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Serendipity: Towards a taxonomy and a theory

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ABSTRACT

Serendipity, the notion of researchers making unexpected and beneficial discoveries, has played an important role in debates about the feasibility and desirability of targeting public R & D investments. The purpose of this paper is to show that serendipity can come in different forms and come about in a variety of ways. The archives of Robert K Merton, who introduced the term to the social sciences, were used as a starting point for gathering literature and examples. I identify four types of serendipity (Walpolian, Mertonian, Bushian, Stephanian) together with four mechanisms of serendipity (Theory-led, Observer-led, Error-borne, Network-emergent). I also discuss implications of the different types and mechanisms for theory and policy.

1. Uncertainty, serendipity, and variety in serendipity

Almost all scholars who have studied research and innovation have noticed that uncertainties are involved: from economists (Nelson, 1959; Arrow, 1962) to historians (Rosenberg, 1994; Edgerton, 2007). They have observed that many, if not most, research and innovation efforts fail to achieve anything noteworthy (Rothwell et al., 1974; Freeman, 1982; Petroski, 2006). Attrition and the spectre of failure loom over basic and applied research, and exist in both science and technology (Vincenti, 1990; Ziman, 1994).

Where research does happen to yield something of value, the results are often quite different from what was expected. The term serendipity has been used to refer to this notion, that researchers make unexpected and beneficial discoveries (Merton and Barber, 2004; Sampat, 2014; Murayama et al., 2015). However, it should be apparent that serendipity can come about in a variety of ways and take different forms. Consider the following examples, all of which have been referred to as "serendipitous":

a A measles outbreak in Indian monkeys caused poliomyelitis vaccine preparation to switch to African monkeys. This led Levine to discover the p53 tumour suppressor gene (Meyers, 2007, p. 161).
b Daguerre had spent years trying to coax photographic images out of iodized silver plates. After yet another futile attempt, he stored the plates in a chemicals cabinet overnight to find the fumes from a spilled jar of mercury accidentally produced a perfect image on the plate (Box 256, Roberts, 1989, p. 49).
c Richet, whilst searching for threshold doses of various poisons, discovered that he could induce sensitization to a toxic substance thereby developing understanding of allergies and anaphylaxis (Box 427). Accepting his Nobel Prize, he said, "It is not at all the result of deep thinking, but of a simple observation, almost accidental" (Roberts, 1989, p. 125).
d Elrich discovered Salvarsan, dubbed the first magic bullet, knowing very little about how it worked. It emerged from an extraordinary focus on the idea of chemotherapy (where chemicals might kill pathogens selectively). Salvarsan was the 606th preparation, the 605 before it having each gone through their own set of experiments (Box 424, Meyers, 2007, p. 62).

Clearly, the term serendipity is a label for a broad and multifaceted phenomenon. Levine and Richet were searching in one problem space (vaccinology and toxicology) when they came across their solutions for quite another (oncology and physiology, respectively). The same cannot be said of Daguerre and Elrich, who solved the same problems they were working on (photography and chemotherapy), though the way in which they arrived at their solution was unexpected (spillage, and trial and error). Richet places emphasis on 'simple observation', Daguerre on methodological error, Elrich on a committed hypothesis, and Levine on a network that allowed him to connect fields as far as vaccinology and oncology. Each of these emphases might have distinct implications for policy and theory.

In this paper, I aim to clarify the meaning of the term serendipity, principally by drawing attention to the heterogeneity of the phenomenon. I analyse "serendipitous" episodes to identify different types and mechanisms. Section 2 describes how I gathered my collection of

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examples and where I learnt about much of the existing literature on serendipity. Section 3 develops a typology of serendipity. Section 4 characterises some of the mechanisms by which serendipity may occur. Section 5 discusses potential policy implications, and the desirability and feasibility of measuring these types and mechanisms of serendipity. Section 6 concludes.

2. Research design: Merton as an unexploited source for serendipity

We are fortunate to stand on the shoulders of Robert K Merton, whose prolonged interest in serendipity led him to chart its lexicographical history and sociological semantics, a project that began in the 1940s and culminated with his posthumous book on serendipity with Elinor Barber in 2004. I spent six months in the archive that holds Merton's notes, most of which have not been published. It contains his detailed reading notes relating to serendipity, countless clippings from magazines, newspapers, and journals mentioning serendipity, and correspondence with scientists and sociologists of his day. From the Merton papers alone, I was able to hand-compile a qualitative database containing dozens of examples of serendipity and build an extensive bibliography with which I was able to find (hundreds) more examples of serendipity.

The Merton archive was a good place to start the search for varieties of serendipity, not least because it was he, as one of the "most influential sociologists of the twentieth century" (Calhoun, 2010, p. vii), who introduced the term into the social sciences.[1] The publication of Merton and Barber's (2004) book seems to have instigated much of the recent scholarship focusing on serendipity (e.g. Cunha et al., 2010; Murayama et al., 2015). Even publications that preceded Merton and Barber (2004) seem indebted to Merton's work or private communication with him (e.g. "Merton gave me an [unpublished] copy" (Andel, 1994, p. 648)).

Merton, as a towering figure of sociology, had an extensive collegial network that was aware of his interest in serendipity. Merton was sent excerpts and examples of serendipity, one with a covering letter that revealingly noted, "I don't know what is serendipitous about this, but it appeared in American Airlines magazine" (Box 429:i4906). Merton himself acknowledged that many of these short anecdotes of serendipity are either understated or exaggerated, or apocryphal legends. Merton scrawled reminders down margins to check for authenticity, most of which went unanswered because he was unable to satisfy himself regarding their veracity.

However, for the purposes of building an initial typology of serendipity patterns, my requirement was only that the examples be potentially plausible. After screening the titles of the 513 manuscript boxes that comprise the archive for possible relevance to serendipity, selecting 38 boxes for perusal, and making detailed notes on 22 boxes and their subfolders, I identified examples of serendipity and references for further reading. I gathered them into a database totalling 118 examples, taking note of the main protagonist(s), what was discovered, a short (circa 60 words) description of how the discovery was made, and the sources used to compile the example.

The most common way the examples were reported was by discovery, a unit of analysis whose drawbacks I detail in Section 5. Most discoveries were reported by multiple authors; these were recorded in the database as a single example. Consistency and variation in accounts of the same example allowed us to explore how the term serendipity was being applied rather than to establish reliability of the example in question through triangulation.

I coded the examples according to various characteristics because they initially appeared as similarities and differences. I drew on relevant literature by matching patterns identified with those reported by other authors. I iterated between the examples and emerging theory before settling on the motivations underlying the discovery and the outcomes of the discovery as two of the most important dimensions of serendipity. As a result, eight examples were dropped from the database following development of the typology.[2] I developed a typology based on these two dimensions, yielding four methodological ideal types (McKinney, 1966; Bailey, 1994; Doty and Glick, 1994).

The next section will describe Walpolian, Mertonian, Bushian and Stephanian serendipity types and will highlight some of the examples reviewed as illustrative of each type. This is a conceptual rather than an empirical endeavour. Conceptually, a sphere and a plane touch at only one contact point, but empirically, allowances need to be made for the roughness of surface and the pressure of a real sphere on a plane. Such irregularities are lost when describing the ideal type because typologies are only instrumental and subordinate to the aims of the research. Since there is no such thing as a type independent of selective interests and the purposes for which it was developed, I make my interests and purposes explicit in Section 5, outlining how they reside in certain research policy problems.

3. An illustrated typology of serendipity

I analysed hundreds of discoveries referred to as serendipity using a number of guiding questions. What are the similarities and differences across the examples, and between the various accounts of the same discoveries? How are authors (implicitly or explicitly) justifying their use of the term serendipity in their account? I found two consistently reappearing themes: the motivations underlying the discovery and the outcomes of the discovery. They can help one to determine whether a discovery is serendipitous or not, and also serve as dimensions along which serendipitous discoveries may be distinguished as different ideal types. This section will describe the four types and will provide some of the examples reviewed as illustrative of each type.

3.1. Targeted search solves unexpected problem

Serendipity has been an inherently ambiguous word since its first documented use in 1754. Horace Walpole's whimsical reference to a tale about the Three Princes of Serendip combines accident with sagacity. Most pertinently, the Princes were making discoveries "of things which they were not in quest of" (Merton and Barber, 2004, p. 2). This forms the basis of our first type – **Walpolian** serendipity – discovery of things which the discoverers were not in search of – for which I can offer some of the most well-known discoveries as examples.

In 1897, whilst searching for a way of extracting proteins from bacteria for immunization, Buchner discovered that cell-free yeast extract could still convert sugar to alcohol and carbon dioxide. This discovery proved that whole cells were not necessarily required for fermentation and thereby inaugurated the field of enzymology (Kohler, 1971; Box 378: i1652). In 1943, an explosion left soldiers exposed to mustard gas. Investigators were dispatched to find out whether it was an enemy bombing. Instead they found soldiers' white blood cell counts dropping. The link was made that perhaps mustard gas, or its derivatives, could treat cancers caused by the over-expression of white blood cells – modern chemotherapy was born (Meyers, 2007, p. 123).

The most important features of this type of serendipity are the

[1] Merton's interest in the 'unanticipated consequence of purposive social action' was published in 1936. His first published usage of the term serendipity was in 1945. Merton went on to define the term explicitly in 1948. These dates coincide with the start of its rapid diffusion according to Google Ngram, which charts the usage of any word found (in sources printed between 1800 and 2012, in the major languages, normalised by number of books published annually).

[2] These examples would be better described as co-incidental multiples rather than as serendipity. They are remarkable because the discovery was made simultaneously and independently, and this seems to be the sole basis upon which the word serendipity was used. (Though, Cozzens (1989) suggests that the term multiples may be an artefact of social control and co-ordination processes in science for resolving priority disputes over the degree of similarity between discoveries.)