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Observing Serendipity in Digital Information Environments

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ABSTRACT

We often interact with digital information environments to find useful information. But sometimes useful information finds *us* unexpectedly, propelling us in new and exciting directions. In previous work, people have self-reported coming across information serendipitously. However, there has been limited success in directly observing people doing so. To see if we could have more success, we conducted naturalistic observations of 45 users interacting with different types of digital information environments. Without priming them about serendipity, we asked the users to conduct self-chosen naturalistic information tasks, which varied from broad tasks such as browsing online news to narrow tasks such as finding a particular product to buy. We noted several examples where users either 1) stated they were looking for information on a particular topic or product and unexpectedly found useful/potentially useful information about something else or 2) unexpectedly found useful/potentially useful information when not looking for anything in particular. Our findings suggest that, with a carefully-considered approach, serendipity-related information interaction behaviour *can* be directly observed. This allows designers of digital information environments to better understand this behavior and use their enriched understanding to reason about ways of designing new or improving existing support for serendipity. We illustrate this approach by discussing implications for the design and evaluation of digital information environments.

Keywords

Serendipity, digital libraries, e-commerce, online news

INTRODUCTION

We usually interact with digital information environments in order to find useful information. However, sometimes useful information finds *us* – and unexpectedly. Coming across information serendipitously can take us on a valuable journey of discovery, surprising and delighting us along the way. It involves encountering information that we perceive to be both useful/potentially **useful and unexpected** either:

1. When **not looking for information** at all
2. When **looking for information on something else** (i.e. in a different topical area) or

3. When **not looking for any information in particular** (i.e. with no specific, or only a vague idea of the information sought).

Existing (mostly interview-based) studies found people self-report to come across information serendipitously. However, there has so far been limited success in directly observing people experiencing perceived serendipity when interacting with digital information environments in controlled settings (e.g. research labs). This may be because serendipity involves an element of unexpectedness and therefore cannot be created or observed on demand.

To see if we could have greater success, we conducted naturalistic observations of 45 students interacting with 3 different types of digital information environment; digital libraries, e-commerce sites and online news sites (15 students per type). We asked the students to conduct real or realistic self-chosen information tasks, without priming them about serendipity beforehand. We then asked them if they thought they had come across information they considered to be both useful/potentially useful *and* unexpected and analysed screen recordings of all interactions in this category. We noted several examples that might be considered serendipitous; where users either 1) were looking for information on a particular topic or product but unexpectedly found useful/potentially useful information on a different topic/product or 2) unexpectedly found useful/potentially useful information when they only had a vague idea of what they were looking for.

Our findings suggest that, with an appropriate methodology, coming across information serendipity *can* be observed in a research setting. First-hand observation allows designers to better understand how existing digital information environments create opportunities for serendipity and to use this understanding to reason about how to design new or improve existing support. It also allows designers to check whether environments they designed to create opportunities for serendipity actually do.

The rest of this paper is structured as follows; firstly, in our background section, we discuss the definition and important aspects of serendipity. We then review existing empirical studies that have examined how people come across information serendipitously when interacting with digital information environments. We also review existing studies that have tried to observe users coming across information serendipitously in controlled settings. While doing so, we critique these existing studies to suggest reasons why their

success may have been limited. We then describe the approach we followed when planning and conducting our think-aloud observation of people interacting with digital information environments. Next, we discuss the findings of our observation – focusing on describing interactions where participants felt they had come across useful information unexpectedly. In doing so, we present two types of examples of participants coming across information serendipitously; 1) where they were looking for information on one topic and unexpectedly found useful/potentially useful information on another (unrelated or partly-related) topic and 2) where they were looking for information with only a vague aim and found useful/potentially useful information unexpectedly. Next, we discuss the implications of our findings (framed as advice for future researchers who wish to observe serendipity in controlled settings). We conclude by discussing the potential benefits of directly observing serendipity in controlled environments.

BACKGROUND

Definition and important aspects of serendipity

There is no agreed definition of the word ‘serendipity.’ Often referred to as a ‘happy accident,’ the word was coined by Horace Walpole after a fairy tale – ‘The Three Princes of Serendip,’ in which the princes were “*always making discoveries by accidents and sagacity, of things they were not in quest of.*” (Merton & Barber, 2004, pp. 1-2). When we asked people to explain what the word meant to them (see [removed for anonymity]), we found that serendipitous experiences involved three ‘essential ingredients’: unexpected circumstances (the ‘accident’), an insightful ‘aha’ moment (the ‘sagacity’) and a valuable or potentially valuable outcome (the ‘happy’). This outcome must also be *unanticipated* as “*no discovery of a thing you are looking for comes under this description* [Walpole’s emphasis]” (Merton & Barber, 2004, p. 2).

In the context of coming across information serendipitously, a ‘valuable unanticipated outcome’ is likely to be useful, unexpected information. We therefore define ‘coming across information serendipitously’ as ‘finding useful or potentially useful information unexpectedly – either when not looking for information at all, when looking for information about something else or when looking for information with no particular aim in mind.’ This definition complements the findings of other empirical studies into serendipity in digital information environments (which we discuss shortly).

A highly-related concept to serendipity in the context of finding information is ‘information encountering.’ Erdelez (2005) describes information encountering as “*an instance of accidental discovery during an active search for some other information*” (p. 180). According to Erdelez, this is part of a broader phenomenon, which she refers to as the ‘Opportunistic Discovery of Information’ (ODI). According to Erdelez (Erdelez, 2014, personal communication), ODI can occur 1) when actively looking for information on an

unrelated or partly-related topic (in which case it can also be considered Information Encountering), 2) when actively looking for information without a particular aim in mind or 3) when not actively looking for information at all. Therefore we can consider the concept of ODI as equivalent to what we term ‘coming across information serendipitously.’ While it may be difficult or impossible to observe people coming across information serendipitously when they are not looking for information at all, we wanted to find out whether it would be possible to observe examples of 1) or 2) in a controlled research environment.

Coming across information serendipitously

Several existing interview studies have been carried out where different groups of people have self-reported to have come across information serendipitously. These include academics (Foster & Ford, 2003; McCay-Peet & Toms, 2010; McBirnie, 2008; Sun et al., 2011; Makri & Blandford, 2012), jazz improvisers (McBirnie, 2008), online news readers (Yadamsuren & Erdelez, 2010) and creative professionals (Makri et al., 2014).

Foster & Ford (2003) found that interdisciplinary academic researchers widely experienced serendipity – for example when following chains of citations between information sources. Similarly Yadamsuren & Erdelez (2010) found that many online news readers stated they had experienced ‘incidental exposure’ to online news – often by finding unusual or knowledge-enhancing news during their regular news reading. Both Foster & Ford (2003) and McCay-Peet & Toms (2010) found that coming across information serendipitously often took researchers in new directions – highlighting the importance of serendipity in the context of information acquisition. McBirnie (2008) noted that both jazz improvisers and academic researchers stated the importance of being flexible during information-seeking in order to maximise the chance of experiencing serendipity.

The academics interviewed by Makri & Blandford (2012) provided several examples of experiencing serendipity when interacting with digital information environments. These included a student coming across a news article that would later provide her with a novel ‘angle’ for answering an exam question and a researcher who intended to type ‘Digital Learning Network for Museums, Libraries and Archives’ into Google to find their website, but accidentally submitted her search after typing only ‘Digital Learning Network.’ She found a report about digital learning in museums that was useful for different research she was carrying out on behalf of a UK museum. As well as when searching the Web, academics have also self-reported coming across information that was useful for their studies unexpectedly when using social media tools such as Facebook and Twitter (Dantonio et al., 2012).

Aside from interviews, other indirect research methods have also been used to examine serendipity (albeit in a general rather than information context). For example, Sun et al. (2011) asked researchers to capture their serendipitous

experiences in photos and text using a mobile 'serendipity diary' app. They then used the photos and texts as interview probes to better understand the researchers' experiences. Rubin et al. (2011) searched the GoogleBlog archive for a variety of serendipity-related keywords, with the aim of identifying blog entries that discussed serendipity in everyday life. They found that several bloggers reflected on their everyday experiences of serendipity. These indirect research methods can provide insight into peoples' experiences of serendipity. However, we wanted to see if we could *directly* observe people coming across information serendipitously. Observing serendipity in controlled environments has been attempted, but with limited success. We now discuss previous studies that have sought to directly observe this phenomenon.

Observing serendipity in controlled environments

André et al. (2009) explain that *"because serendipity is inherently rare, it is hard for researchers to capture or induce it for study and experimentation"* (p. 307). However, this has not deterred some researchers from attempting to do so. Indeed, Cunha et al. (2010) argue that *"while serendipity might seem to be an elusive concept, one that is difficult to capture empirically, such difficulties should serve to stimulate interest rather than discourage it"* (p. 320). In this section, we discuss studies by the few researchers who have so far attempted to observe serendipity in controlled environments.

Toms (2000) asked 47 digital newspaper readers to either 'find the answer to a set of questions' (i.e. a specified goal) or 'read/browse the newspaper for the next 20 minutes' (no assigned goal). Participants could access newspaper articles either by searching or by selecting from a dynamically-created list of similar 'suggested' news articles. Toms found that participants with no assigned goal selected more articles from the suggestions than those with a specified goal and reported finding more interesting articles than those with a specified goal. She concluded that these chance encounters were potentially enriching and rewarding and that the suggested news articles *"seemed to facilitate serendipity"* (p. 445).

Erdelez (2004) observed 10 students carrying out a prescribed search task – where the search results included an item relevant to one of the students' current assignments on a different topic. The students' 'foreground task' was to shop online for a surfboard and their assignment involved researching and writing a report on the size of the market for Web analytics software. The search results list included a result where the snippet included the phrases 'web analytics market increases' and 'surfing, right on target' as well as 'Motorola Surfboard cable modem.' Erdelez found that although 9 of the 10 students noticed the search result and 8 of them reported that they made the connection between it and their assignment, none clicked on it. This may be because they were concerned about stopping the shopping task they had been set and going off on a tangent.

Erdelez stated the study 'did not succeed' in observing users encounter information in a controlled research environment, speculating this may be due to the 'artificial nature' of the foreground task.

Toms & McCay-Peet (2009) examined the impact of suggested news articles further by developing a novel interface for accessing Wikipedia articles that included links to suggested pages based on the current Wikipedia article being viewed. They asked 96 students to use the digital information environment to carry out broad information tasks and did not brief them on the 'suggested pages' functionality beforehand or ask them to use it specifically. Although only 38 (40%) of the participants used the functionality (as many perceived it might lead them astray from their assigned task), many of the students commented that it was useful for suggesting ways in which the existing search terms might be altered and for providing a new search direction or new perspective on the topic being searched for. Students also commented that the suggested pages were useful for providing a general understanding of the topic. Many students, however, commented that the functionality was only useful when the suggested pages were highly related to the research topic. They highlighted that the functionality had the potential to distract them and to take them too far away from their task. Toms and McCay-Peet noted that very few students used the functionality for exploring other topics, stating that this *"may have been due to the primary experimental scenario in which they were immersed"* (p. 200).

Following on from this study, McCay-Peet & Toms (2011) also asked participants to use a novel Wikipedia interface – this time with no prior set tasks; they were asked to examine any articles they wished. After 20 minutes had passed, they were asked whether they had read anything 'unexpected, surprising or novel,' anything that they did not previously know about or anything that they want to tell someone else about. The vast majority of participants (105 of 124) answered 'yes' to one or more of these questions - which may be possible indicators of having come across information serendipitously. The study did not aim to observe serendipity in a controlled environment per se, but to identify 'dimensions' of serendipity that it may be possible to design digital information environments to support. However, the findings suggest that giving participants self-chosen, naturalistic tasks to carry out may be useful when attempting to observe the phenomenon.

Yadamsuren & Erdelez (2010) used the think-aloud method *"to capture respondents' incidental exposure to online news in real time."* Yadamsuren (2010) explains that although some participants stated they experienced incidental exposure to online news during the session, the think-aloud component of the interview was not particularly successful. She suggested this was because asking participants to consciously reflect on their news reading was 'unnatural.' This highlights the importance of striking a balance between asking participants what they are doing to prompt

thinking aloud and *not* interrupting during reading. It is also possible that priming participants about the purpose of the study beforehand might have biased their behaviour.

Bogers et al. (2013) asked 20 students to complete 3 search tasks using Amazon. and Digg (selected “*because of their expected potential for serendipity*,” p. 704). The authors based 2 of these tasks on ‘cover stories,’ but allowed students to select their own third task based on their personal interests. The students were asked to bookmark ‘relevant and interesting’ pages and, afterwards, to rate the pages based on how interesting and task-relevant they thought they were. The students rated several pages as interesting but not task-relevant (which the authors considered to be an indication of serendipity). Bogers et al. also examined the effect of informing the students that the study was on serendipity and the effect of a researcher being present during the search session. Although their results were not statistically significant, they noted a trend that students who were told the study was about serendipity and those who conducted their searches with a researcher in the same room rated fewer pages as interesting but not task-relevant. They suggest the need to “*keep controlled experiments designed to measure serendipity as natural as possible*” (p. 706) by not informing participants at the beginning of the study that the specific focus of the study is on serendipity and by not having the researcher in the room.

Erdelez (2005) notes that experimental research may well be useful for understanding how people unexpectedly encounter information, but warns that “*many challenges in experimental research design and instrumentation would first need to be overcome*” (p. 182). Erdelez (2004) suggests that challenges in observing serendipity in controlled environments “*can be overcome with very careful planning, high attention to detail, and ongoing adjustments in a development and execution of a research design*” (p. 1023). She also suggests that studies of serendipity in a controlled environment might be more successful if they incorporate naturalistic and self-chosen (rather than artificial and researcher-chosen) information tasks. We followed Erdelez’s advice and asked our participants to choose their own ‘real or realistic’ information tasks to carry out. We found this approach particularly useful for observing serendipity in digital information environments.

METHOD

We wanted to find out whether it was possible to observe people coming across information serendipitously in a controlled research setting and, if it was, to convey a detailed understanding of their serendipitous information encounters. To this end, we recruited 45 existing users of 3 different types of digital information environment; digital libraries (15 users), e-commerce sites (15 users) and online news sites (15 users). We did not recruit across different types of environment to compare users’ experiences across environment types (our sample size was not large enough

for that), but to see whether our findings generalised beyond a particular environment type. We therefore aimed to recruit a roughly even split across types of environment. Before the study, we asked participants how often they used the particular type of digital environment we were planning to ask them to interact with (daily, weekly, monthly, less often). Within each type of digital environment, we recruited a roughly even split across these categories. Although we would have also preferred to recruit a roughly even split across age and gender groups, we felt we would be most successful recruiting students from within our university department (Computer Science). Reflecting the demographics of the department, most users recruited were aged 19-24 (93%) and were male (78%). As we found in a previous study that people of all ages and genders report to come across information serendipitously (see [removed for anonymity]), we do not believe this impacts on the validity of our findings. None of the Computer Science students had been previously taught about information encountering or serendipity, or by the lead author (who has serendipity as a research interest). When asked at the end of the study, almost all students stated they were previously unfamiliar with the concept of serendipity.

We recruited by e-mail, which stated we would be observing them carrying out a real or realistic task when using digital libraries/e-commerce sites/online news sites of their choice. We only mentioned our specific focus on serendipity in post-observation interviews (explained later). We took particular care to avoid deceiving participants about the study; we made sure we gave them a general (but accurate) description of what we would be observing before the study, then a more specific description (incorporating serendipity) during the post-observation interviews. The study was approved by our university Ethics Committee.

The study took place in an office, with only a researcher and the participant present. The participants’ interactions with digital information environments and think-aloud verbalizations were recorded using eLecta Live screen recorder. Participants were given the opportunity to review or delete their recordings (but none of them opted to do so). They were asked to ‘use your choice of one or more digital libraries/e-commerce sites/online news sites to conduct a real or realistic information task.’ They were told to ‘where possible, make your task a real task that you actually need to do. If not, make your task as realistic as you can.’

We provided participants with a general example of a possible narrow or broad information task for the type of environment they would be using; they were told that ‘a real or realistic task using a digital library might be to obtain information for your studies (either on a specific topic, or on an area of general interest). For an e-commerce site it might be to obtain information about or buy products or services (either specific products/services you are already interested in or products/services of general interest). For an online news site it might be to obtain news on topics you are specifically interested in or on general

topics. If a participant asked for a definition or examples of the type of digital information environment they had been asked to use, we told them that ‘a digital library stores and lets users access digital information,’ ‘an e-commerce site lets users buy and sell products or services’ and ‘an online news site lets users find out about news and current affairs.’ This was sufficient to guide most participants (without biasing their choice of information environment).

Participants were asked to think aloud during the task, ‘telling me constantly what you are doing and why.’ During the task, participants were asked to bookmark any information they thought was useful (or likely to be useful in the future). They were also asked to take a screenshot of the information (in case the bookmarked links were not persistent). Participants were given the opportunity to ask questions before the task and told that the researcher may not be able to answer their questions during the task as he did not want to bias their interaction behaviour. If a participant stated they had finished their task before 30 minutes had passed, we asked them to think of another real or realistic task. This was because we wanted to give all our participants an equal amount of time to potentially experience perceived serendipity. We decided to go against Bogers et al.’s (2013) advice that the researcher should leave the room; this was for pragmatic reasons - we wanted to be able to remind users to think aloud and bookmark useful pages if they forgot to. The researcher kept interruptions to a minimum to ensure the interaction behaviour displayed was as natural as possible.

Participants were asked to tell the researcher about their self-selected task before starting. This was for two reasons; firstly, it allowed the participant to carry out a well-considered task. Secondly, it allowed the researcher to understand the participant’s aim (whether it be vague, specific or somewhere in-between). We did not use information about the task to infer whether participants had experienced serendipity (e.g. when they bookmarked information that they thought was useful/potentially useful but did not seem to be task-related). This was because we believe that, due to the dynamic and evolving nature of many information tasks, it is difficult if not impossible to take objective measures of task-relatedness (or of serendipity in general). Instead, we acknowledged the subjective nature of the study and of serendipity and chose to focus on participants’ *perceptions* of usefulness and unexpectedness rather than trying to ‘measure’ serendipity objectively. The subjective nature of the study also dictated that we should avoid placing much weight on quantitative data. Information considered to be useful or unexpected by one person might not be by another. We therefore make very limited use of quantitative findings here.

After the task, the researcher asked the participant to click on every bookmark they had saved and asked them why they thought the information was useful (or likely to be useful in the future). For each bookmark, the researcher also asked whether they thought finding the information

was also unexpected and, if so, why. ‘Usefulness’ and ‘unexpectedness’ were chosen as both were found to be important aspects of serendipity (see Makri & Blandford, 2012). The researcher stated it was important that they responded honestly ‘rather than telling me what you think I want to hear.’ Afterwards, the researcher introduced the study’s focus on ‘coming across information serendipitously’ and explained the phenomenon (using the definition from our ‘background’ section).

We analysed our data through a partly inductive and partly deductive process. Our inductive process was partly informed by Grounded Theory Methodology (see Corbin & Strauss, 2008). We coded the observation and interview data by ‘listening’ to it and by constantly comparing the participants’ perceived experiences of coming across information serendipitously with each other. We do not claim to have followed Grounded Theory Methodology itself. This is because 1) our process was partly deductive, 2) we did not follow a cyclic data-gathering and analysis process (access to participants was often in bursts, whenever groups of students had spare time) and 3) we did not check our emerging findings with subsequent participants as we felt this would be more likely to bias rather than validate the data in this particular study. Our deductive process involved looking for examples in the observation data of when participants 1) were looking for information on a topic but found useful information unexpectedly on another (unrelated or partly-related topic) and 2) found useful information unexpectedly when looking for information with only a vague aim. We looked for these types of examples as they have been previously noted in the literature (see Erdelez, 2005; Makri & Blandford, 2012). We found 12 of these examples across the 45 participants we observed. Each observation lasted 20-30 minutes. We numbered participants ON1-15, EC1-15 and DL1-15, with the letters ‘ON’ denoting online news sites, ‘EC’ e-commerce sites and ‘DL’ digital libraries.

FINDINGS AND DISCUSSION

The vast majority of participants identified one or more bookmarks where they considered the information found to be both useful *and* unexpected. However, this is *not* an indication of high levels of perceived serendipity; most bookmarks were of information participants were not previously aware of, but was strongly related to their self-chosen task. For example, participant EC6 was looking for a coat and came across one with a zip-off hood (a type of hood he did not know existed). We did, however, note several examples that were *not* strongly task-related and can be considered serendipitous. These were examples of information participants considered useful/potentially useful *and* unexpected that they found either 1) when looking for information on a partly-related or unrelated topic/product or 2) when they only a vague idea of what information they were looking for. To place our serendipity-related findings in context, we first briefly discuss reasons why our participants considered the

information they found to be useful/potentially useful and unexpected. We then focus on examples we consider serendipitous: those that involved finding useful information unexpectedly when not looking for anything in particular and finding useful information unexpectedly when looking for information on something else.

Why the information was considered useful

Our participants thought the information they bookmarked was useful or likely to be useful in the future for several reasons. One of the main reasons was when they thought the information could be used to **support their writing** (e.g. by helping to shape an essay argument) or to **support their decision-making** (e.g. by helping them decide whether or not to buy a particular product or discuss a particular aspect of a topic in their writing). For example, participant ON3 read a technology news article that contained benchmark tests of a smartphone and commented *"I wasn't going to know how the phone would perform in their tests and it does amaze me. It convinces me that I might want to buy this phone."*

Other reasons information was considered useful was because it **enhanced participants' knowledge** of or **provided them with a new perspective** on a topic. For example, participant ON1 skimmed a news article on Facebook's approach to digital legacy and commented *"I'd never thought about what happens to all your online data when you die."* Similarly DL3 searched the Taylor & Francis DL for 'women in leadership' and found an article entitled 'the heart, head and hands of transforming leadership.' He commented: *"it gave me a better understanding of issues in women's leadership as a whole, rather than for an individual minority. It was unexpected to get a new perspective on analysing leadership."* – DL3

Why the information was considered unexpected

There were also a variety of reasons why participants considered the information they bookmarked to be unexpected. The reasons most frequently reported were that the information itself was unexpected (**unexpected information content**), that the information provided the participants with **unexpected new insight** and that the information was from an **unexpected source**. To illustrate finding information with unexpected content, ON15 found a news article about Apple releasing a security patch for its iOS 7 mobile operating system and stated *"I thought iPhones were much safer security-wise. I didn't really expect something to happen in terms of security."* Similarly, DL6 searched the ACM digital library for 'feminine identities' to find information for an essay on the effects of feminine identities on primary school-aged girls. She found an article entitled 'girls playing games: rethinking stereotypes' and stated: *"I hadn't previously given much thought to this area, but I think this will definitely be part of my research from now on – taking different stereotypes of girls into account."* Regarding finding information from

unexpected sources, DL15 was surprised to find a textbook during a digital library search.

Participants also stated other reasons for considering the information they found to be unexpected. Some of these reasons were related to the type of digital information environment they were using. For example, participants who used e-commerce sites often considered information to be unexpected because they found an **unexpected product**. For example, participant EC2 was looking on the North Face Website for a ski jacket and stumbled upon ski trousers and ski pants. On the Ski pants, the participant commented: *"I found it along with the Ski trousers and jacket, so yeah I took a print screen. You need to wear these underneath your ski trousers for padding and to protect you in cold conditions. It was unexpected because I was looking for something else actually. I was looking for a ski jacket. I wasn't looking for the trousers. And when I saw the trousers, it reminded me that I needed ski pants too."*

Other participants who used e-commerce sites considered the information they found to be unexpected because something about a product surprised them (an **unexpected product attribute**) or **unexpected detail** in the product description. For example, participant EC8 was looking on eBay for yoga mats and found a 'thick' mat. He stated: *"it's on eBay and it's a different kind of yoga mat; it's a thicker mat, so I can use it outside. I didn't know they had thick yoga mats until seeing this."* Related to unexpected detail, EC11 was looking on Tripadvisor for reviews of hotels in Thailand. She commented on the detail of the reviews:

"I didn't think people would spend hours writing an essay for a review, so that was unexpected." – EC11

Participants who found product-related information on e-commerce sites were often not surprised by the information itself, but by the price or value of the product; an **unexpected offer**. For example, when looking at the Gran Turismo 6 game on PS3, participant EC10 noted its low price. Similarly, EC1 went to the Topman Website to find a jacket and although he did not find one he liked, he noticed a limited-time 20% discount for students, which he found unexpected because he noted that Topman rarely increase their usual 10% student discount.

Participants using digital libraries mostly considered the information they found to be unexpected due to unexpected content, the information providing them unexpected new insight or due to the information being from an unexpected source. However, when questioned about some of the bookmarks, participants also stated they considered information they found to be unexpected due to the way it was presented (**unexpected information presentation**) and because it was unexpectedly clear (**unexpected information clarity**).

Our findings on usefulness and unexpectedness do not relate directly to serendipity (they are simply concepts that are important for coming across information

serendipitously), but serve to validate and extend similar findings from a study by Foster & Ford (2003). Foster and Ford noted that when interdisciplinary scholars came across useful information unexpectedly, they either considered the information itself to be 'of unexpected value' or the existence or location of the information to be unexpected. Our examples of unexpected information content, presentation, clarity and detail can be regarded as examples of information itself being considered unexpected. Finding information from an unexpected source can be considered similar to Foster & Ford's 'unexpected location.' Where we found that information could be considered unexpected due to the new insight it provided, Foster & Ford found something similar; that the information they encountered could "*take the researcher in a new direction*" (p. 330).

We now discuss examples that might be considered serendipitous. These were examples of information participants considered useful/potentially useful *and* unexpected that they found either 1) when looking for information on a partly-related or unrelated topic/product or 2) when they only a vague idea of what information they were looking for. When asked at the end of the study whether they thought any of their bookmarks were examples of 'coming across information serendipitously' as defined by our definition in the background section, participants answered 'yes' for all the examples we discuss that fell into categories 1) and 2). However, serendipity is a highly subjective concept and therefore what is considered serendipitous by one person may not be by another.

Finding useful information unexpectedly when looking for information on something else

Examples where people look for information on one topic but find information on an unrelated or partly-related topic are often regarded as classic examples of coming across information serendipitously (see McCay-Peet & Toms, 2010). Although only a handful of our participants' experiences fell into this category (presumably because these experiences are rare), we were encouraged that it was possible to observe them in a controlled environment. We discuss three examples here (two from e-commerce participants and one from a digital library participant). None of the online news participants' examples fell into this category (presumably because most participants chose to browse for news with no particular aim in mind).

Participant EC2 stated he was "*looking for a warm jacket that will be good for skiing – preferably a North Face jacket*" and browsed by brand on the House of Fraser Website. Unable to find 'North Face' in the list of brands, he decided to look at 'Helly Hansen' jackets instead. He clicked on a particular Helly Hansen jacket and noticed another (general purpose rather than ski) jacket, this time by Hugo Boss, on the 'other customers also viewed' bar on the product description page. He clicked on the link to the jacket and commented that he 'really liked' it and that they had his size in stock. The participant noted that he preferred this jacket to the others he had found and was aware that

this was not a ski jacket, but a general purpose jacket. He stated "*I didn't expect to find this jacket. It's not something I was looking for. I just happened to come across it while I was looking at the other one.*"

Participant EC6 was looking for a portable antenna for a Freeview HD television. He searched for 'TV antenna' in Amazon and found an amplified antenna that he bookmarked. He then refined his search to 'TV antenna wire' to look for "*an extension cable to plug the TV in my bedroom into the aerial point in my living room, in case I don't buy this antenna.*" While looking at images of one of the aerial extension cables in the results list, he stated that if he decided to opt for an extension cable rather than a portable antenna, he would also need to buy a splitter to allow the TV signal to be sent to both televisions. Without changing his query terms, the participant continued to scroll down the results list and noticed a splitter. This was not a two-way splitter, but a device that allowed the signal to be sent to up to three TV sets. He commented "*I didn't expect it to be a three-way splitter, only two-ways. It'll allow me to share the signal to more TVs than I thought I could. And it's a similar price to a two-way.*" This might be considered by some to be an example of *pseudoserendipity* or 'arriving at the right destination by the wrong boat' (McCay-Peet & Toms, 2010) as the participant was looking for a TV signal splitter, but found one while looking for TV cables.

Participant DL13 had been researching the roles of amino acids in the human diet on the Eschobost digital library. She then switched to ScienceDirect and conducted a search for 'role of essential amino acids in humans.' She clicked on an article in the results list entitled 'Current Topics in the Biotechnological Production of Essential Amino Acids...' and skimmed the text of the article. Next, she scrolled to the 'recommended articles' section (presented in a menu bar on ScienceDirect) and stated "*I'm going to click on recommended articles, which are probably somewhat related to what I have searched for.*" Although she commented that she did not think the recommended articles were likely to be relevant to her research topic, she decided to click on one of them – 'Plant Genome Sequencing - Application for Crop Improvement.' Before examining the abstract, the participant stated that "*although this might not have anything to do with my research, it often helps to read up on work in a broader area.*" While reading through the paper, DL13 noted that much of the content linked well with her prior knowledge of amino acids and prompted her to make links between plant genome sequencing and the role of essential amino acids in the human diet. She noted that "*this was an article that wasn't strictly related to my topic, but since sequencing gene sequence protein crops gives us essential amino acids, it is actually related to my work.*" The participant also noted that the article was useful as it was "*something I can base my research on*" and, to her, unexpected "*as genome sequencing wasn't in any of the keywords I searched for.*"

Finding useful information unexpectedly when not looking for any information in particular

As well as looking for information on one topic and finding information on another, coming across information serendipitously can also occur when looking for information with no particular aim (Toms, 2000; Erdelez, 2005). As with 'look for A, find B' examples, there were only a handful of these examples too. We suggest this may be because e-commerce and digital library participants tended to set themselves specific, narrow information tasks (i.e. they often had a specific aim in mind when looking for information). Experiences in this category were more common across online news participants (who often were browsing for news without a particular aim). Here we discuss two examples from our observations – one from an online news and one from an e-commerce participant.

Participant ON5 stated he wanted to look at news on the IGN Entertainment Website *"to see what's happening in the gaming world, because I'm quite a big gamer."* After reading an article and watching a video trailer for a game called Titanfall, he scrolled down the 'top stories' section on the homepage and clicked on an article entitled 'Wolf of Wall Street becomes Scorsese's Biggest Hit.' He commented *"I've just come across this article. I think I clicked on it because I've already seen this film and liked it."* ON5 proceeded to read the article, pausing at the final paragraph which stated that actors Leonardo DiCaprio and Jonah Hill were 'keen to team up again.' He clicked on a hyperlink to another news article about the actors' plans to star in a new drama based on the man falsely vilified as the Atlanta Olympics bomber. He stated *"I'm surprised to see a movie article on a gaming news Website and you don't really get many actors that act together in several different movies. I didn't expect these two actors to reunite again. So this article is unexpected."*

Participant EC8 had been searching Amazon for 'yoga mats,' but had not found a suitable mat to buy. Later in the observation, he decided to *"go back to Amazon and see what else they have there."* He browsed the homepage, explaining he was not looking for anything particular but for any 'interesting offers' he might find. He scrolled down to the 'additional items to explore' section on the homepage and noticed a product with the title 'Adidas Training Mat – Black/Red.' Although this was a general purpose gym mat rather than a yoga mat, the participant stated *"I need this. This mat has caught my eye from the offers on the homepage, so I am going to bookmark this."* EC8 demonstrated an awareness that the Adidas mat was presented based on his previous searches, stating *"the homepage shows offers based on what I previously viewed."* He noted that he had not noticed this particular mat in the results list of his previous search for 'yoga mats' though. In this example, the participant may have come across the training mat because Amazon's personalised homepage not only displays products the user has recently viewed, but also similar products to those viewed recently.

IMPLICATIONS FOR DESIGN AND EVALUATION

Direct observation allows us to witness users' experiences of serendipity first-hand rather than relying on self-reports in interviews or surveys. This can help us better understand user behaviour when encountering information serendipitously using existing digital information environments which, in turn, can highlight how and how well existing environments support serendipity. It also allows us to consider how to improve support for this behaviour (e.g. by supporting it in new ways). While it is possible to do both of these without user involvement, as with other types of user evaluation, directly observing users' interaction behaviour has the potential to provide additional or alternative insights that might not have been gained from simply inspecting a digital environment from the viewpoint of supporting serendipity. Most of the digital information environments used by our participants supported serendipity by making *recommendations* of related products, or academic/news articles. This is a common way of creating opportunities for serendipity in current digital information environments. However, there is scope for supporting 'serendipitous' recommendations in new ways and for looking beyond recommendation as a means of creating opportunities for serendipity.

New ways of supporting recommendations

While it is common for digital information environments to make recommendations for similar products or academic/news articles (as with the ski vs. general purpose jacket example from EC2 and the yoga vs. training mat example from EC8), there is scope to move beyond 'customers who viewed this also viewed'-style recommendations when looking to create opportunities for serendipity. This might be achieved by introducing more diversity into recommendations; recommending items that are similar to those a user is currently or has previously viewed on some dimensions, but different on others. Currently, if a user searches for a 'Lonely Planet' travel guide for a particular country on Amazon, recommendations only feature other Lonely Planet guides. A greater diversity of recommendation types might see recommendations for different brands of guide for the same country, Lonely Planet city guides for cities within that country or Lonely Planet guides for neighboring countries.

Digital libraries might move beyond recommending academic articles by the same author, published in the same journal or on similar topics to ones currently viewed. Instead, they might recommend articles from different disciplines that cite common articles to the article currently being viewed or articles on a similar topic written by people who have previously co-authored with the author of the article currently being viewed. These new types of recommendation should focus on helping users identify their own, seemingly unexpected, relationships between documents (just as participant DL13 did when reading an article on genome sequencing in plants when looking for information on the role of essential amino acids in humans).

Online news sites might move beyond recommending recent news on similar topics to also recommending content on topics that are only *somewhat* similar. For example, a user a news story on the 2014 Ebola outbreak in West Africa might not only be recommended more stories on Ebola (e.g. on its pathology, its spread across the world), but also stories on other major recent health outbreaks (e.g. Bird/Swine Flu, SARS). This would allow news recommendations to extend across topical boundaries (in a similar way to which participant ON5 found out about an upcoming film collaboration between actors he liked when watching a video game trailer).

Design implications beyond recommendation

As well as using direct observation as a springboard for making suggestions for improving existing serendipity-related functionality, observation also provides the opportunity for us to ask ‘how can we move beyond existing functionality?’ We might move beyond recommendation by supporting *information visualization* to assist users in making connections between information that is related across some dimensions, but not others. E-commerce sites might allow users to select ‘essential’ and ‘desirable’ facets of a product they are interested in and show them a Venn diagram to illustrate available products that match all specified facets, or all the essential and some of the desirable facets. For example, a user might want to find a suit in a particular size, fit and price range (essential facets), but be open to different styles, colors or brands (desirable facets). Digital libraries might visually present connections between academic articles based on links that are ‘less obvious’ than topical similarity, such as method similarity or co-authorship/co-citation relationships. Just as books on similar topics can be shelved together in physical libraries, a digital bookshelf visualisation might present books that share these ‘less obvious’ links in close proximity. Online news sites might visually represent links between news articles which are only partly topically-related (e.g. a story on virtual currency Bitcoin and a story on the ‘Dark Web,’ where virtual currencies are used to provide anonymity to users who buy illegal products or services). This would allow users to make connections between content that they might not otherwise have made.

Implications for evaluation

As well as providing implications for design, being able to directly observe users coming across information serendipitously can also facilitate the *evaluation* of digital information environments; by observing users coming across information serendipitously in particular environments, we can see how well those environments create opportunities for it and propose design improvements. It can also allow us to reason about how we can support or better support serendipity in environments we design. Future work that focuses on the development and testing of serendipity-focused user evaluation methods is likely to help us systematize this process.

IMPLICATIONS FOR FUTURE RESEARCH

In the previous section, we discussed implications of our findings on the design and evaluation of digital information environments. We now reflect on what we have learned from conducting our study to provide advice for future researchers who wish to observe people coming across information serendipitously in controlled environments. Note that while we make no strong claims about the novelty of our approach (after all, naturalistic studies have been conducted to observe information behavior for decades), we are encouraged that this approach allowed us to observe people coming across information serendipitously where previous studies have, so far, have had limited success. Our advice comes in the form the following recommendations:

Ask participants to carry out naturalistic self-chosen information tasks. Participants should be encouraged to look for information on either specific or general topics. This is likely to provide them with the opportunity to either unexpectedly find useful information on one topic while looking for information on an unrelated or partly-related topic or unexpectedly find useful information when they only have a vague idea of what they are looking for.

Allow participants to choose which digital information environments to use. This is likely to expose them to more opportunities for coming across information serendipitously (as different environments are likely to support searching, browsing and recommendation in different ways). However, if the purpose of the study is to understand whether and how a particular digital information environment creates opportunities for serendipity, restricting use to a specific environment is recommended.

Do not prime participants that the purpose of the study is to observe serendipity as this might bias their interactive behaviour or responses to questions. Instead, inform them at the outset that the study’s purpose is to observe how they interact with digital information environments and inform them at the end of the study that a particular focus is on observing coming across information serendipitously (i.e. coming across useful information unexpectedly when looking for information on a different topic or when looking for information without a particular aim in mind).

Ask participants to think-aloud while using digital information environments. Verbalising what they are doing and why can be useful in understanding their interaction behaviour and rationale. Keep interventions to a minimum during the observation, restricting them mostly to asking participants ‘what are you doing now?’ if they forget to or stop thinking aloud and ‘what did you just do (and why)?’ to better understand their interactive behaviour. Avoid interventions when participants are reading. Record the screen and audio of the observation to aid analysis.

Ask participants why they saved each bookmark in a wrap-up interview. This allows the researcher to probe the participants’ ‘useful and unexpected’ examples in more detail. A suitable question to understand their bookmarking

rationale might be ‘why do you consider this an example of finding useful information unexpectedly?’

Ask questions to understand the task context surrounding each of the bookmarks. Although it is possible to understand participants’ information tasks by reviewing screen recordings of their interactions, it is also possible to ask questions to understand the task context surrounding each bookmark. Although we did not ask such questions in our study, in hindsight we think this may have been useful. We suggest asking questions aimed at ascertaining the participant’s information task for each bookmark (e.g. ‘were you looking for any information in particular when you found this? If so, what?’). If the participant states they were looking for particular information, we suggest asking further questions to better understand how the information they found relates to the information they were looking for; for example ‘do you consider this an example of looking for information on one topic and finding information on another? Why?’ and ‘how related do you think the information you found is to the topic you were looking for information on? Why?’

CONCLUSION

As serendipity involves some unexpectedness, it cannot be created on demand. This makes it difficult to observe in controlled research environments. However we have demonstrated that, with a carefully-considered approach, it is possible. While this approach is not novel, we found it to be effective for observing serendipity and we invite other researchers to adopt and adapt it for their observations.

Directly observing information encountering behaviour (rather than relying on self-reported data) allows designers of digital information environments to better understand this behaviour. They can then feed this enriched understanding into the design of new and improvement of existing functionality for supporting serendipity. Being able to directly observe users coming across information serendipitously can also facilitate the *evaluation* of digital information environments; it has the potential to allow designers to check whether environments they *think* create opportunities for serendipity actually do.

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