Examination of relationships among serendipity, the environment, and individual differences

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Abstract
Under what conditions is serendipity most likely to occur? How much is serendipity influenced by what a person brings to the process, and how much by the environment in which the person is immersed? This study assessed a) selected human characteristics that may influence the ability to experience serendipity (openness to experience, extraversion, and locus of control), and b) selected perceptions of the environment in which people are immersed, including the creative environment, and selected characteristics (trigger rich, highlights triggers, enables connections, and leads to the unexpected). Finally, the study examined the relationships among these internal and external variables. Professionals, academics, and students engaged in thesis work (N=289) responded to a web-based questionnaire that integrated six scales to measure these variables. Results were analysed using principal components analysis, multivariate analysis of variance, and multiple regression. We found some types of digital environments, (e.g., websites, databases, search engines, intranets, social media sites) may be more conducive to serendipity than others, while environments that manifest selected characteristics (trigger-rich, enable connections, and lead to the unexpected) are perceived more likely to foster serendipity than others. However, the perceived level of creativity expected in work environments was not associated with serendipity. In addition, while extraverted people may be more likely to experience serendipity in general, those who are open to experience or have an external locus of control are no more likely to experience serendipity than their counterparts. Notable from our findings was a failure in identifying individual differences that may influence a person’s likelihood to experience serendipity, in contrast with our success in identifying how the environment in which the user is immersed may create a fertile environment for serendipity to occur.

Keywords
Serendipity; scale development; digital environments; individual differences

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1. Introduction

Serendipity is often associated with luck, accident, and chance. But it is more than that – it is an experience marked by an interruption or discontinuity triggered by ideas, information, or phenomena that stops us in our tracks and prompts us to make connections that may have personal, organizational, community, or global outcomes (McCay-Peet & Toms, in press). Despite serendipity’s association with events outside our control, it is serendipity’s positive impact that motivates people and organizations to find ways to nurture and facilitate it.

In her Rice Centennial Lecture, Shirley Ann Jackson, President of New York’s Rensselaer Polytechnic Institute, argued that funding basic research spurs serendipity and thus innovation “because without [serendipity], there is no vitality in the innovation ecosystem. Indeed, there is no innovation” (Jackson, 2012, n.p.). While Jackson suggested that basic research facilitates serendipity, companies such as Google design buildings and rearrange furniture to maximize the potential for serendipitous encounters among co-workers (Lindsay, 2013), and developers create mechanisms such as recommender systems to support serendipity for users in digital environments (Shani & Gunawardana, 2011). But despite a push to support serendipity and understand how it may be influenced (see for example, Makri et al., 2014), we know very little about how the complex relationships among the traits and abilities of individuals and the environments in which they are immersed may lead to serendipity. Thus, we are blind to how we may facilitate serendipity through policy, education, or systems design.

The purpose of our research is to examine whether selected characteristics of people, i.e., individual differences, and selected characteristics of environments influence likelihood of serendipity to occur, and whether some combination of the two interact to lead to serendipity. Before we can examine these relationships, we first need to develop a way to measure perception of serendipity and a way to assess whether an environment in which the user is immersed has the potential to facilitate serendipity. A perception of serendipity scale and a serendipitous digital environment scale were first developed so that relationships among serendipity, the environment, and the individual could be explored. Measuring an abstract, subjective construct such as serendipity is a difficult task. People have different notions of what serendipity means and what experiences they would describe as serendipitous (McCay-Peet & Toms, in press). However, the lack of tools to measure serendipity hampers the ability to improve research policy, educational strategies, and digital environments. Without tools to measure serendipity, for example, we are unable to verify whether changes to the interface or algorithms of a digital environment supports or hinders serendipity.

2. Prior Research

We define serendipity as an unexpected experience prompted by an individual’s valuable interaction with ideas, information, objects, or phenomena. In a study of how twelve scholars and working professionals experienced serendipity, a serendipitous experience was identified as a process consisting of five main elements: trigger, connection, follow-up, valuable outcome, and unexpected thread. Driving this process are the internal and external factors that are hypothesized to influence both the process and perception of serendipity (McCay-Peet & Toms, in press). Erdelez’s (2005) model of an information encountering (IE) episode, often cited in the serendipity literature, is “an instance of accidental discovery of information during an active search for some other information” (p. 180) that illustrates the beginning of a potentially serendipitous experience, encompassing aspects of the trigger, connection, and follow-up.
Our definition of serendipity and its complementary model (McCay-Peet & Toms, in press) share many of the features of previous definitions and discussions of serendipity in its emphasis on the unexpected and positive aspects of the phenomenon as well as the interaction that takes place between the individual and the environment that drives the experience. Merton, for example, postulated chance favours “those at work in microenvironments that make for unanticipated sociocognitive interactions between those [with] prepared minds;” what he referred to as the “serendipitous sociocognitive microenvironment” (Merton & Barber, 2004, p. 259-260). Serendipity has also been defined as “the interactive outcome of unique and contingent ‘mixes’ of insight coupled with chance” (1996, p. 434), suggesting internal and external factors are at play. The main elements of serendipity have similarly been described as “a mix of unexpectedness and insight [that lead] to a valuable, unanticipated outcome” (Makri & Blandford, 2012a, p. 684). McBirnie and Urquhart (2011) noted that their “accepted understanding of the phenomenon requires the internal (e.g., the prepared mind) and the external (e.g., outside context and events) to come together in the right way, with neither on its own considered enough for the classification of an experience as serendipity” (np). Each of these definitions and extrapolations extend the more basic notion of serendipity as an aptitude or a happy accident, embedding within them how and why serendipity unfolds.

Interactions between individuals and their environments appear to be important for serendipity to occur but how can we deconstruct this? That is, what characteristics of the environment (external factors) and the individual (internal factors) may facilitate and influence serendipity?

**Environment.**

This research focuses in particular on the more stable characteristics of the individual’s environment rather than situational factors such as time pressures and information strategies, which are discussed elsewhere (e.g., Makri et al., 2014; McBirnie, 2008; Sun et al., 2011). We sought to understand what it is about digital environments that might facilitate serendipity, recognizing that people do not interact with digital environments in a vacuum and experiences with their broader work environment may exert an influence on experiences of and perception of digital environments.

While we know of no research that has tested whether the type of environment, digital or physical, influences the likelihood of experiencing serendipity, research does suggest that some environments are more likely to support serendipity than others (e.g., Björneborn, 2008; Toms, 1997). Settings more conducive to serendipity include those designed to deliver information such as libraries, lecture rooms, as well as unfamiliar environments where new information can be found (Sun et al., 2011). Equally, some features and functions of digital environments may be more conducive to serendipity than others. Toms (1997) found in her experimental study of 47 adults that navigational mechanisms in a digital newspaper to support browsing also supported serendipity by exposing users to useful news stories they did not intend to find. Björneborn (2008) examined the characteristics of the physical library space that lead to divergent behaviour. The information behaviours of patrons in two public libraries were observed over several months. A number of these patrons (N=118) were interviewed while eleven further participated in think-aloud sessions. Björneborn identified ten ‘serendipity dimensions’ of the physical library, for example: diversity of resources, activities, and physical spaces; curiosity-invoking displays of resources; imperfections in the library interfaces (e.g., misshelved resources); and explorability (i.e., users are encouraged to move around the library). While the research stops short of verifying whether the divergent behaviour prompted by the environment led to serendipity, the dimensions are significant, shedding light on environmental features that have the potential to support serendipity.
Based on an investigative study of serendipity involving semi-structured interviews with twelve scholars and working professionals who shared specific experiences of work-related serendipity as well as prior research (e.g., Björneborn, 2008), McCay-Peet and Toms (in press) identified four main external or environmental factors that may facilitate the process of serendipity – an environment that is trigger-rich, highlights triggers, enables connections, and enables capturing. McCay-Peet et al. (2014) reexamined these four facets through a digital lens, proposed five facets of a potentially serendipitous digital environment, and developed a self-report questionnaire to measure how well a digital environment supports serendipity. The content validity of the scale was tested and content subsequently refined through an expert review by eight researchers experienced in serendipity-related research and further tested and refined using a web-based questionnaire in which 107 university students rated how well the items reflected each facet’s meaning. The five facets are defined below: enables exploration, trigger-rich, highlights triggers, enables connections, and leads to the unexpected (McCay-Peet et al., 2014).

1. Enables exploration: the degree to which a digital environment supports exploration and examination of its information, ideas, or resources.

Digital environments that enable exploration provide individuals with opportunities to bump into information and ideas they may not have otherwise found through mechanisms that, for example, allow users to browse content (Toms, 1997). The digital environment that enables exploration supports unimpeded and direct access, stopability, explorability, and multi-reachability (Björneborn, 2008).

2. Trigger-rich: the degree to which a digital environment contains a variety of information, ideas, or resources that is interesting and useful to the user.

Trigger is one of the main elements of the process of serendipity (McCay-Peet & Toms, in press). A trigger is a verbal, textual, or visual cue that initiates or sparks an individual’s experience of serendipity. In digital environments, the information encountered must be interesting and useful to have the potential to be serendipitous. It must contain triggers. Just as “browsing depends on the ability of a piece of text to be recognized and examined” (Toms, 2000, p.424), its textual affordances perceived, serendipity is reliant on an individuals’ interaction with text that can act as triggers of serendipity due to relationships to their own interests or needs, or what have been referred to as a person’s interest space or problem (Björneborn, 2008; Sun, et al., 2011; Toms, 1997).

3. Highlights triggers: the degree to which a digital environment brings interesting and useful information, ideas, or resources to the user’s attention.

Face-to-face communication, visual saliency, noise, and emotion highlight triggers, bringing our focus of attention to information, ideas, or phenomenon we may not have otherwise noticed (McCay-Peet & Toms, in press). Our visual attention, for example, is known to be guided by size, colour, motion, and orientation (Wolfe & Horowitz, 2004); therefore, applying these attributes to potential serendipitous triggers may help ensure they are noticed. Highlighting triggers through curiosity-invoking displays, striking contrasts, and pointers (Björneborn, 2008) has been found to prompt divergent behaviour in physical libraries and thus may also prompt serendipity. With this rationale, Max, a web-based system that emails users links to websites with unexpected and interesting information (Campos & Figueiredo, 2002), and Mitsikeru, an ambient intelligence
system that calls attention to interesting or surprising content (webpage links) relative to the user through visual cues (Beale, 2007), were both developed to support serendipity.

4. Enables connections: the degree to which a digital environment makes relationships or connections between information, ideas, or resources apparent.

Connections is another main element of the process of serendipity; the recognition of a relationship between the trigger and the individual’s knowledge and experience (McCay-Peet & Toms, in press). A serendipitous digital environment enables connections, something that may be possible through visualization tools (e.g., Thudt et al., 2012) or social media sites that connect people to other people with interesting ideas and information.

5. Leads to the unexpected: the degree to which a digital environment provides opportunities for unexpected interactions with information, ideas, or resources.

Unexpected thread is an important element of the process of serendipity; the unexpected, chance, accidental, or surprising element that is evident in one or more of the trigger, connection, follow-up, or valuable outcome elements of the serendipitous experience (McCay-Peet & Toms, in press). Therefore, an environment that is capable of leading to the unexpected may increase opportunities for serendipity. In physical environments, this may take the form of imperfections such as misshelved books in libraries (Björneborn, 2008). In digital environments, it may relate to the content encountered or how it was encountered; for example, an idea for a work project gleaned from a social media site primarily used for connecting with friends and family.

These five facets characterize user expectation about what a serendipitous digital environment might facilitate. But, there is also research that suggests a connection between serendipity and one’s creative environment or characteristics of the environment that support a person’s creativity. There are many areas of convergence between creativity and serendipity research. Creativity, like serendipity, has been linked to environmental conditions (Mayfield & Mayfield, 2008). For example, one broad definition of creativity includes the environment: creativity is “a combination of interacting individual and environmental resources leading to the production of valuable solutions” (Mouchiroud & Bernoussi, 2008). The theme of flexibility in the creative environment research (e.g., Mayfield & Mayfield, 2008; Mouchiroud & Bernoussi, 2008) finds a conceptual parallel with divergence in the serendipity research (e.g., Björneborn, 2008; Heinström, 2006). With the right environmental conditions, an individual’s creative output may be enhanced leading to the creation of new products and ideas (Oldham & Cummings, 1996) or creative solutions to social problems (Mouchiroud & Bernoussi, 2008). Despite the potential for a creative work environment to support serendipity, no research to date has explored the relationship between the creative work environment and serendipity. Moreover, while many believe that, like creativity, support for serendipity is possible through education, practice, and tools, we know little of the relationships between the environment and serendipity.

Individual differences.

While the environment in which an individual is immersed is one part of the equation of serendipity, individual differences is another. It was not possible to explore all of the individual differences that might influence why one person has a propensity to have serendipitous experiences, while another does not. Therefore, we selected three individual differences that may be influential identified through prior research (e.g., Heinström, 2006; McCay-Peet & Toms, in press) that may be influential: openness to experience, extraversion, and locus of control.
At face value, openness to experience and extraversion, two of the Big Five personality traits (McCrae & Oliver, 1992), appear central to serendipity. Lexical studies of personality structure commonly describe those open to experience as “intellectual, creative, unconventional, innovative, [and] ironic” while extraversion is associated with people who are “outgoing, lively, extraverted, sociable, talkative, cheerful, [and] active” (Ashton & Lee, 2007, p. 154). Findings from serendipity-related research often point to these qualities and behaviours of individuals. For example, Dantonio et al. (2012) found in interviews with 15 postgraduates that spending both time and energy creating, sharing, and exploring social media content and making an effort to engage in conversations on social media sites had the potential to lead to more opportunity for serendipity. As noted earlier, the creative environment may play a key role in serendipity, but it has also been posited that creative imagination is a necessary component of serendipity in science; scientists must not only draw upon their knowledge and experience (prepared mind) but also their ingenuity and creativity to provide an explanation for unexpected observations (Barber & Fox, 1958).

In research on students’ incidental information acquisition (IIA) (Heinström, 2006), two studies (N=305 masters’ students; N=27 library and information science students) in which the NEO Personality Inventory (Costa & McCrae, 1992) was administered found a significant relationship between extraversion and incidental information acquisition (IIA) – “acquiring (useful or interesting) information while not consciously looking for it” (Heinström, 2006, p. 580), but not between openness to experience and IIA. More empirical research is required to support these findings and explore their complexities. McCrae (1987), for example, was careful to point out that while research indicates a relationship between openness to experience and divergent thinking, practice over time or incentives may lead those with relatively low openness scores to do equally well on divergent thinking tasks as open individuals. Perhaps incentives can make us behave in an extraverted and open manner that may otherwise be out of character, increasing opportunities for serendipity by changing the quality and frequency of our interactions with information, ideas, and phenomenon.

Serendipity is tightly associated with accident, luck, chance (Fine & Deegan, 1996) and its perception tied to a lack of control (Rubin et al., 2011). Consequently, the notion of trying to exert control over serendipity or facilitate it through the development of strategies (Makri et al., 2014) or the design of digital environments (André et al., 2009) is somewhat paradoxical (see McBirnie, 2008). But some individuals appear able to reconcile control and lack of control in the context of serendipity, attributing their serendipitous experiences to both “luck and choice” or “chance and preparation,” for example (McCay-Peet & Toms, in press). However, locus of control exists on a continuum between internal and external and is defined as “the degree to which an individual sees himself in control of his life and the events that influence it” (Locus of control, n.d.). Therefore, some people may be more likely to attribute stumbling upon a new research idea to chance rather than preparation and knowledge in their field or a great job offer to luck rather than the series of life choices and hard work that led up to the opportunity. Many factors have the potential to influence locus of control making it a challenging construct to examine. This challenge is evident in conflicting research findings in which individuals with an internal locus of control perceived their career paths were less influenced by chance events than those with an external locus of control in one study (Bright et al., 2005) while a later study (Bright et al., 2009) found no such relationship.

In summary, while prior research suggests that both external and internal factors may influence serendipity and its perception, no research has empirically examined how different digital environments and their characteristics may facilitate serendipity. Likewise, while some prior research examined relationships between personality traits and concepts related to serendipity
(e.g., chance events, incidental information acquisition), no research has investigated the influence of personality on the perception of serendipity in digital environments.

3. Research Design

Using a web-based survey, multiple questionnaires relating to the individual and the environment were administered to 289 professionals, academics, and graduate students. Our survey was designed to meet our main research objective:

To test whether the type of digital environment and selected characteristics of the individual, the work environment, and the digital environment have the potential to facilitate or influence serendipity.

To this end, several previously developed questionnaires were selected to measure individual differences and the work environment:

- locus of control of behaviour (Craig et al., 1984),
- openness to experience (Lee & Ashton, 2004),
- extraversion (Lee & Ashton, 2004), and
- creative environment perceptions (Mayfield & Mayfield, 2010)

But how can we reach our research objective without instruments to measure serendipity? Without tools to measure the perception of serendipity and the serendipitous digital environment, three main problems persist:

1. Comparisons across digital environments are limited.
2. Examining the potential interactions between the individual and their environment is problematic.
3. Heuristics for the development of serendipitous digital environments are hit and miss.

We met the challenge of a lack of measures through the development of self-report questionnaires for the purposes of this research.

The serendipitous digital environment scale (McCay-Peet, Toms, & Kelloway, 2014), which was in the process of development and refined through research reported here, was used to both help further its development (see section 7) and test relationships among serendipity, the environment, and individual differences. The serendipitous digital environment scale followed scale development procedures (e.g., DeVellis, 2003) and was designed to assess the degree to which a particular digital environment has facets or characteristics that foster serendipity: 1) enables explorations, 2) trigger-rich, 3) highlights triggers, 4) enables connections, and 5) leads to the unexpected.

In addition, we needed a measure of serendipity itself. A perception of serendipity scale was developed for the purposes of this study to assess how frequently individuals perceive they experience serendipity at three levels: in a specific digital environment, digital environments in general, and in general (see section 4.1.1). Through the development of a tool to measure how frequently individuals perceive they experience serendipity – a global or direct measure of serendipity – we could then explore what variables may fuel these perceptions. Moreover, the perception of serendipity scale gave us the tool needed to test the construct validity of the serendipitous digital environment scale (McCay-Peet, Toms, & Kelloway, 2014). While research supports the inclusion of five facets in the serendipitous digital environment scale and some current approaches to facilitate serendipity reflect these facets, research is needed to validate whether digital environments that better embody them are more likely to support serendipity than those that do not.
The inclusion of the instruments described above allowed for the exploration of the relationships among factors including types of digital environment (e.g., social media versus databases). Three main research questions (RQs) guided our research:

**RQ1 How does the type of digital environment an individual uses influence serendipity?**

For example, do people experience serendipity more frequently in social media sites than databases?

**RQ2 How does the type of digital environment influence a user’s perceptions of its characteristics?**

In other words, are certain types of digital environments like databases more closely associated with characteristics such as leading to the unexpected or enabling connections than search engines?

**RQ3 What relationships exist among the perception of serendipity and the underlying facets of a serendipitous digital environment, creative environment perceptions, locus of control, openness to experience, and extraversion?**

Several hypotheses relating to these RQs were generated and are described in section 8. Principal components analysis (PCA), multiple regression, and multiple analysis of variance (MANOVA) were used to analyze the data.

### 4. Methodology

#### 4.1 Study Variables

An overview of the twelve study variables including origin, definition, and composition are outlined in Table 1. Study variables are bolded for clarity. The following sections describe the five types of variables outlined in Table 1: perception of serendipity, serendipitous digital environment, type of digital environment, work environment, and individual differences. Because the perception of serendipity and serendipitous digital environment variables were developed specifically for this research, their origin is described in more detail than the others.

<table>
<thead>
<tr>
<th>Measure of</th>
<th>Variable (origin)</th>
<th>Definition</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Perception of serendipity</td>
<td>Serendipity-Specific DE (section 6)</td>
<td>A user’s perception of how frequently serendipity occurs in the specific digital environment they selected to assess.</td>
<td>Mean ratings of 4 items</td>
</tr>
<tr>
<td></td>
<td>Serendipity-DEs (section 6)</td>
<td>A user’s perception of how frequently serendipity occurs in digital environments in general.</td>
<td>Mean ratings of 4 items</td>
</tr>
<tr>
<td></td>
<td>Serendipity-General (section 6)</td>
<td>A user’s perception of how frequently serendipity occurs in general.</td>
<td>Mean ratings of 3 items (reduced from 4 items, see section 5)</td>
</tr>
<tr>
<td>B. Serendipitous digital environment (reduced from five to four facets during principal components)</td>
<td>SDE-Enables Connections (McCay-Peet et al., 2014; section 7)</td>
<td>A user’s assessment of the degree to which a digital environment makes relationships or connections between information, ideas, or resources apparent.</td>
<td>Mean ratings of 3 items (reduced from 7 items, see section 7)</td>
</tr>
<tr>
<td></td>
<td>SDE-Highlights Triggers (McCay-</td>
<td>A user’s assessment of the degree to which a digital environment brings interesting and useful</td>
<td>Mean ratings of 4 items (reduced</td>
</tr>
<tr>
<td>Measure of analysis, section 7</td>
<td>Variable (origin)</td>
<td>Definition</td>
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<td></td>
<td>Peet et al., 2014; section 7</td>
<td>information, ideas, or resources to the user's attention.</td>
<td>from 9 items, see section 7</td>
</tr>
<tr>
<td>SDE-Leads to the Unexpected (McCay-Peet et al., 2014; section 7)</td>
<td>A user’s assessment of the degree to which a digital environment provides opportunities for unexpected interactions with information, ideas, or resources</td>
<td>Mean ratings of 5 items (reduced from 7 items, see section 7)</td>
<td></td>
</tr>
<tr>
<td>SDE-Trigger-Rich (McCay-Peet et al., 2014; section 7)</td>
<td>A user’s assessment of the degree to which a digital environment contains a variety of information, ideas, or resources that is interesting and useful to the user.</td>
<td>Mean ratings of 3 items (reduced from 7 items, see section 7)</td>
<td></td>
</tr>
</tbody>
</table>

C. Type of digital environment

| DE Type (Content analysis of digital environments selected by participants; see section 5, Table 3) | Type of digital environment. |
| Website |
| Intranet |
| Database |
| Search engine |
| Social media |

D. Work environment

| Creative Environment Perceptions (Mayfield & Mayfield, 2010) | A person’s perceptions of the level of creativity in their working environment. |
| Mean ratings of 9 items* |

E. Individual differences

| Locus of Control of Behaviour (Craig et al., 1984) | The extent to which a person perceives that events are influenced by their own behaviour or, conversely, by something external to them (e.g., by chance, other people, outside actions, or events). |
| Mean ratings of 17 items* |
| Openness to Experience (Lee & Ashton, 2004) | A person’s perceptions of their aesthetic appreciation, inquisitiveness, creativity, and unconventionality. |
| Mean ratings of 16 items* |
| Extraversion (Lee & Ashton, 2004) | A person’s perceptions of their expressiveness, social boldness, sociability, and liveliness. |
| Mean ratings of 16 items* |

Note. *Mean substitution, described in section 4, was used to compute variables in cases of missing data.

4.1.1 Perception of Serendipity

Three variables measuring the perception of serendipity were developed (see Table 1, Row A). Prior research has designed direct measures of serendipity-related constructs to assess participants’ experience with information encountering (Erdelez, 1995; Pálsdóttir, 2010), incidental information acquisition (IIA) (Heinström, 2006), and incidental online news exposure (Tewksbury et al., 2001). Administered via interview or questionnaire, questions posed to participants in these previous studies have varied depending on the intent of the research. For example, some questions focused on the particular type of information encountered such as news or health; others were broader, specifying useful information while others focused on where the experience occurs or type of resources used, and still others were more general in nature and did not reference a particular topic or environment. For the purposes of our research, we developed three scales, each containing a set of statements designed to be direct measures of how frequently individuals perceive they experience serendipity

1) in a specific digital environment;
2) in digital environments in general; and
3) in general (no specific environment).

The three scales can be thought of as measuring nested levels of the perception of serendipity (Figure 1), differing in specificity grounded in the environment but each capturing the phenomenon of serendipity and thus related. The three levels capture the three ways in which discussions of serendipity are often framed today. Digital environments are pitted against environments in general (e.g., digital libraries versus physical libraries) and comparisons are
made between specific digital environments such as Twitter and Google, with one held up as superior to another (see, for example, Andrew, 2014)

![Figure 1 Nested levels of the perception of serendipity](image)

Each of the three scales contains four items. Responses to items are on a 5-point frequency scale (never, rarely, sometimes, frequently, very frequently; I don’t know). Item wording is retained across these three scales. For example, the first question indicated in each of the three scales in Table 2 includes the statement “I experience serendipity that has an impact on my everyday life.” However, the specific digital environment scale prefaces this statement with “In the digital environment I selected” (S-SpecificDE-1), the digital environments in general scale prefaces the statement with “In digital environments” (S-DEs-1), while the general sub-scale contains no preamble (S-Gen-1).

While two of the statements in each of the sub-scales outlined in Table 2 use the word serendipity, one refers to serendipity in everyday life and the other to work-related serendipity because boundaries between the two appear to be blurred (McCay-Peet & Toms, in press). The last two statements of each of the three subscales take a definitional approach, avoiding the use of the word serendipity to help cover the broad conceptual space of serendipity. One mirrors Erdelez’s (2005) definition of information encountering: “an instance of accidental discovery of information during an active search for some other information” (p. 180). The other was derived from Makri and Blandford’s (2012) main elements of serendipity identified “a mix of unexpectedness and insight [that lead] to a valuable, unanticipated outcome” (p. 684).

Following principal components analysis, the three scales were computed to three study variables: Serendipity-SpecificDE, Serendipity-DEs, and Serendipity-General. This analysis is described in section 6.
### 4.1.2 Serendipitous Digital Environment

Variables measuring the serendipitous digital environment were derived from a scale comprised of five facets developed in prior research (McCay-Peet, Toms, & Kelloway, 2014): enables exploration, enables connections, highlights triggers, trigger-rich, and leads to the unexpected (See Table 1, Row B). Their origins in prior research are described in section 1. The scale is comprised of items such as “I bump into unexpected content in it” (U1) and responses to items are on a 5-point agreement scale (strongly agree, disagree, neither agree nor disagree, agree, strongly agree; I don’t know). All items are listed in the Appendix. Following principal components analysis, four factors were extracted and computed to study variables: SDE-Enables Connections, SDE-Highlights Triggers, SDE-Trigger-Rich, and SDE-Leads to the Unexpected. This analysis is described in section 7.

#### 4.1.3 DE Type

The DE Type variable was derived from the specific digital environment each participant chose to assess: databases, social media, search engines, websites, or intranets. For example, one participant chose to select PubMed, which we subsequently categorized as a database. In this way, comparisons could be made among types of digital environments. This type of comparison would not have been possible to conduct among specific digital environments due to the sheer number of diverse digital environments selected, as exemplified in Table 3.
Table 3 Type of digital environments selected by participants with examples

<table>
<thead>
<tr>
<th>Digital environment type (DE Type)</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Databases:</strong> “a usually large collection of data organised especially for rapid search and retrieval (as by a computer)” (Database, n.d.)</td>
<td>“Pubmed”; “WorldCat”; “ACM digital library”; “My universities library website”</td>
</tr>
<tr>
<td><strong>Social media:</strong> “forms of electronic communication (as Web sites for social networking and microblogging) through which users create online communities to share information, ideas, personal messages, and other content (as videos)” (Social media, n.d.)</td>
<td>“Reddit”; “Google group listserv”; “Twitter”; “Moodle”; “Hootesuite”; “YouTube”; “LinkedIn; “Facebook”; “Digg”; “Quora question and answer site”</td>
</tr>
<tr>
<td><strong>Search engines:</strong> “computer software used to search data (as text or a database) for specified information; also: a site on the World Wide Web that uses such software to locate key words in other sites” (Search engines, n.d.)</td>
<td>“Google”; “Google Scholar”; “Moxilla Firefox”; “search engine”</td>
</tr>
<tr>
<td><strong>Websites:</strong> “a group of World Wide Web pages usually containing hyperlinks to each other and made available online by an individual, company, educational institution, government, or organization” (Web sites, n.d.)</td>
<td>“W3c.org”; “news websites”; “imbd.com”; “Government of Canada website”; “Wikipedia”; “EDUCAUSE website”; “Boing Boing Blog”</td>
</tr>
<tr>
<td><strong>Intranets:</strong> “a network operating like the World Wide Web but having access restricted to a limited group of authorised users (as employees of a company)” (Intranets, n.d.)</td>
<td>“My government Intranet”; “My organization’s intranet”; “Agency intranet”; “company intranet”</td>
</tr>
<tr>
<td><strong>Multiple:</strong> A variety of digital environments rather than one or indicated a general digital environment (e.g. the web) that contains a number of types of digital environments.</td>
<td>“ux websites, pinterest for examples, twitter, work hard drive”; “facebook, twitter, various organizations websites”; “the web generally”</td>
</tr>
<tr>
<td><strong>Unclear:</strong> Participant response was vague, ambiguous, or indecipherable.</td>
<td>“Company website”; “Ning”; “I”; “HY”; “website”</td>
</tr>
<tr>
<td><strong>Other:</strong> The digital environment did not fit into the main types of digital environments and did not have sufficient numbers to warrant their own category.</td>
<td>“digo”; “email”; “RSS Feeds (Google Reader)”</td>
</tr>
</tbody>
</table>

4.1.4 Work Environment
The **Creative Environment Perceptions** variable was derived from the creative environment perceptions scale (Mayfield & Mayfield, 2010). The scale captures peoples’ perceptions of the level of creativity in their working environment through responses to nine items including for example, “My supervisor encourages me to be creative” and “My organization encourages me to work creatively.” The questionnaire includes nine items with responses on a Likert scale of agreement (strongly disagree, disagree, neutral, agree, and strongly agree). The mean of the nine items was computed to create the **Creative Environment Perceptions** variable.

4.1.5 Individual Differences
**Locus of Control of Behaviour**: The locus of control of behaviour questionnaire (Craig et al., 1984) asks individuals to reflect on the extent to which they perceive that events are influenced by their own behaviour or, conversely, by something external to them through seventeen questionnaire items including as “A great deal of what happens to me is probably just a matter of chance” and “Everyone knows that luck or chance determine one’s future.” Responses are on a Likert scale of agreement (strongly agree, generally disagree, somewhat disagree, somewhat agree, generally agree, and strongly agree). The mean of the seventeen items was computed to create the **Locus of Control of Behaviour** variable.

**Openness to Experience**: Lee and Ashton’s (2004) openness to experience questionnaire asks individuals how much they agree with sixteen statements relating to a person’s perceptions of their aesthetic appreciation, inquisitiveness, creativity, and unconventionality such as “I enjoy looking at maps of different places” and “I would like a job that requires following a routine rather than being creative.” Responses are on a Likert scale of agreement (strongly disagree, disagree, neutral [neither agree nor disagree], agree, and strongly agree). The mean of the sixteen items was computed to create the **Openness to Experience** variable.
Extraversion: The extraversion questionnaire (Lee & Ashton, 2004) asks individuals how much they agree with sixteen questionnaire items relating to interpersonal behaviours that characterize their expressiveness, social boldness, sociability, and liveliness such as “In social situations, I’m usually the one who makes the first move” and “Most people are more upbeat and dynamic than I generally am.” Responses are on the same Likert scale of agreement as Openness to Experience. The mean of the sixteen items was computed to create the Extraversion variable.

4.2 Questionnaire

The questionnaire had the following components:

1. Introduction and consent.
2. Demographics questionnaire to gain a profile of the participants.
3. Participant’s selection of a specific digital environment to assess (see Table 3).
4. Serendipitous digital environment scale (see Appendix). For the purposes of this study, for each item we replaced “the digital environment” with “the digital environment I selected.” Responses to the 37 items are on a 5-point agreement scale (strongly agree, disagree, neither agree nor disagree, agree, strongly agree; I don’t know).
5. Perception of serendipity scale. Responses to the 12 items are on a 5-point frequency scale (never, rarely, sometimes, frequently, very frequently; I don’t know).
6. Environment and individual differences scales:
   • Creative environment perceptions (Mayfield & Mayfield, 2010): nine items on a five-point agreement scale (strongly disagree to strongly agree; not applicable) that measures individuals’ perceptions of the level of creativity in their working environment.
   • Openness to experience (Lee and Ashton, 2004): 16 items on a five-point scale (strongly disagree to strongly agree) that measures individuals’ perceptions of their own aesthetic appreciation, inquisitiveness, creativity, and unconventionality.
   • Extraversion (Lee and Ashton, 2004): 16 items on a five-point scale (strongly disagree to strongly agree) that measures individuals’ interpersonal behaviours that characterize their expressiveness, social boldness, sociability, and liveliness.
   • Locus of control of behaviour (Craig et al., 1984): 17 items on a six-point scale (strongly disagree to strongly agree) that measures individuals’ sense of control on a range between internal and external.
7. Option to provide email address to enter the prize draw, receive recruitment notices in the future, and receive a copy of the consent form.
8. Opportunity to comment on study.
9. Thank-you for participating.

For the full study instrument see McCay-Peet (2013, Appendix 5).

Two versions of the questionnaire were created, but were nearly identical. In both cases, participants selected a digital environment, but the questionnaires were designed to prompt participants to recall different kinds of digital environments. Several examples were provided to help participants in their selection.

What digital environment (e.g., intranet, website) comes to mind when you read the following statement?

[Questionnaire 1] I use this digital environment to find specific information or resources that are useful to my work or academic studies.
[Questionnaire 2] When I use this digital environment, I find information, ideas, or resources that are useful to my work or academic studies that I had not planned to find.
Please indicate the name of one digital environment that comes to mind in the space provided below. Examples: your organization's intranet, a government website, ACM digital library, Twitter social media site, CNN website, Digg social news website

The two different prompts were developed to ensure participants selected a variety of digital environments to evaluate. An adequate amount of variance is required for factor analysis. While the first was designed to prompt participants to recall digital environments in which they purposeful sought information, the second was designed to prompt participants to recall experiences with digital environments in which they came across information, ideas, or resources in a more serendipitous manner. Recognizing that serendipity is not limited to big-impact serendipity but encompasses a spectrum inclusive of “micro-serendipity” or “unplanned everyday incidents” (Bogers & Björneborn, 2013, p. 205), we used the phrase, “had not planned to find,” to help cover the range of serendipitous experiences.

4.3 Recruitment and Participants
Professionals and academics who frequently search for and monitor information relating to their work and graduate students engaged in thesis work were invited to participate. Participants were recruited via flyers handed out at an academic conference and on a university campus, through web-based forums, listservs, and social media, and by encouraging colleagues and participants to pass on the study link. As incentive, participants were given the opportunity to enter a draw for a chance to win one of twenty $20 online gift certificates.

Of the 289 participants (female=207, 71.6%), 151 (52.2%) completed Questionnaire 1 and 138 (47.8%) completed Questionnaire 2. Ages ranged primarily from 21 to 55 (N= 256, 88.6%). Most participants reported their highest level of education as Master’s (N=158, 54.7%), but many indicated undergraduate (N=61, 21.1%) or doctorate (N=41, 14.2%). Participants include both those employed (N=184, 63.7%) and students (N=102, 35.3%). The students’ (N=102) area of study ranged and included social sciences (N=35, 34.3%) or professions and applied sciences (N=30, 29.4%), though some were in formal sciences (N=11, 10.8%), humanities (N=8, 7.8%), and natural sciences (N=5, 4.9%). The employed (N=184) primarily indicated the broad category of social science, education, government service, and religion (N=99, 53.8%) best described their area of occupation, while 11.4% (N=21) selected management. Other categories such as sciences and art, culture, recreation, and sport accounted for less than 5% of occupations.

4.4 Procedure
The questionnaire was accessible via the web over a one-month period from February to March 2013. Participants were provided the survey URL via the paper- and web-based recruitment instruments. On access, each was randomly assigned to one of the two versions described above (Questionnaire 1 or 2).

The survey instrument used open source LimeSurvey software, and was hosted on a secure university server. Participants moved through the survey in the order indicated in section 4.2; however, the order in which participants were presented with the creative environment perceptions, openness to experience, extraversion, and locus of control of behaviour questionnaires was randomized to reduce order effects. Similarly, the items for those questionnaires as well as the serendipitous digital environment scale and the perception of serendipity scale were randomized to prevent order effects.

Data were downloaded and converted to SPSS and Microsoft Excel files for analysis. The emails collected for the prize draw, consent form, and future recruitment were downloaded without
participant ID numbers and saved to a separate Excel file. Random number software was used to select the prize draw winners and those who requested the consent form were emailed a copy.

5. Data Analysis
The data was first checked to ensure it was suitable for multivariate analysis. Of the original 353 participants, 289 remained after missing data and univariate and multivariate outliers were checked, using the following steps:

1) Reverse scoring: Questionnaires containing negative items were reverse scored.
2) Mean substitution: Means were computed for those participants who responded to at least 14 of the 16 openness to experience and extraversion, 15 of the 17 locus of control of behaviour, and seven of the nine creative environment perceptions items. Those not meeting their respective thresholds were recorded as missing data. Transformation to reduce the amount of missing data was not performed for the serendipitous digital environment or perception of serendipity scale data due to the study’s objective.
3) Univariate outliers: Two sets of data were removed due to careless responders.
4) Normality and linearity: Checked and found satisfactory.
5) Multivariate outliers: One multivariate outlier was identified. Analyses were run with and without this outlier. The outlier influenced the results and was thus removed.
6) Correlations: Correlations of 53 variables (37 serendipitous digital environment scale items, 12 perception of serendipity scale items, openness to experience, extraversion, locus of control of behaviour, and creative environment perceptions) were checked. S-Gen-1 of the perception of serendipity scale was removed due to high correlation with S-Gen-2 (see Table 2), though analyses were run with the same results both with and without this item.

In summary, 64 cases were removed due to two careless or inattentive responders, one multivariate outlier, and 61 cases with missing values. Missing values and responses of “I don’t know” or “not applicable” were dispersed evenly across the 53 variables with no variables containing more than 5% missing data, which is an indication that none of the items were problematic.

The free-text responses in which participants selected a specific digital environment to respond to the serendipitous digital environment scale were deductively coded as databases, social media, search engines, websites, or intranets to prepare this data for further analysis. Those digital environments that did not fit in the five main categories were coded “multiple,” “unclear,” or “other.” The definitions of digital environment types together with examples are contained in Table 3.

Once the data were prepared, data analysis unfolded as follows, which outlines the next three sections of the paper:

Section 6: Principal components analysis of the perception of serendipity data to identify variables for further analysis in section 8.

Section 7: Principal components analysis of the serendipitous digital environment data to identify variables for further analysis in section 8.

Section 8: MANOVA and multiple regression analysis of relationships among perception of serendipity (section 6), the serendipitous digital environment (section 7), work environment, and individual differences.
6. Identifying Perception of Serendipity Variables

Principal components analysis with varimax rotation and extraction based on eigenvalues was applied to the data drawn from the perception of serendipity scale (see Table 2). Three factors were extracted explaining 71.6% of the variance in a single iteration of exploratory factor analysis, a robust solution. All four items in the first factor were serendipity in Digital Environments in General items and explained 25.9% of the variance. All four items in the second factor were serendipity in a Specific Digital Environment items and explained 24.7% of the variance. Finally, all three items in the third factor were serendipity in General items and explained 21.0% of the variance. The communalities ($h^2$) were fairly high, ranging from .61 to .78. Results are shown in Table 4. Subscale reliability for all three was very good:

- Digital Environments in General = .88.
- Specific Digital Environment = .83.
- General = .83.

The mean of each of the three factors were computed to prepare them for use as dependent variables in Section 8 of this paper.

Summary

In a single iteration of exploratory factor analysis, the number of items of the perception of serendipity scale was maintained at eleven (a twelfth item was removed prior to this analysis in section 5 due to high correlation) and three factors were extracted explaining 71.6% of the total variance – a robust solution. All three factors had very good subscale reliability:

- Digital Environments in General.
- Specific Digital Environment.
- General.

These three factors were computed into variables for analysis and are henceforth referred to as **Serendipity-Specific DE, Serendipity-DEs**, and **Serendipity-General**. Variance in responses to the scale items, which made factor analysis possible, indicate that serendipity is not a phenomenon experienced by everyone with the same frequency. Further analyses (section 8.2.2) will help us understand what characteristics of the individual and the environment may influence these variances.
Table 4 Results of exploratory factor analysis for perception of serendipity scale items

<table>
<thead>
<tr>
<th>Item</th>
<th>Factors</th>
<th>$h^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>S-DEs2 In digital environments I experience serendipity that has an impact on my work.</td>
<td>.81</td>
<td>.27</td>
</tr>
<tr>
<td>S-DEs4 In digital environments I experience mixes of unexpectedness and insight that lead to valuable, unanticipated outcomes.</td>
<td>.81</td>
<td>.25</td>
</tr>
<tr>
<td>S-DEs1 In digital environments I experience serendipity that has an impact on my everyday life.</td>
<td>.80</td>
<td>.23</td>
</tr>
<tr>
<td>S-DEs3 I encounter useful information, ideas, or resources that I am not looking for when I use digital environments.</td>
<td>.79</td>
<td>.14</td>
</tr>
<tr>
<td>S-Spe4 In the digital environment I selected, I experience mixes of unexpectedness and insight that lead to valuable, unanticipated outcomes.</td>
<td>.21</td>
<td>.82</td>
</tr>
<tr>
<td>S-Spe2 In the digital environment I selected, I experience serendipity that has an impact on my work.</td>
<td>.22</td>
<td>.82</td>
</tr>
<tr>
<td>S-Spe3 I encounter useful information, ideas, or resources that I am not looking for when I use the digital environment I selected.</td>
<td>.16</td>
<td>.76</td>
</tr>
<tr>
<td>S-Spe1 In the digital environment I selected, I experience serendipity that has an impact on my everyday life.</td>
<td>.19</td>
<td>.75</td>
</tr>
<tr>
<td>S-Gen3 I encounter useful information, ideas, or resources that I am not looking for.</td>
<td>.18</td>
<td>-.04</td>
</tr>
<tr>
<td>S-Gen4 I experience mixes of unexpectedness and insight that lead to valuable, unanticipated outcomes.</td>
<td>.18</td>
<td>.08</td>
</tr>
<tr>
<td>S-Gen2 I experience serendipity that has an impact on my work.</td>
<td>.23</td>
<td>.15</td>
</tr>
<tr>
<td><strong>Eigenvalues</strong></td>
<td>2.85</td>
<td>2.72</td>
</tr>
<tr>
<td><strong>Percentage of variance</strong></td>
<td>25.9</td>
<td>24.7</td>
</tr>
</tbody>
</table>

Note. $N = 289$. Analysis: principal components, varimax rotation, and extraction based on eigenvalues. S-DEs = items developed to reflect perception of serendipity in digital environments in general; S-Spe = items developed to reflect perception of serendipity in a specific digital environment; S-Gen = items developed to reflect perception of serendipity in general; $h^2$ = communalities. Items with loadings > .63 are bolded.

7. Identifying Serendipitous Digital Environment Variables

The sets of seven to nine items for each of the five serendipitous digital environment facets (see list in Appendix) were each examined separately in SPSS 17.0 using principal components analysis with varimax rotation and extraction based on eigenvalues to reduce the items of each facet to more parsimonious sets. Items of the serendipitous digital environment scale are referred to in this paper by a single letter (E=Enables Exploration; H=Highlights Triggers; T=Trigger-Rich; C=Enables Connections; U=Leads to the Unexpected) and a number (e.g., H1, H2).

The four or five highest loading items per facet were retained for further analysis, which resulted in the total number of items being reduced from 37 to 24. Previous research (McCay-Peet et al., 2014) had been unable to deduce whether the Highlights Trigger and Trigger-Rich facets were confounded or simply correlated. In the current study, three of the four items (H1, H3, H5) containing qualifiers indicating the quality of the content (i.e., valuable, interests me, helps me) fell out during this preliminary iteration of factor analysis, confirming their potentially confounded relationship with Trigger-Rich items. With the exception of one item (H2), the remaining five Highlights Triggers items focus on the attentional aspects of the facet rather than the usefulness or helpfulness of the information contained in the digital environment, which was the intended primary function of the Trigger-Rich facet.
For factor analysis, Meyers et al. (2006) recommend a sample size to variables ratio of ten to one, though not below $N=200$. Therefore, a sample size of 289 was adequate to proceed with data analysis of the remaining 24 items.

To identify the most parsimonious set of items of the serendipitous digital environment scale and identify its factors without imposing a pre-conceived structure on the outcome, exploratory factor analysis using principal components, varimax rotation, and extraction based on eigenvalues was performed. Comrey and Lee (1992, in Tabachnick & Fidell, 2013) consider factor loadings greater than .71 excellent, .63 very good, .55 good, .45 fair, and .32 poor. Before analysis, we decided that items loading <.63 (low loading) would be removed from further analysis as well as items loading on more than one factor >.32 (cross loading). A solution is considered robust if it accounts for at least 50% of the total variance (Tabachnick and Fidell, 2013). Due to correlations among factors, both orthogonal (varimax) and oblique (oblimin) rotations were performed. Results were the same for both, therefore, only the results of the varimax rotation are reported here. Three iterations of analysis were conducted and results are summarized below.

**First iteration:** Five factors extracted. Total variance explained = 67.2%. Items reduced from 24 to 19. Items C8, H4, E1, E8 removed due to cross loading. T2 removed due to low loading.

**Second iteration:** Four factors extracted. Total variance explained = 65.3%. Items reduced from 19 to 15. Items E2, E9, C2 removed due to cross loading. E3 removed due to low loading.

**Third iteration:** Four factors extracted. Total variance explained = 70.6%. All 15 items retained.

All five items in the first factor were from the original Leads to the Unexpected facet (U1, U4, U5, U7, U2) and explained 23.4% of the variance. All four items of the second factor were from the original Highlights Triggers facet (H8, H10, H2, H9) and explained 18.1% of the variance. All three items from the third factor were from the original Enables Connections facet (C3, C1, C9) and explained 15.5% percent of the variance. Finally, all of three items of the fourth factor were from the original Trigger-Rich facet (T5, T6, T7) and explained 13.7% of the variance. None of the items from the original Enables Exploration facet remained. Results of the final iteration of exploratory factor analysis are shown in Table 5.

The communalities ($h^2$), the proportion of each item’s variance that can be explained by the factors, were fairly high, ranging from .62 to .79. Subscale reliability or internal consistency was assessed using Cronbach’s alpha and DeVellis’ (2003) guideline for interpreting alpha.

- Leads to the Unexpected = .89 (very good);
- Highlights Triggers = .83 (very good);
- Enables Connections = .86 (very good); and
- Trigger-Rich = .75 (respectable).

The mean of each of the four serendipitous digital environment factors were computed to prepare them for use as dependent variables.

**Summary**

With three iterations of exploratory factor analysis, the number of items of the serendipitous digital environment scale was reduced to fifteen items and four factors were extracted explaining 70.6% of the total variance. Enables Exploration, a proposed facet of the serendipitous digital environment (McCay-Peet, Toms, & Kelloway, 2014) did not emerge as a distinct factor. Enables
Exploration items appeared to share too much in common with more than one factor. The four factors that did emerge had good subscale reliability:

1. Leads to the Unexpected.
2. Highlights Triggers.
3. Enables Connections.

These four serendipitous digital environment (SDE) factors were computed into variables for further analysis and are henceforth referred to as SDE-Leads to the Unexpected, SDE-Highlights Triggers, SDE-Enables Connections, and SDE-Trigger-Rich.

Table 5 Results of exploratory factor analysis for serendipitous digital environment scale items

<table>
<thead>
<tr>
<th>Item</th>
<th>Factors</th>
<th>h²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>U1 I bump into unexpected content</td>
<td>.87</td>
<td>.09</td>
</tr>
<tr>
<td>U4 I come across content by chance</td>
<td>.82</td>
<td>.04</td>
</tr>
<tr>
<td>U5 I am exposed to unanticipated</td>
<td>.81</td>
<td>.08</td>
</tr>
<tr>
<td>U7 I stumble upon information</td>
<td>.81</td>
<td>.17</td>
</tr>
<tr>
<td>U2 I encounter the unexpected in</td>
<td>.78</td>
<td>.22</td>
</tr>
<tr>
<td>H8 It has features that draw my</td>
<td>.20</td>
<td>.80</td>
</tr>
<tr>
<td>attention to information.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H10 It has features that alert me</td>
<td>.14</td>
<td>.77</td>
</tr>
<tr>
<td>to information.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H2 It has features that ensure</td>
<td>.07</td>
<td>.77</td>
</tr>
<tr>
<td>that my attention is drawn to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>useful information.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H9 I am pointed toward content</td>
<td>.10</td>
<td>.75</td>
</tr>
<tr>
<td>C3 I can see connections between</td>
<td>.08</td>
<td>.23</td>
</tr>
<tr>
<td>topics in it.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1 It enables me to make</td>
<td>.17</td>
<td>.26</td>
</tr>
<tr>
<td>connections between ideas.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C9 I come to understand</td>
<td>.19</td>
<td>.19</td>
</tr>
<tr>
<td>relationships between ideas in it.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T5 It is full of information that</td>
<td>-.03</td>
<td>.03</td>
</tr>
<tr>
<td>is useful to me.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T6 I find information that is of</td>
<td>.16</td>
<td>.13</td>
</tr>
<tr>
<td>value to me in it.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T7 It is a treasure trove of</td>
<td>.11</td>
<td>.27</td>
</tr>
<tr>
<td>information.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. N = 289. Analysis: principal components, varimax rotation, and extraction based on eigenvalues. U=item from original Leads to the Unexpected facet; H=item from original Highlights Trigger facet; C=item from original Enables Connections facet; T=item from original Trigger-Rich facet; h² = communalities. Items with loadings > .63 are bolded.

8. Relationships among the Perception of Serendipity, Environment, and Individual Differences

This third analysis addressed the relationships among the three perception of serendipity variables (Serendipity-Specific DE, Serendipity-DEs, and Serendipity-General), the four serendipitous digital environment variables (SDE-Enables Connections, SDE-Highlights Triggers; SDE-Trigger-Rich; and SDE-Leads to the Unexpected), DE Type, Creative Environment Perceptions, Openness to Experience, Extraversion, and Locus of Control.

To explore relationships we developed the following five hypotheses relating to our three research questions.

RQ1 How does the type of digital environment an individual uses influence serendipity?

H1 The type of digital environment (DE Type) will influence how frequently people experience serendipity (Serendipity-Specific DE).
**RQ2** How does the type of digital environment influence a user's perceptions of its characteristics?

H$_2$ The type of digital environment (DE Type) will influence whether people perceive the digital environment enables connections, highlights triggers, is trigger rich, and leads to the unexpected (SDE-Enables Connections; SDE-Highlights Triggers; SDE-Trigger-Rich; and SDE-Leads to the Unexpected).

**RQ3** What relationships exist among the perception of serendipity and the underlying facets of a serendipitous digital environment, creative environment perceptions, locus of control, openness to experience, and extraversion?

H$_3$ How frequently people experience serendipity in a specific digital environment (Serendipity-Specific DE) is influenced by the creativity of their work environments, their locus of control, how open to experience and extraverted they are, and whether people perceive the specific digital environment enables connections, highlights triggers, is trigger rich, and lead to the unexpected (Creative Environment Perception; Locus of Control of Behaviour; Openness to Experience; Extraversion; SDE-Enables Connections; SDE-Highlights Triggers; SDE-Trigger-Rich; and SDE-Leads to the Unexpected).

H$_4$ How frequently people experience serendipity in digital environments in general (Serendipity-DEs) is influenced by the creativity of their work environments, their locus of control, and how open to experience and extraverted they are (Creative Environment Perception; Locus of Control of Behaviour; Openness to Experience; Extraversion).

H$_5$ How frequently people experience serendipity in general (Serendipity-General) is influenced by the creativity of their work environments, their locus of control, and how open to experience and extraverted they are (Creative Environment Perception; Locus of Control of Behaviour; Openness to Experience; Extraversion).

Data analysis examining relationships consisted of two main stages. The first stage was designed to test $H_1$ and $H_2$ using MANOVA with DE Type as the independent variable while the remaining study variables functioned as dependent variables. All study variables were included in the MANOVA though formal hypotheses were not developed for each variable. By performing analyses including all of the dependent variables, interrelations between the variables can be taken into account and a more complete picture of perceptions of digital environments may be captured.

The second stage of data analysis tested $H_3$, $H_4$, and $H_5$. Three separate multiple regression analyses were performed with Serendipity-Specific DE, Serendipity-DEs, and Serendipity-General as dependent variables while the four serendipitous digital environment variables, Creative Environment Perceptions, Openness to Experience, Extraversion, and Locus of Control as the independent variables.

### 8.1 Data Analysis

Descriptive statistics and correlations of the study variables are shown in Table 6.

The following section describes the results of the two main stages of data analysis:

**Stage 1:** MANOVA with DE Type as the independent variable and the study variables in Table 6 as the dependent variables. This analysis was designed to test $H_1$ and $H_2$.

**Stage 2:** Three separate multiple regression analyses with Serendipity-Specific DE, Serendipity-DEs, and Serendipity-General as the dependent variables and the remaining variables in Table 6 as the independent variables. This analysis was designed to test $H_3$, $H_4$, and $H_5$. 

20
Table 6 Descriptive statistics and correlations of study variables

<table>
<thead>
<tr>
<th></th>
<th>SDE-Leads to the Unexpected</th>
<th>SDE-Highlights Triggers</th>
<th>SDE-Enables Connections</th>
<th>SDE-Trigger-Rich</th>
<th>Serendipity-DEs</th>
<th>Serendipity-General</th>
<th>Creative Environment Perceptions</th>
<th>Openness to Experience</th>
<th>Extraversion</th>
<th>Locus of Control of Behaviour</th>
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<tbody>
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<td></td>
<td></td>
<td>3.63 (.66)</td>
<td>3.88 (.49)</td>
<td>3.47 (.59)</td>
<td>1.60 (.55)</td>
</tr>
<tr>
<td>2</td>
<td>M: 3.65 SD: .82</td>
<td>.33**</td>
<td>.38**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>3</td>
<td>M: 3.57 SD: .89</td>
<td>.32**</td>
<td>.34**</td>
<td>.50**</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
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</tr>
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<td>.64**</td>
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<td>.48**</td>
<td>.34**</td>
<td>3.68 (.76)</td>
<td>3.88 (.49)</td>
<td>3.47 (.59)</td>
<td>1.60 (.55)</td>
</tr>
<tr>
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<td>.15**</td>
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<td>8</td>
<td>M: 3.47 SD: .59</td>
<td>.14**</td>
<td>.01</td>
<td>.05**</td>
<td>.13**</td>
<td>.14**</td>
<td></td>
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<tr>
<td>9</td>
<td>M: 3.63 SD: .66</td>
<td>.06</td>
<td>.13**</td>
<td>.08**</td>
<td>.15**</td>
<td>.09**</td>
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<td>10</td>
<td>M: 3.40 SD: .68</td>
<td>.45**</td>
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<td>.08</td>
<td>.08**</td>
<td>1</td>
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</tr>
</tbody>
</table>

Note: N = 289. *p < .05; **p < .01 (two-tailed)

8.2 Results

We first examine the results of a MANOVA designed to test the hypotheses that the type of digital environment (e.g., website, search engine, database) will influence how frequently people experience serendipity (H₁) and influence whether people perceive a specific digital environment (e.g., PubMed, Twitter) enables connections, highlights triggers, is trigger rich, and leads to the unexpected (H₂). We then examine the results of three multiple regression analyses through which we test the remaining three hypotheses that how frequently the three levels of the perception of serendipity is influenced by the creativity of their work environments, their locus of control, how open to experience and extraverted they are (H₃, H₄, H₅) and how well a specific digital environment enables connections, highlights triggers, is trigger rich, and leads to the unexpected (H₆).

8.2.1 Assessing Effect of Type of DE on Perception of Serendipity in a Specific Digital Environment and the Serendipitous Digital Environment

RQ1 How does the type of digital environment an individual uses influence serendipity?

RQ2 How does the type of digital environment influence a user's perceptions of its characteristics?
To answer our first two research questions and test our hypotheses (H₁, H₂) that digital environment type matters, a multivariate analysis of variance (MANOVA) was performed with all study variables contained in Table 1. The independent variable was DE Type and the remaining eleven variables relating to serendipity, the environment and the individual were the dependent variables. Only those datasets (N=254; 87.9%) in which participants selected digital environments (DE Type) that fell into the five main types were analysed: databases (N=74, 26%), social media (N=69, 24%), search engines (N=48, 17%), websites (N=42, 15%) and intranets (N=21, 7%). Comparisons of digital environments in which the type was unclear (N=13, 4.5%), multiple digital environments spanning two or more of the main types of digital environments (N=15, 5.2%), and a handful of digital environments that did not fit into the five main categories (N=7, 2.4%) would not yield interpretable results and therefore were left out of this analysis. Effect sizes of partial $\eta^2$ were interpreted as small (.01), medium (.09), and large (.25) (Cohen, 1988).

Using Wilk’s criterion the composite dependent variate was significantly affected by DE Type, Wilk’s $\lambda$, $F[44, 916.31] = 3.62, p < .001$, partial $\eta^2 = .14$. Univariate ANOVAs were conducted on each variable separately to determine the cause for the significant multivariate, medium-sized effect. Five of the variables were significantly affected by DE Type. A medium effect size was found for

- Serendipity-Specific DE, $F(4, 249) = 11.47, p < .001$, partial $\eta^2 = .16$.
- SDE-Leads to the Unexpected, $F(4, 249) = 13.61, p < .001$, partial $\eta^2 = .18$.
- SDE-Trigger-Rich, $F(4, 249) = 6.14, p < .001$, partial $\eta^2 = .09$.

A small effect size was found for DE-Enables Connections, $F(4, 249) = 3.83, p < .01$, partial $\eta^2 = .06$. Though not hypothesised, a small effect size was also found for Openness to Experience, $F(4, 249) = 2.90, p < .05$, partial $\eta^2 = .04$.

Those variables with significant results are explored through posthoc results. Results of the MANOVA are displayed in Table 7. Table 8 contains the mean scores and standard deviations for the eleven dependent variables as a function of DE Type.
Table 7 Multivariate and univariate analysis of variance for the eleven dependent variables as a function of DE Type

<table>
<thead>
<tr>
<th>Source</th>
<th>Multivariate</th>
<th>Univariate</th>
<th>TRIGG</th>
<th>CONN</th>
<th>HIGH</th>
<th>UNEX</th>
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<tbody>
<tr>
<td>DE Type</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.62</td>
<td>6.14***</td>
<td>3.83**</td>
<td>1.16</td>
<td>13.61***</td>
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<tr>
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<table>
<thead>
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<th>Univariate</th>
<th>S-Spe</th>
<th>S-DEs</th>
<th>S-Gen</th>
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<tr>
<td>DE Type</td>
<td>F²</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>3.62</td>
<td>11.47***</td>
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<tr>
<td>MSE</td>
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<th>OPEN</th>
<th>CEP</th>
<th>LCB</th>
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<tr>
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<td></td>
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<td>.91</td>
<td>.39</td>
<td>.11</td>
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<tr>
<td>MSE</td>
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<td>.65</td>
<td>.38</td>
<td>.11</td>
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</tbody>
</table>

Note. N = 254. Multivariate F ratios were generated from Wilk’s criterion.

b. Univariate df = 4, 249

*p < .05; **p < .01; ***p < .001. (2-tailed)

TRIGG=SDE-Trigger-Rich; CONN=SDE-Enables Connections; HIGH=SDE-Highlights

Triggers; UNEX=SDE-Leads to the Unexpected; S-SPE=Serendipity-Specific DE; S-DEs=Serendipity-DEs; S-Gen=Serendipity-General; EXTRA=Extraversion; OPEN=Openness to Experience; CEP=Creative Environment Perceptions; LCB=Locus of Control of Behaviour.

Table 8 Mean scores and standard deviations for the eleven dependent variables as a function of DE Type

<table>
<thead>
<tr>
<th>DE Type</th>
<th>TRIGG</th>
<th>CONN</th>
<th>HIGH</th>
<th>UNEX</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
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<tr>
<td>Websites</td>
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<td>.46</td>
<td>3.92b</td>
<td>.75</td>
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<td>Intranets</td>
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<td>.65</td>
<td>3.14d</td>
<td>1.09</td>
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<tr>
<td>Databases</td>
<td>3.46c</td>
<td>.51</td>
<td>3.56</td>
<td>.81</td>
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<tr>
<td>Search engines</td>
<td>4.31</td>
<td>.60</td>
<td>3.33g</td>
<td>1.00</td>
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<td>Social media</td>
<td>4.12d</td>
<td>.69</td>
<td>3.57</td>
<td>.82</td>
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</table>

<table>
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<tbody>
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<td></td>
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<td>SD</td>
<td>M</td>
</tr>
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<td>3.59</td>
</tr>
<tr>
<td>Intranets</td>
<td>2.62a</td>
<td>.63</td>
<td>3.64</td>
</tr>
<tr>
<td>Databases</td>
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<td>3.60</td>
</tr>
<tr>
<td>Search engines</td>
<td>3.16d</td>
<td>.79</td>
<td>3.63</td>
</tr>
<tr>
<td>Social media</td>
<td>3.61l</td>
<td>.81</td>
<td>3.87</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>DE Type</th>
<th>EXTRA</th>
<th>OPEN</th>
<th>CEP</th>
<th>LCB</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Websites</td>
<td>3.50</td>
<td>.57</td>
<td>3.86</td>
<td>.50</td>
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<tr>
<td>Intranets</td>
<td>3.43</td>
<td>.47</td>
<td>3.61i</td>
<td>.56</td>
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<tr>
<td>Databases</td>
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<td>Social media</td>
<td>3.41</td>
<td>.66</td>
<td>3.99w</td>
<td>.45</td>
</tr>
</tbody>
</table>

Note. N = 254. Means with superscripted letters differed significantly at the .05 level (2-tailed) by means of Tukey HSD post hoc test.

Serendipity-Specific DE post hoc. DE Type shares a relationship with individuals’ perceptions of how frequently they experience serendipity in a specific digital environment. Serendipity-Specific DE was significantly higher for social media (M = 3.61, SD = .81) than for databases (M = 2.89, SD = .71), search engines (M = 3.16, SD = .79), and intranets (M = 2.62, SD = .63).
Serendipity-Specific DE was also significantly lower for intranets than websites ($M = 3.25, SD = .72$) and search engines.

**SDE-Leads to the Unexpected** post hoc. DE Type shares a relationship with individuals’ perceptions of how well a digital environment leads to the unexpected. Specifically, **SDE-Leads to the Unexpected** was significantly higher for social media ($M = 4.42, SD = .63$) than for intranets ($M = 3.47, SD = .70$), databases ($M = 3.62, SD = .72$), and search engines ($M = 3.82, SD = .85$). **SDE-Leads to the Unexpected** score for websites was also significantly higher than that for intranets and databases.

**SDE-Trigger-Rich** post hoc. DE Type shares a relationship with individuals’ perceptions of their environment as trigger-rich. **SDE-Trigger-Rich** was significantly higher for websites ($M = 4.48, SD = .46$) than intranets ($M = 3.94, SD = .65$) or social media ($M = 4.16, SD = .69$) and higher for databases ($M = 4.46, SD = .51$) than intranets or social media.

**SDE-Enables Connections** post hoc. DE Type shares a relationship with individuals’ perceptions of the ability of a digital environment to enable connections. **SDE-Enables Connections** was significantly higher for websites ($M = 3.92, SD = .75$) than for intranets ($M = 3.14, SD = 1.09$) and search engines ($M = 3.33, SD = 1.00$).

**Openness to Experience** post hoc. DE Type shares a relationship with **Openness to Experience**. Those assessing social media sites had significantly higher **Openness to Experience** scores ($M = 3.99, SD = .45$) than those assessing intranets ($M = 3.61, SD = .56$).

**Summary**

$H_1$ was confirmed while $H_2$ was partially confirmed. Results of the MANOVA indicated that some types of digital environments may be more conducive to serendipity than others ($H_3$) and ratings of three of the four proposed facets of a serendipitous digital environment vary by type of digital environment ($H_4$). These results suggest that common features and functions of these digital environments may underlie perception of serendipity. In other words, findings give credence to the belief that we can design digital environments to better support serendipity. Serendipity was perceived to occur more frequently in some digital environments than others – namely, in social media versus databases, search engines, or intranets and in websites and search engines versus intranets. Examining particular features and functions common to these digital environments may point to how we can design for serendipity. However, while there were differences in perceptions of how trigger-rich a digital environment is and how well it enables connections and leads to the unexpected across different types of digital environments, digital environments did not significantly differ in how well they are perceived to highlight or bring content to users’ attention. Given our high level of analysis and the myriad of differences that could exist between, for example, the various websites assessed (see Table 3), more research is needed to examine these perceptions. Moreover, while the findings are encouraging, more research is needed to confirm all of the findings of this MANOVA due to the relatively low number of participants ($N=21, 7\%$) who assessed intranets in particular. In addition, the finding that those who assessed a social media site had higher levels of openness to experience than those who selected intranets to assess was not anticipated. However, this result makes sense relative to prior research indicating people more open to experience are more likely to use social media (Amichai-Hamburger & Vinitzky, 2010) and thus perhaps more likely to select a social media site to assess for this study.
8.2.2 Testing Relationships among Serendipity, the Serendipitous Digital Environment, Work Environment, and Individual Differences

**RQ3** What relationships exist among the perception of serendipity and the underlying facets of a serendipitous digital environment, creative environment perceptions, locus of control, openness to experience, and extraversion?

To answer our final research question and test our hypotheses (H3, H4, and H5) that relationships do exist, three multiple regression analyses were performed using Serendipity-Specific DE, Serendipity-DEs, and Serendipity-General as the dependent variables and the variables relating to the serendipitous digital environment, work environment, and individual differences as the independent variables. The results are described below and outlined in Table 9. Effect sizes of $R^2$ were interpreted as small (.02), medium (.13), and large (.26) (Cohen, 1988).

Table 9 Three multiple regression results with Serendipity-Specific DE, Serendipity-DEs, and Serendipity-General as the dependent variables

<table>
<thead>
<tr>
<th></th>
<th>Serendipity-Specific DE</th>
<th>Serendipity-DEs</th>
<th>Serendipity-General</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>SE B</td>
<td>Beta</td>
</tr>
<tr>
<td>SDE-Leads to the Unexpected</td>
<td>.51</td>
<td>.05</td>
<td>.51***</td>
</tr>
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<td>SDE-Highlights Triggers</td>
<td>.08</td>
<td>.05</td>
<td>.09</td>
</tr>
<tr>
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<td>.20</td>
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<td>.17</td>
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<td>.13***</td>
</tr>
<tr>
<td>Creative Environment Perceptions</td>
<td>.05</td>
<td>.05</td>
<td>.05</td>
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<tr>
<td>Openness to Experience</td>
<td>.08</td>
<td>.07</td>
<td>.05</td>
</tr>
<tr>
<td>Extraversion</td>
<td>-.04</td>
<td>.06</td>
<td>-.03</td>
</tr>
<tr>
<td>Locus of Control of Behaviour</td>
<td>.13</td>
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<td>.09</td>
</tr>
<tr>
<td>$R^2$</td>
<td>.51***</td>
<td>.12***</td>
<td>.05***</td>
</tr>
</tbody>
</table>

Note. N = 289; *p < .05; **p < .01; ***p < .001

Serendipity in specific digital environments. H3, which examined relationships between serendipity in a specific digital environment (Serendipity-Specific DE) and environmental and individual differences variables was partially confirmed. We did find that perceptions of how frequently serendipity occurs in a specific digital environment such as Twitter or Google is influenced by peoples’ perceptions of how well it enables connections, highlights triggers, is trigger rich, and leads to the unexpected (SDE-Enables Connections, SDE-Trigger-Rich, SDE-Leads to the Unexpected). However, how well the digital environment highlighted triggers (SDE-Highlights Triggers) or brought information to people’s attention had no influence on the perceived serendipitousness of the digital environment. Creative Environment Perceptions, Openness to Experience, Extraversion, or Locus of Control of Behaviour also had no influence on perception of serendipity. The model’s variables, however, explain 51% of the
variance of how frequently serendipity occurs in the digital environment they selected, a large
effect size.

**Serendipity in digital environments in general.** \( H_4 \), which examined relationships between
perceptions of serendipity in digital environments in general and environmental and individual
differences variables was not confirmed. No relationships were found between participants’
perceptions of how frequently serendipity occurred and any of the hypothesized variables
(*Creative Environment Perceptions, Openness to Experience, Extraversion, or Locus of
Control of Behaviour*). Though not hypothesised, a relationship was found between
Serendipity-DEs and **SDE-Leads to the Unexpected** and **SDE-Enables Connections**. The
model, however, explains just 12% of the variance, a small effect size.

**Serendipity in general.** \( H_5 \), which examined relationships between the perception of serendipity in
general (**Serendipity-General**) and environmental and individual differences variables was
partially confirmed. Only **Extraversion** had an influence on how frequently people perceived
they experience serendipity. Though not hypothesised, a relationship was also found between
Serendipity-General and **SDE-Enables Connections**. The model, however, explains only 5% of
the variance, a small effect size.

**Summary**

\( H_3 \), relating to what influences perception of serendipity in a specific digital environment and \( H_4 \)
relating to perception of serendipity in general were partially confirmed. \( H_4 \), relating to perception
of serendipity in digital environments in general was rejected. Results indicate how trigger-rich a
specific digital environment is and how well it enables connections and leads to the unexpected
influences perceptions of how frequently serendipity occurs in that digital environment. This was
not, however, the case for how well a digital environment highlights triggers, which challenges
the hypothesis that a digital environment that points to or alerts users to interesting information
supports serendipity. As well, the creativity of their work environments, their locus of control,
and how open to experience individuals are had no influence on how frequently they experienced
serendipity in a specific digital environment, digital environments in general, or in general.
However, we did find a significant, though small, relationship between those with higher levels of
extraversion and a propensity to experience serendipity in general.

The results that were not hypothesised included: 1) a relationship between how frequently
serendipity occurs in digital environments in general and how well the specific digital
environment leads to the unexpected and enables connection; and 2) between how frequently
serendipity occurs in general and how well the specific digital environment enables connections.
However, given that the perception of serendipity scale measures nested levels of the perception
of serendipity (**Figure 1**), perception of specific digital environments are encompassed with the
broader measures of serendipity in digital environments in general and serendipity in general,
causing a pebble-in-the-water ripple effect. The decreasing ability of the factors relating to the
serendipitous digital environment to explain variance in the three models of decreasing levels of
granularity helps supports this interpretation.

**9. Discussion**

This research examined a number of variables relating to the individual and the environment that
may influence serendipity and found that the type of digital environment such as social media and
databases as well as the more specific perceived characteristics of a digital environment play a
significant role in perception of serendipity.
While five potential facets of the serendipitous digital environment were examined, the enables exploration facet perhaps shares too much conceptual space with the other four facets to be a distinct factor. Environments that enable exploration may still support serendipity but instead may manifest in part through trigger-rich perceptions. After all, comprehending how trigger-rich an environment is—the extent of its information, ideas, or resources—may be facilitated in part through mechanisms that enable exploration. The highlights triggers facet did emerge as a distinct factor but was not found to share a relationship with serendipity. Maybe it is enough for digital environments to be trigger-rich; users will notice what is most salient to them, what catches their interest, not just what is most visually salient (McCay-Peet et al., 2012). Or perhaps there is no relationship because a digital environment that highlights triggers prompts divergent behaviour, but not the more complex phenomenon of serendipity, the process of which involves five main elements: trigger, connection, follow-up, valuable outcomes, and an unexpected thread that runs through one or more of the elements (McCay-Peet & Toms, in press). Our findings, however, did confirm trigger-rich, enables connections, and leads to the unexpected have the potential to support serendipity and in doing so also helped to confirm, at least indirectly, three of the five main elements of model of the process of serendipity.

While the environment may help shape people’s experience with serendipity (e.g., Sun et al., 2011), how creative their work environment is did not emerge as an important factor despite the apparent overlap between serendipity and creativity. Surprisingly, with the exception of extraversion, individual differences examined in this research also do not appear to be good predictors of how frequently individuals perceive they experience serendipity. It makes sense that those more likely to think events in their lives are controlled by external factors such as chance would indicate that serendipity occurred more frequently in the specific digital environment they chose to assess. But this was not the case despite the fact that control is often identified as an important theme in both general discussions of serendipity and efforts to support serendipity (e.g., Rubin et al., 2011). However the concept of control in relation to the phenomenon of serendipity has elements of both personal agency (e.g., prepared mind) and external influence (e.g., chance events) and this push and pull may lead people to attribute their experiences to both internal and external factors (McCay-Peet & Toms, in press). This balancing act may have been captured in the results of the current study in which individuals’ locus of control did not significantly influence perception of serendipity. Perhaps those with an internal locus of control are just as apt to perceive they experience serendipity as those with an external locus of control because of the duality of the meaning of serendipity, a recognition of both the internal and external forces at play. For example, someone with an internal locus of control who recalls stumbling upon a link to an article on a social media site may rationalize their serendipitous experience in the following manner: I came across the article by chance; however, experience and knowledge allowed me to recognize the article’s importance and do something useful with it. Or perhaps rather than locus of control, serendipity is more closely associated with expectations that may vary depending on the environment and the situation.

While this research supports prior research that found people who are open to experience may use social media more than those closed to experience (Amichai-Hamburger & Vinitzky, 2010), those who are closed to experience are just as likely to have serendipitous experiences within social media sites as their more open counterparts. It may be that digital environments have an equalizing effect in which personality may be less important than characteristics of the digital environment in enabling serendipity. However, the cumulative qualitative evidence in prior research of an association between openness and serendipity cannot be dismissed. While openness as a personality trait may not be an important factor in serendipity, other forms of openness may be; for example, those grounded in situations or in work-related strategies or best
practices rather than personality. Professionals and academics, the focus of this research, have incentives to be open to experience relative to their work and research, motivations to keep an eye out for information and ideas that might be useful. Moreover, professionals and academics may have been trained to be open to experience in relation to their work, leading to equal opportunity for serendipity despite potential personality differences.

While we confirmed a relationship between extraversion and serendipity in general, its relationship is relatively weak and does not extend to serendipity within digital environments. Perhaps, like openness to experience, technology provides a democratizing effect, giving intraverts and extraverts alike the opportunity for serendipity within digital environments, regardless of how extraverted they may be in face-to-face interactions. Extraversion’s weak relationship to serendipity buoys McBirnie and Urquhart’s (2011) caution that social interaction is not a necessary precursor of serendipity. Though an increasing number of social media tools are centre stage (e.g., Twitter) or play a supporting role (e.g., social recommendations) in digital environments, interactions within these digital environments may still be predominantly object-oriented rather than social in nature. People do interact with other people in digital environments, but it is also possible to interact with information and ideas presented by others without ever having a personal exchange. Research, for example, suggests that Twitter may be described as an information network rather than a social network due to the lack of reciprocal ties (Kwak et al. 2010).

This research has a number of limitations. We asked participants to recall their experience in a specific digital environment when responding to the serendipitous digital environment scale. Thus, the recency of these experiences and participants’ ability to recall them may have influenced responses. As well, the nature of serendipity itself has been historically attributed to both the environment and the individual; therefore, we felt it was important to test these relationships. Consequently, we had a large number of variables increasing the possibility of a type 1 error – falsely concluding there is a relationship when in fact none exists. Therefore, further research is needed to support our findings. Furthermore, though significant, our analysis of and results relating to types of digital environments was rough. The types of digital environments we identified from participants’ freeform responses overlapped; for example, social media sites and websites. And there is a potentially wide array of differences within these types of digital environments (e.g., Facebook versus Reddit). As well, some types were selected more than others leading to some low cell counts in the analysis, potentially weakening the strength of the results. Finally, while we were able to identify relationships between several variables, they do not prove causation. Future work will need to examine through controlled studies whether, for example, a digital environment that scores high on the serendipitous digital environment scale is assessed as more serendipitous than a digital environment that scores low on the serendipitous digital environment scale.

10. Conclusions and Future Research
Through our web-based study of 289 professionals, academics, and students engaged in thesis work, we developed a 11-item scale to measure serendipity at three nested levels, reduced the serendipitous digital environment scale to a more parsimonious set of 15 items, explored relationships between serendipity, the environment, and individual differences, and came to the following main conclusions.

- Enables exploration, one of the five proposed facets of the serendipitous digital environment, appears to share too much conceptual space with the other facets. Thus while support for exploration may still be an important to designers and developers interested in facilitating
serendipity, a system’s capacity for supporting exploration may be assessed through other elements of the scale (e.g., enables connections).

• Three of the four proposed factors of the serendipitous digital environment were found to share a relationship with serendipity. An environment that highlights triggers did not share a significant relationship with serendipity. This finding may have implications for systems design; it suggests that overt tactics for drawing attention to information and ideas, however useful and unexpected, may backfire if the intent is to facilitate serendipity. Personalized email alerts or recommendations, for example, may lessen the perception of serendipity by revealing the structure and control that underlies the design of all digital environments. Future research will seek to understand whether this is the case and why.

• The three factors of the serendipitous digital environment scale that share a relationship with serendipity – trigger-rich, enables connections, and leads to the unexpected – help confirm the model of process of serendipity (McCay-Peet & Toms, in press) that contains the corresponding elements of trigger, connection, and unexpected thread.

• Whether the digital environment is a website, database, social media site, work intranet, or search engine may influence how frequently users perceive they experience serendipity in that environment. Future research will examine which specific features (e.g., related items, alerts, personalized results) of these digital environments are perceived to be associated with serendipity and develop heuristics for those who aim to develop digital environments to support serendipity.

• Extraversion shares a significant, though small, relationship with serendipity in general though this relationship is not evident relative to serendipity in digital environments.

• Openness to experience, locus of control, and creative environment perceptions shared no relationship to perception of serendipity. Perhaps future research could examine the influence of other broad work environment factors, more social factors, for example, relating to networking or collaboration and different factors relating to the individual such as the prepared mind or temporary states such as unfocussed attention.

More work needs to be done to further develop and validate the perception of serendipity and serendipitous digital environment scales, but more tools and methods are needed to help examine the complex problem of support for serendipity. Despite research indicating serendipity’s significance across a number of fields and the pervasive and persuasive anecdotal reports of its importance, research into how serendipity may be facilitated has only just begun. Our findings lead us to conclude that while further research is needed to understand these relationships, environment matters. Design for serendipity in digital environments is within reach if we can further understand and embody the perceived characteristics of the serendipitous digital environment in our databases, websites, social media sites, and search engines.

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References


Appendix

The following outlines the original five facets and 37 items of the serendipitous digital environment questionnaire (McCay-Peet et al., 2014) that were used in the web-based study of 289 participants described in this paper. Those 15 items retained following exploratory factor analysis are bolded and italicized.

**Enables Exploration:** A user’s assessment of the degree to which a digital environment supports exploration and examination of its information, ideas, or resources.

1. E1 It is easy to explore [the digital environment]’s content.
3. E3 It is easy to wander around in [the digital environment].
4. E6 There are many ways to explore information in [the digital environment].
5. E7 [The digital environment] invites examination of its content.
7. E9 [The digital environment] is a tool for exploration...
**Trigger-Rich:** A user’s assessment of the degree to which a digital environment contains a variety of information, ideas, or resources that is interesting and useful to the user.

8. **T1** The content contained in [the digital environment] is diverse.
9. **T2** [The digital environment] is rich with interesting ideas.
10. **T3** [The digital environment] offers a wide variety of information.
11. **T4** There is a depth of information in [the digital environment].
12. **T5** [The digital environment] is full of information useful to me.
13. **T6** I find information of value to me in [the digital environment].
14. **T7** [The digital environment] is a treasure trove of information.

**Enables Connections:** A user’s assessment of the degree to which a digital environment makes relationships or connections between information, ideas, or resources apparent.

15. **C1** [The digital environment] enables me to make connections between ideas.
16. **C2** Associations between ideas become obvious in [the digital environment].
17. **C3** I can see connections between topics in [the digital environment].
18. **C4** It is easy to see links between information in [the digital environment].
19. **C6** I make useful connections in [the digital environment].
20. **C8** The features of [the digital environment] help me see connections between its content.
21. **C9** I come to understand relationships between ideas in [the digital environment].

**Highlights Triggers:** A user’s assessment of the degree to which a digital environment brings interesting and useful information, ideas, or resources to the user's attention.

22. **H1** I am directed toward valuable information in [the digital environment].
23. **H2** [The digital environment] has features that ensure that my attention is drawn to useful information.
24. **H3** Information that interests me is highlighted in [the digital environment].
25. **H4** The way that [the digital environment] presents content captures my attention.
26. **H5** I am alerted to information in [the digital environment] that helps me.
27. **H7** I notice content I wouldn’t normally pay attention to in [the digital environment].
28. **H8** [The digital environment] has features that draw my attention to information.
29. **H9** I am pointed toward content in [the digital environment].
30. **H10** [The digital environment] has features that alert me to information.

**Leads to the Unexpected:** A user’s assessment of the degree to which a digital environment provides opportunities for unexpected interactions with information, ideas, or resources.

31. **U1** I bump into unexpected content in [the digital environment].
32. **U2** I encounter the unexpected in [the digital environment].
33. **U3** I am surprised by what I find in [the digital environment].
34. **U4** I come across topics by chance in [the digital environment].
35. **U5** [The digital environment] exposes me to unfamiliar information.
36. **U6** My interactions in [the digital environment] are unexpectedly valuable.
37. **U7** I stumble upon information in [the digital environment].

Note. E=SDE-Enables Exploration items; T=SDE-Trigger-Rich items; C=SDE-Enables Connections items; H=SDE-Highlights Triggers items; U=SDE-Leads to the Unexpected items.