the best of our knowledge, apart from the studies mentioned above temporal patterns in S&T related user activity in *Google* and *Wikipedia* have not been systematically documented and compared.

Research Aim and Hypotheses

The present paper builds upon previous findings on the significant role of news media and educational cues to trigger S&T information seeking. It hypothesizes that these cues would affect differently on the online engagement or information seeking patterns. We study this by comparing the temporal patterns of online engagement in two prominent channels: *Google* search, a channel operated mostly by a machine, and *Wikipedia* visits, a system operated collaboratively by humans and machines (Niederer & van Dijck, 2010).

News media and education cues. The type of extrinsic cue (ad hoc and cyclic) served as the independent variable in this study. Ad hoc and cyclic search patterns display the main motivations to search for scientific information (news and education respectively). This is based on previous findings (Segev & Baram-Tsabari, 2012), showing that ad hoc searching behavior is typically associated with news coverage of scientific events and concepts. Cyclic searching behavior, on the other hand, is typically associated with the education period.

Online engagement. Our dependent variables include the temporal pattern in *Google* searches and *Wikipedia* visits to S&T terms (see the method section below). We studied four temporal characteristics of information-seeking behavior: The half-life of terms, their *Google-Wikipedia* correlation, the time lag between the week with peak activity in *Google* and *Wikipedia*, and the correlation between related scientific issues.

For our first hypothesis, we analyzed the duration of interest in S&T topics (namely their "half-life") by calculating the rate of decay of *Google* searches and *Wikipedia* visits after the maximal value of each search term (see below for the selection process of search terms). A "half-life" is defined as the number of weeks, in which the search activity for a scientific term is at least half of the maximum value during the entire period studied (from December 2007 to December 2012) (see also Baram-Tsabari & Segev, 2013). The half-lives of terms in each group, and the correlations between half-lives of *Google* searches and *Wikipedia* visits in each group, were considered as our dependent variables. For example, we would expect that a classic cyclic term such as "geology", which is being searched mainly during the academic period, would have a much longer half-life than an ad hoc term such as "tsunami" or "earthquake", since the former is searched for almost all over the year and the latter is searched only in response to specific events (see also Segev & Baram-Tsabari, 2012). Thus, our first hypothesis is:

H1. The half-lives of cyclic terms would be significantly higher than those of ad hoc terms

Following the association between *Google* and real time events (Li et al, 2014; Nisbet, 2011; Weltevrede et al., 2014), we would expect that for specific ad hoc events, people search for information in *Google* but may not always deepen their knowledge and read the related *Wikipedia* entries. By contrast, when terms are part of the curricula, people may both search for the terms in *Google* and visit the relevant *Wikipedia* entry, since the latter has been indicated as the main source for scientific related information for students (Head & Eisenberg, 2010). Thus, we hypothesize that:

H2. The correlation between *Google* searches and *Wikipedia* visits would be significantly lower for ad hoc terms than for cyclic terms

Likewise, with respect to time lag differences, we would expect that the peak activity in *Google* would match the peak activity in *Wikipedia* for ad hoc terms, but not much for cyclic terms. For example, news coverage of an earthquake might trigger rise in *Google* searches for more related news, but possible also more visits to related *Wikipedia* entries. This is also in line with Laurent and Vickers (2009) findings on the high ranking of *Wikipedia* in *Google* search results and the increase in *Wikipedia* traffic following related news coverage. However, in case the scientific event is unique (for example, a Nobel Prize Laureate), and does not have a specific *Wikipedia* entry yet, it is possible that the peak activity in *Wikipedia* would be delayed. The third hypothesis is therefore:

H3. *Google* searches would match or precede *Wikipedia* visits for ad hoc terms more often than for cyclic terms

Finally, we examined the correlations between related terms in order to understand whether scientific events encourage people to further expand their knowledge by searching *Google* or reading related information on *Wikipedia*. This would be less relevant for cyclic terms that follow academic periods, but more so for ad hoc events such as scientific discoveries. Particularly, we explored whether the announcement of Nobel Prize laureates would encourage people to search also for their related scientific discoveries. Apart from the correlation between those terms, we compared the time lag between their peaks as well as the half-life around their peak. While the half-life of each term was measured in this study for the entire period, half-life around the peak focuses only on the weeks before and after the peak. In the case of specific ad hoc terms, such as Nobel Prize laureates and their discoveries it helps to focus on a particular event. This is mainly since scientific discoveries may be searched without connection to the announcement of Nobel laureates. Hence, our fourth and last hypothesis is:

H4. *Google* searches and *Wikipedia* visits to Nobel laureates information would precede or match and be significantly shorter than *Google* searches and *Wikipedia* visits to information on their related discoveries

Methodology

Data Source. This study is based on public data available from *Google* and *Wikipedia*. *Google Trends* was used in order to study weekly changes in searches for specific scientific terms in *Google Search* (See also Baram-Tsabari & Segev, 2011). It analyzes and displays the proportion of searches for terms, compared to the total number of searches made on *Google* over a defined period of time (between 2004 and

the present). Statistics available from *Wikipedia* were used in order to study weekly changes in visits to the same scientific entries. A granulation of one week was chosen as our unit of analysis, since it is the smallest available in *Google Trends*. The research period starts on December 2007 since it is the earliest period in which data is freely available from *Wikipedia*. Overall, 264 time points (weeks) were examined between December 2007 and December 2012.

Sampling Search Terms. Following the distinction between media and school motivations for scientific information seeking behavior (Segev & Baram-Tsabari, 2012), a list of scientific terms in English was constructed based on various media and educational sources (see Table 1). Although *Google* allowed limiting the data to U.S. searches only, visits to specific terms in *Wikipedia* were available by language rather than by country. We chose to focus on English terms in both *Google* and *Wikipedia* in order to make the comparison as valid as possible.

Terms were classified as ad hoc (such as discoveries and disasters) or cyclic (human or natural events) based on their origin: Lists of discoveries and disasters for ad hoc terms, versus school science guidelines and curricula for cyclic terms. Initially, this list included 388 terms, however, not all terms followed distinctive cyclic or ad hoc patterns as expected from their source.

First, we manually filtered out the terms that did not follow the expected cyclic or the ad hoc patterns in *Google Trends*. For example, "biotechnology" derived from school curricula, but did not display distinctive cyclic patterns in *Google Trends*, as it was frequently searched also in commercial contexts (findings biotechnology-related job vacancies). On the other hand, "supernovae" derived from a media event, but did not display distinctive ad hoc patterns in *Google Trends*. It was not only related to the 2011 Nobel Prize winning, but also partly corresponded to the academic period. In

most cases terms that did not follow strict cyclic or ad hoc patterns were relatively rare and therefore displayed sporadic searches (e.g., “cryobiology” or “stellar astronomy”). Among the misfit popular terms there were those associated with commercial, entertaining or other non-scientific context (e.g., “anatomy”, which was searched mostly in the context of the TV show “Grey’s Anatomy”).

For the purposes of this analysis, we relied on school year calendars from large, public education systems in the English-speaking world (European Commission, 2012, 2015). As expected, *Google* search volumes for cyclic terms such as "Biology," "Chemistry," and "DNA," as first characterized in Segev & Baram-Tsabari (2010), have consistent local minima in July and August, and, less saliently, around December and early January. This pattern closely corresponds to the school year.

Additionally, in order to differ statistically between ad hoc and cyclic terms we calculated the coefficient of variation for the weekly trends of each term. A larger coefficient of variation would typically fit ad hoc terms, as it indicates that *Google* searches or *Wikipedia* visits were more spontaneous, containing more peaks. A smaller coefficient of variation, on the other hand, would fit cyclic terms as it indicates that *Google* searches or *Wikipedia* visits were more even and homogenous over time. A t-test confirmed the term division into two groups. The mean coefficient of variance of *Google* searches for ad hoc terms was 4.07, while for cyclic terms 1.34 ($p < 0.001$). The mean coefficient of variance of *Wikipedia* visits for ad hoc terms was 2.69, while for cyclic terms 1.1 ($p < 0.001$).

After filtering out terms that did not follow distinctive ad hoc or cyclic patterns, our final list included 196 science-related terms. Table 1 provides examples and summarizes the number of terms from each group used in our analysis. Cyclic and

ad hoc terms were further divided based on their source and topic. The full list of scientific related terms is available upon request.

Table 1. Number of terms used in each group

Category	**Explanation and no. of terms** (n)	**Examples**
Cyclical events	**106**	
1A. Cyclical natural events[1]	Celestial and astronomical events (11)	"equinox", "solstice"
1B. Cyclical human events[2][3]	1B.1. Wikipedia science categories and school science concepts (71)	"chemistry", "chloroplast", "metabolism", "ozone"
	1B.2. International observance days (24)	"world AIDS day", "world environment day"
Ad hoc events	**90**	
2A. Scientific discoveries[4]	Science Nobel laureates and their related discoveries (48)	"Andre Geim", "graphene"; "Yoichiro Nambu", "broken symmetry"
2B. Natural disasters[5]	Earthquakes and deadly heat waves (30)	"Haiti earthquake", "Russia heat wave"
2C. Cyclical natural events, difficult for non-technical publics to predict[1]	Solar eclipses, lunar eclipses, etc. (12)	"mars opposition", "meteor shower"

Data Collection and Analysis

In total, 196 scientific terms (including 106 cyclic and 90 ad hoc terms) were used for this analysis. For each of these terms, the following stages were performed:

[1] Sea and Sky (www.seasky.org), US Naval Observatory, NASA/Goddard Space Flight Center, and the Old Farmer's Almanac

[2] Wikipedia's categories of natural science, and the US National Science Education Standards (1996) and the National Research Council (1996)

[3] United Nation website (www.un.org/en/events/observances/days.shtml)

[4] Nobel Prize website (www.nobelprize.org)

[5] US Geological Survey (USGS) data and the Emergency Events Database (EM-DAT)

(I) *Web mining data from Google and Wikipedia*. *Google Trends* provided data on the changes in the relative share for its *Google* searches. *Wikipedia* provided data on the number of unique visits to each scientific entry.

(II) *Normalizing time units*. While data from *Wikipedia* is provided daily since December 2007, *Google* provides only weekly or monthly data for periods longer than three months. In order to allow comparison between *Google* and *Wikipedia* data, we used weeks as the unit of comparison. We calculated the average weekly number of unique visitors to each of the relevant *Wikipedia* entries. In total, we used data on 264 weeks between December 2007 and December 2012 for each of the terms, representing *Google* searches and *Wikipedia* visits.

(III) *Identifying the peaks.* For each term we identified its peak, that is, the specific week with the maximum *Google* searches and *Wikipedia* visits. This allowed us to identify time-lag differences of the same term between *Google* and *Wikipedia* or between two related terms.

(IV) *Calculating Wiki-Google peak difference*. The peak can vary between *Google* searches and *Wikipedia* visits. We calculated for each term the difference in weeks between the two in order to understand the information retrieval patterns. If most people arrive to a *Wikipedia* term immediately after searching it in *Google*, the peak would be measured on the same week with the difference being zero. On the other hand, if people search for a term in *Google*, and decide to read about it in *Wikepedia* only a few days or weeks later, there would be a time lag difference. We looked at time lags of 1 to 3 weeks between *Google* and *Wikipedia* maximum values. A month difference or more would indicate that the two are not aligned.

(V) *Calculating the half-life*. We define half-life as the period in which values are higher than half of the maximum (See Baram-Tsabari & Segev, 2013). For each

term we calculate the half-life during the entire period and the half-life around the peak in both *Google* and *Wikipedia*.

(VI) *Identifying Google-Wiki Correlation*. We calculated the Pearson correlations between weekly *Wikipedia* views and weekly *Google* searches for each term in order to study the differences between *Google* search patterns and *Wikipedia* visit patterns when it comes to scientific terms.

(VII) *Identifying category differences*. We analyzed the mean differences between the six categories of the scientific terms (see Table 1).

Results

Table 2 presents the mean half-life of *Wikipedia* visits and *Google* searches for each category and sub-category of scientific terms. It shows, in line with H1, that the half-life of cyclic terms is much higher than the half-life of ad hoc terms. In *Wikipedia* the general half-life of cyclic terms is 56.76 weeks compared to 8.93 weeks of ad hoc terms (out of 264 weeks). In *Google* the general half-life of cyclic events is 133.91 weeks compared to 14.6 weeks of ad hoc terms. A one-way ANOVA confirms that these are indeed significant differences with $F(1, 195) = 31.753$, $p < .001$ for *Wikipedia*, and $F(1, 195) = 113.601$, $p < .001$ for *Google*.

Table 2. The mean half-life (HL) of each group in weeks and the Pearson correlation between channels

Category (N)	Mean Wikipedia Visits HL (HL Peak)	Mean Google Searches HL (HL Peak)	Wikipedia-Google Correlation*
1 All Cyclic terms (106)	56.76 (9.56)	133.91 (38.92)	.479
2 All Ad-hoc terms (90)	8.93 (2.51)	14.60 (5.37)	.511
1A Cyclic Natural (11)	2.64 (1.00)	10.91 (2.91)	.587
1B.1 Cyclic Human – Curricula (71)	83.48 (13.75)	194.34 (56.65)	.434
1B.2 Cyclic Human – Scientific Events (24)	2.54 (1.08)	11.50 (2.96)	.550
2A Ad-hoc discoveries (48)	9.50 (3.02)	12.88 (4.29)	.614
2A.1 Laureates (37)	1.00 (1.00)	3.41 (3.38)	.414
2A.2 Discoveries (11)	38.09 (9.82)	44.73 (7.36)	.414
2B Ad-hoc disasters (3)	10.77 (2.20)	21.17 (8.27)	.414
2C Non-predicted cyclic events (12)	2.08 (1.25)	5.08 (2.42)	.309
Total (196)	34.8 (6.32)	79.12 (23.51)	.494

Note: "HL" refers to the half-life during the entire five-year period, while "HL Peak" refers to the half-life around the peak (the week with maximum activity). For example, for 9.5 weeks out of the entire five-year period people were visiting ad-hoc discoveries (2A) in a volume larger than half of the maximum. However, only for 3.02 weeks around the peak people were visiting ad-hoc discoveries in a volume larger than half of the maximum. * All mean correlations are significant at $p < 0.001$ ($n = 264$ weeks). Significant correlation values for each search term are from $r > 0.16$ for $p < 0.01$, and $r > 0.13$ for $p < 0.05$.

Table 2 presents also the mean differences in each of the sub-categories. It indicates that among cyclic terms, the mean half-life of cyclic natural terms is significantly shorter than that of curricula related terms in both *Google* and *Wikipedia*. This is mainly since cyclic natural terms, such as "Solstice" or "Equinox", behave similar to ad hoc terms, and are usually sought and retrieved during very limited and specific periods. By contrast, cyclic human terms, which are part of the school or university curricula, are being sought and retrieved all over the academic period.

Among the ad hoc terms, non-predicted cyclic events, such as "Meteor shower" or "Lunar eclipse", have a considerably shorter half-life (2.08 weeks in *Wikipedia* and 5.08 weeks in *Google*) than that of ad hoc discoveries or disasters. However, both scientific discoveries and natural disaster have a similar half-life in *Wikipedia* of about 10 weeks. In *Google* the half-life of scientific discoveries is shorter (12.88 weeks) than that of natural disasters (21.17 weeks). However, when looking

separately at Nobel laureates and their related discoveries, Table 2 shows that discoveries tend to grab much longer attention (38.09 weeks in *Wikipedia* and 44.73 weeks in *Google*). This implies that people look for terms related to Nobel Prize winning during the entire sampling period and not only as a result of the ad hoc media reports on the Nobel Prize. When the focus is on the half-life around the peak only (HL-Peak) the half-life of scientific-related discoveries are much shorter, but still significantly longer than that of the laureates (9.82 weeks for discoveries in *Wikipedia* compared to 1 week for laureates, and 7.36 weeks for discoveries in *Google* compared to 3.38 weeks for laureates. See more on the comparison between laureates and their discoveries below).

The mean Pearson correlation between *Google* searches and *Wikipedia* visits remains relatively constant along categories, ranging from $r = .309$ to $r = .614$. Although the mean correlation of ad hoc terms is slightly higher ($r = .511$) than that of cyclic terms ($r = .479$), there are no significant differences between the two. A one-way ANOVA confirms that the mean correlation levels of cyclic and ad hoc terms is non significant with $F(1, 198) = .525$, $p = .47$. In general, all categories show moderate correlation levels between *Google* and *Wikipedia*. This finding is in contrast with H2, suggesting that the different patterns between *Google* searches and *Wikipedia* visits for scientific terms cannot be explained by their categories.

Table 3 summarizes the time-lag differences between the week with the maximum *Google* searches and the week with the maximum *Wikipedia* visits. It shows that the peaks of *Wikipedia* visits and *Google* searches for the cyclic terms were largely different from each other (73.6% of the terms mismatched). The peaks of ad hoc related terms, on the other hand, were relatively more similar to each other (only 35.6% of the terms mismatched).

Most of the matched terms were either with no time lag at all (marked by 'Matched') or with a short time lag (1-3 weeks) with *Google* searches preceding *Wikipedia* visits. In line with H3, when a time lag did occur, *Google* searches preceded *Wikipedia* visits (12.2%) rather than the other way around (0%) for ad hoc terms. Similarly, *Google* searches preceded *Wikipedia* visits (3.8%) rather than *Wikipedia* visits preceding *Google* searches (1.9%) for cyclic terms. Still, the peak activity in *Google* would come before the peak activity in *Wikipedia* when looking for ad hoc terms than when looking for cyclic terms ($\chi^2 = 32.47$, $p < 0.001$).

A closer look at the ad hoc category shows that for Nobel laureates and their scientific discoveries (sub-category 2A), most *Wikipedia* and *Google* peak activity occurred in the same week (81.2% of the terms). In contrast, when people searched for natural disasters, *Wikipedia* and *Google* peak activity was not as synchronized (56.7 of the terms mismatch). Yet when there was a fit between the peak activities of the two, the peak activity in *Google* mostly preceded (23.3% of the terms) the peak activity in *Wikipedia*.

Table 3. Percentage of scientific terms with time lag between channels by term group

Category	*Wikipedia* Visits	*Google* Searches	Matched	Mismatched	Total
1 All Cyclic terms	1.9% (2)	3.8% (4)	20.8% (22)	73.6% (78)	106
2 All Ad-hoc terms ($\chi^2 = 32.47^{**}$)	0.0% (0)	12.2% (11)	52.2% (47)	35.6% (32)	90
1A Cyclic Natural	0.0% (0)	27.3% (3)	45.5% (5)	27.3% (3)	11
1B.1 Cyclic Human – Curricula	2.8% (2)	0.0% (0)	11.3% (8)	85.9% (61)	71
1B.2 Cyclic Human – Scientific Events	0.0% (0)	4.2% (1)	37.5% (9)	58.3% (14)	24
2A Ad-hoc discoveries	0.0% (0)	0.0% (0)	81.2% (39)	18.8% (9)	48
2B Ad-hoc disasters	0.0% (0)	23.3% (7)	20.0% (6)	56.7% (17)	30
2C Non-predicted cyclic events ($\chi^2 = 107.4^{**}$)	0.0% (0)	33.3% (4)	16.7% (2)	50.0% (6)	12
Total	1.0% (2)	7.65% (15)	35.2% (69)	56.1% (110)	196

Note. $^{**} = p < .001$. Values represent percentages of the total terms in a category. The actual number of terms appears in brackets. "Wikipedia" column indicates that the week with maximum visits in Wikipedia preceded that of Google searches in 1-3 weeks. "Google" column indicates that the week

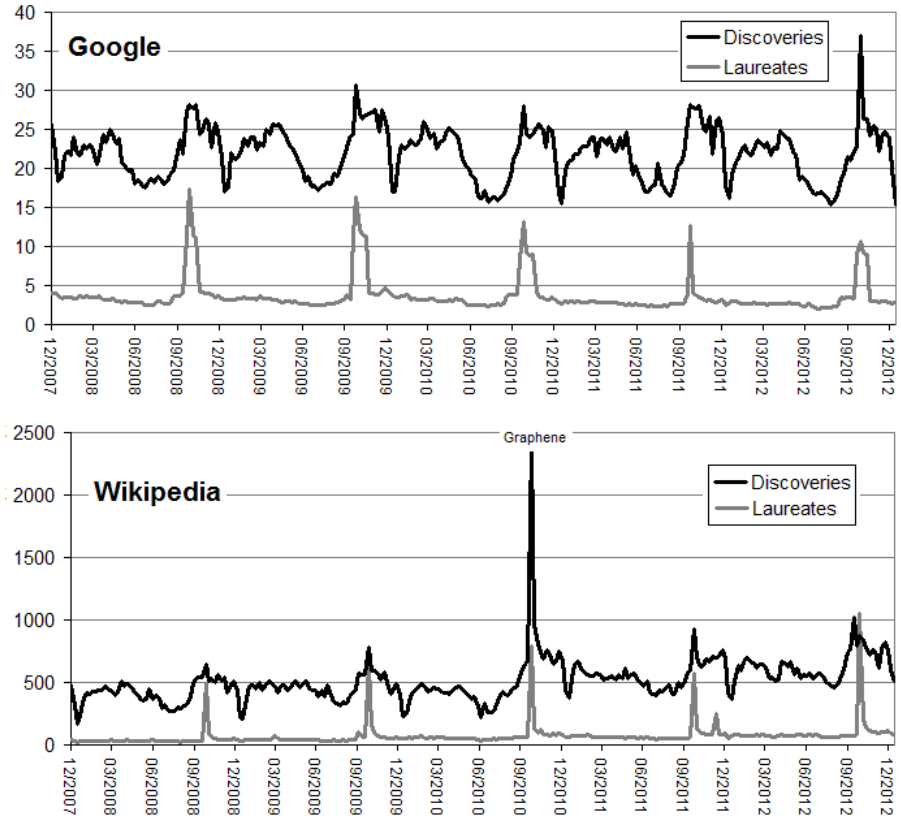
with maximum visits in Wikipedia followed that of Google searches after 1-3 weeks. "Matched" column indicates that the maximum Google searches and Wikipedia visits occurred in the same week. "Mismatched" column indicates that the difference between the peaks was higher than 3 weeks.

A prominent example of that lag can be displayed during the most powerful earthquake ever recorded in Japan on March 11, 2011. On the same day, following the high news attention around the world, *Google* searches peaked to the maximum, falling to less than 50% of the maximum during the next day on March 12, 2011. In *Wikipedia*, on the other hand, the relevant entry was massively edited on March 11, 2011 (about 45 times), but got a record number of visits (about 11,000) only a day after. While searches in *Google* completely decayed on the week between March 13 and March 19, visits to *Wikipedia* faded more gradually. Thus, the total number of visits to *Wikipedia* entry on the earthquake in Japan was actually higher during the following week.

Finally, searches for Nobel laureates and their related discoveries were compared in both *Google* and *Wikipedia*. It was found that the week with peak interest in Nobel laureates does not always match with that of their specific discoveries (61.5% of the terms in *Wikipedia* and 46.2% of the terms in *Google*). This is mainly, as was mentioned earlier (see Table 2), since some scientific discoveries such as "telomeres" are sought during the entire year and not necessarily more so during the related Nobel Prize event. Interestingly, however, in both *Wikipedia* (38.5% of the terms) and, to a greater extent, *Google* (53.8% of the terms) people seek for information related to the specific scientific discoveries at the same week of the Nobel Prize announcement. This provides a partial support for H4, suggesting that people seek to expand their scientific knowledge related to the relevant discoveries mostly during the Nobel Prize announcement.

Although the sample of Nobel laureates is inevitable small to conduct further statistical analysis, it clearly demonstrates how media event of Nobel Prize announcement increases public interests in S&T. Figure 1 displays the mean *Google* searches and *Wikipedia* visits related to Nobel laureates and their scientific discoveries each week. It shows that unlike the ad hoc trends of searches related to Nobel laureates, searches related to their scientific discoveries generally follow cyclic trends corresponding the academic period. However, in both *Google* and *Wikipedia* there is a significant increase in interest related to the scientific discoveries following the announcement of the Nobel Prize winning. An exceptionally high peak was in October 2010, in which the winning of Andre Geim and Konstantin Novoselov triggered an outstanding number of visits to the *Wikipedia* entry "graphene".

Figure 1. *Google* searches and *Wikipedia* visits related to Nobel laureates and their discoveries



Note. The mean number of *Google* searches (in percentages) and *Wikipedia* unique visits (absolute numbers) of all Nobel laureates and their scientific discoveries each week.

Discussion

In this paper the S&T information seeking behavior in *Google* and *Wikipedia* was studied and compared. In order to do so, we constructed a comprehensive list of scientific terms based on media and school curricula motivations. We identified 90 media related ad-hoc terms, and 106 academic related cyclic terms. We then examined their trends in *Google* searches and *Wikipedia* page visits, comparing their average half-life, correlations, and time lag.

In line with the agenda-setting theory (McCombs & Shaw, 1972; Takeshita, 2006), previous observations (Baram-Tsabari & Segev, 2013; Segev & Baram-Tsabari, 2012) found that together with the academic period, media coverage of S&T topics was closely associated with searches for those topics. Using this distinction between ad hoc and cyclic search patterns and their association with media and the education system respectively, the current study advanced the understanding of online engagement in S&T in two aspects. First it compared the duration (or half-life) of ad-hoc and cyclic terms, and second it compared their usage in two prominent S&T channels: *Google* and *Wikipedia*. The former may cater to users with a variety of intentions, whereas the latter offers encyclopedic information on specific topics. Following our expectation (H1), findings show that cyclic terms had significantly longer span than ad-hoc terms. Their average half-life was about nine times longer in *Google* searches and six times in *Wikipedia* visits.

This corresponds with the overall trends observed by surveys (European Commission, 2010; National Science Board, 2014), indicating general interest in S&T, and increasing online engagement (Smith et al., 2015). When considering, however, the significantly longer duration of S&T engagement in cyclic terms in both *Google* and *Wikipedia*, we could infer that, more than news media, educational institutions

have an important role in attracting continuous attention and online engagement in S&T (Head, 2007; Horrigan, 2006; Law, 2009; Thornton, 2010). Media, on the other hand, can reach a broader public, temporarily attracting much greater attention than the education system to ad-hoc S&T events.

As a result of those different cues, we expected a different online engagement in *Google* and *Wikipedia*. In particular, we expected that while both channels would be used to search for cyclic terms stemming from the education system, *Google* would be more instrumental in searching for ad-hoc terms (H2). However, the average correlation between *Google* and *Wikipedia* among ad-hoc terms was not significantly lower from their correlation among cyclic terms. In other words, not only *Google* but also *Wikipedia* was used as an important information source when it comes to ad hoc events such as natural disasters, health crises (Generous et al., 2014; McIver & Brownstein, 2014), or other S&T topics reported by media.

Still, when comparing the week with the maximum usage in *Google* and *Wikipedia*, we identified different patterns between the channels. In partial agreement with our third hypothesis, the week with peak activity in *Google* and *Wikipedia* matched for most ad hoc terms. Some of the ad hoc terms displayed a time-lag, in which the peak activity in *Google* preceded the peak activity in *Wikipedia*. In other words, ad hoc terms associated with news coverage, triggered a massive activity in *Google* that followed by a massive activity in *Wikipedia*. This was not the case for cyclic terms typically associated with educational cues. Our findings further show that terms that tended to peak in *Google* searches first were related to ad hoc natural events or disasters, such as the great earthquake in Japan in March 2011.

The fact that the peak activity in *Google* and *Wikipedia* largely overlapped for ad hoc terms is further in line with Laurent and Vickers (2009) findings regarding the

high ranking of *Wikipedia* in *Google* search results, and its increase following related news coverage. In other words, when interests in ad hoc S&T events rises following news media cues, there is more likelihood to observe an increase in *Google* related searches, accompanied by *Wikipedia* visits to the relevant topics. But, perhaps one of the reasons that the peak activity in *Google* could sometimes precede the peak activity in *Wikipedia* is related to the different platform design and function that each offers.

Google search is mostly based on an automatic algorithm, which prioritizes results based on their currency among other factors (Nisbet, 2011; Weltevrede et al. 2014). It scans news and blog related information and is designed to provide a timely and up-to-date response for new scientific events. Additionally, as was earlier suggested, *Google*'s bias toward mainstream information in general (Gillespie, 2010; Ladwig et al., 2010) and mainstream S&T views in particular (Li et al., 2014), would channel users to the larger and more commercial news website, a process that would further intensify the affiliation between searches and popular news sites.

Wikipedia, on the other hand, has very different function and information retrieval mechanism. It mostly relies on peoples' contributions, and the negotiation between human editors (Borra et al., 2014). Edits in *Wikipedia* are often done in batches since users save multiple minor edits to a single article (Weltevrede et al., 2014). Although editors may react immediately in response to prominent events, it is still possible that some ad-hoc scientific term would appear in *Wikipedia*, and consequently be referred to from the top search results in *Google*, only after enough news information is available. Like in most other websites, the traffic in *Wikipedia* depends on references from *Google*. Once a scientific event has been covered in *Wikipedia* and has been linked from other websites it has greater chances to be ranked higher among *Google* search results.

Finally, in partial agreement with our fourth hypothesis, about half of *Google* searches and *Wikipedia* visits for Nobel laureates matched searches and page visits of their related discoveries. This is mainly due to the fact that many scientific discoveries were cyclic and therefore associated not only with the Nobel Prize event but also with the academic period. Consequently, as expected, the attention span for scientific discoveries was significantly longer than for their laureates. The findings further indicated that external cues such as news coverage of scientific topics may provide the broader public with a further opportunity to gain scientific knowledge that may last for up to several weeks at a time.

As the present study showed, the data available from *Google* and *Wikipedia* is tremendously useful in identifying patterns of S&T information seeking behavior. While we can learn about what and when people search in *Google* for scientific information, or visit scientific information in *Wikipedia*, we still cannot link between the two or study individual information behavior. This is a common limit for many big data studies, and particularly those using aggregated data of user activity (Baram-Tsabari, Segev, and Sharon, Forthcoming). The use of aggregated data further limits our ability to know who used those websites and for what purposes. Future studies should incorporate traditional tools such as interviews and surveys in order to get a more comprehensive picture of what types of individuals are more likely to seek S&T information online, what motivates them to conduct the search, and what is the impact of their information uses.

Additionally, there are measurement limitations in the publicly available tools, and particularly in *Google Trends* (see also Baram-Tsabari & Segev, 2013; Segev & Baram-Tsabari, 2012). First, the use of one-week as a unit for analysis limits our understanding of the dynamic behavior of users when looking for scientific

information. Second, the reliance on internet data raises a representativeness issue, especially in countries with low usage rates and an interpretation issue, as searches could be motivated by many reasons (Mellon, 2013). In our case, data were based on searches in *Google* and visits to *Wikipedia* in English, and therefore could draw mainly on the information behavior in English speaking countries, and predominantly those in the United States.

Notwithstanding these limitations, the overall analysis of the online activity in *Google* and *Wikipedia* revealed interesting patterns. Different stimuli (such as news media and educational cues) have different effect on online engagement in S&T. While news coverage provokes a very intense but short interest among the larger population, education cues trigger much longer but more modest interests in science corresponding to the academic period. The peak activity in *Google* often overlaps with that in *Wikipedia* for most ad hoc terms. These findings could be therefore implemented by public institutions wishing to take the advantage of those "teachable moments" (Baram-Tsabari & Segev, 2013), and increase public awareness and knowledge on specific S&T issues. Our recommendations for catering more effective policies follow both top-down and bottom up approaches.

Governments and policy makers would benefit from using *top-down* approach such as advertising campaigns in traditional media channels along with search engine optimization techniques. In particular, since we found that online engagement in ad hoc scientific events is short and intense, it would be beneficial to invest most of the efforts in advertising and optimizing messages to search engines, and producing relevant content in *Wikipedia* before releasing a media campaign. For example, a ministry of health wishing to increase public awareness to healthier diet should make sure that those messages are available through search engines and *Wikipedia* before

launching a media campaign. Once people learn about healthier diet through traditional media, there is a very short, but intense peak in related *Google* searches and *Wikipedia* visits, which provide policy makers a window of opportunity to cater their messages more effectively.

Unlike event oriented ad-hoc terms, our findings show that the interest in cyclic terms is much longer and less intense. Educators would certainly benefit from moderate but ongoing efforts along the academic period to enhance the search skills of their students as well as their critical assessment of online content both in *Google* and *Wikipedia* (Head, 2007; Thornton, 2010). This could be accompanied by understanding of the basic principles of search engine ranking as well as the active production of quality scientific content. We refer to this as a *bottom-up* approach since the educational experience would be enhanced if more school and university students would adapt critical reading and writing skills as part of their curricula. This is particularly important following previous findings (Gray et al., 2010; Konieczny, 2012) that show that *Wikipedia* has been poorly integrated in classrooms. The gap between our findings regarding the ongoing activity in *Wikipedia* along the academic period and the low attention it has been given among educational institutions also points to the opportunities for improvement.

Moreover, our findings indicate that educators could benefit from teaching information skills not only along the entire academic period, but also and most importantly around the occurrence of certain scientific events. As the online interest in scientific events sharply increases following news coverage, this would provide an effective teachable moment for educators. For example, following a Nobel Prize winning, an astronomic event, or the outbreak of an epidemic more people search for related information. A greater interest following news coverage of scientific events

would therefore be a more effective opportunity for educators to increase the information skills and involvement of their students.

Finally, the fact that *Wikipedia* is used almost twice as long as *Google* to search for ad hoc and cyclic terms, certainly position it as one of most important and influential S&T information sources on the web. Both, educators and policy makers would benefit greatly from expanding the use of *Wikipedia* together with their use of news media and the educational curricula. This process of knowledge gaining should be seen as a cyclic rather than a linear one. Information available from online sources should correspond with media and the educational cues in order to provide a much richer and more effective environment for the enhancement of S&T knowledge.

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