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Creativity in science and the link to cited references: Is the creative potential of papers reflected in their cited references?

Iman Tahamtan[a,*], Lutz Bornmann[b]

[a] School of Information Sciences, College of Communication and Information, University of Tennessee, Knoxville, TN, USA
[b] Administrative Headquarters of the Max Planck Society, Division for Science and Innovation Studies, Hofgartenstr. 8, 80539 Munich, Germany

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ABSTRACT

Several authors have proposed that a large number of unusual combinations of cited references in a paper point to its high creative potential (or novelty). However, it is still not clear whether the number of unusual combinations can really measure the creative potential of papers. The current study addresses this question on the basis of several case studies from the field of scientometrics. We identified some landmark papers in this field. Study subjects were the corresponding authors of these papers. We asked them where the ideas for the papers came from and which role the cited publications played. The results revealed that the creative ideas might not necessarily have been inspired by past publications. The literature seems to be important for the contextualization of the idea in the field of scientometrics. Instead, we found that creative ideas are the result of finding solutions to practical problems, result from discussions with colleagues, and profit from interdisciplinary exchange. The roots of the studied landmark papers are discussed in detail.

1. Introduction

Several scientometric studies have used cited references data for measuring novelty or creativity in science (e.g. Uzzi, Mukherjee, Stringer, & Jones, 2013; Wang, Veugelers, & Stephan, 2017). The general idea here is that if a paper contains many unusual combinations of cited references, the creative potential of the paper is high (Uzzi et al., 2013). Unusual combinations are those which can rarely be found in other publications. Uzzi et al. (2013) claim that combinations of atypical with conventional knowledge (reflected in unusual combinations) may lead to innovativeness (reflected in high impact papers). Therefore, creativity in science can be considered almost a universal phenomenon of conventionality and novelty (Uzzi et al., 2013). However, it is still not clear whether this approach of using cited references for measuring creativity is valid. The empirical studies based on patent data suggest that cited references might not have this prominent role (Callaert, Pellens, & Van Looy, 2014; Nagaoka & Yamauchi, 2015). We are not aware of any study which has similarly tested the approach for publications and cited references. The extent to which cited publications are the sources of inspiration leading to current landmark papers is not yet well understood. Thus, using exemplary landmark papers from the field of scientometrics, this study explores whether the creative potential of a paper is really reflected in its cited references or not.

* Corresponding author.
E-mail addresses: tahamtan@vols.utk.edu (I. Tahamtan), bornmann@gv.mpg.de (L. Bornmann).

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2. Creativity in science

Creativity has been studied widely in the last decade. However, basic questions about the nature of creativity remain under debate (Kaufman & Beghetto, 2009). Numerous studies have attempted to analyze and understand what makes humans creative (Erren, Shaw, & Lewis, 2017). To study creativity and its nature, a group of studies and theories has investigated the lives of well-known and distinguished creators (e.g. Nobel laureates) by surveying or interviewing them – called *Big-C creativity* (Kaufman & Beghetto, 2009).

Intelligence and creativity are two vital ingredients in revolutionary science. Intelligence can be assessed by IQ tests. However, measuring the creativity of scientists is not an easy task (Charlton, 2009), despite the existence of psychological tests of creativity (Eysenck, 1995). The science of creativity aims to understand what leads to novel outcomes (Lee, Walsh, & Wang, 2015). Creativity, success in science, and scientific breakthroughs seem to be the result of several prerequisites such as interest among colleagues who take up on the ideas (Bornmann & Marx, 2012). Previous studies have used a variety of measures to operationalize the creative person in science, including self-reports, peer-ratings, scores on divergent thinking tests or personality inventories, total number of publications and citations, the h-index, etc. (Grosul & Feist, 2014). A variety of factors correlate with creativity, including affect, cognition, training, individual differences, culture, social behavior, and team working (Hennessey & Amabile, 2010). Individuals' characteristics such as intelligence, competency, motivation, knowledge, style, and personality have been the core elements of creativity studies in a variety of fields (Shin & Jang, 2017).

A stream of research has examined the effect of team collaboration on the creativity of research, emphasizing that creativity is the outcome of individuals' interactions within a team (Shin & Jang, 2017). Interactions, collaborative networking, and information exchange might result in serendipitous discoveries in basic science, applied research and technological development activities (Yaqub, 2018). Uzzi et al. (2013) indicated that papers written in collaboration are 37.7% more likely than those of single authors to introduce novel combinations into conventional knowledge domains. Fleming (2007) writes that "multidisciplinary collaboration increases the variance of the outcome, such that failures as well as breakthroughs are more likely" (p. 72). Lee et al. (2015) found that the probability of creative research is positively related to the increase in the number of members in a team, particularly when they have distinct knowledge domains. Lee et al. (2015) also point out the importance of the combination of diverse ideas for producing creative science.

Neumann (2007) interviewed 15 European Molecular Biology Laboratory (EMBL) group leaders (EMBL is a top non-US institution in terms of highly cited molecular biology and genetics publications). He found that scientists bring "together previously unlinked ideas to generate a new concept" (p. 203) or integrate previously puzzling fragments of information into a coherent picture. This study reveals that breakthroughs are largely internal, yet external factors also play an important role. Neumann (2007) notes that the crucial factors for stimulating creativity includes scientists' awareness of the unknown, colleagues' interactions, feedback after the emergence of a new idea, as well as environmental features. The social environment such as culture or team leader behavior can also influence individuals' motivation, and consequently creative performance (Hennessey & Amabile, 2010).

Erren et al. (2017) studied several creativity cases at Cambridge and AT&T's Bell Laboratories. They found that working with 'an open door' leads to more thought exchanges, obtaining feedback, and enhancing individual and group creativity (Erren, 2008). Kasperson (1978) notes that colleagues are valuable sources of information, and creative scientists use such information sources effectively and differently from other scientists. In addition to interaction with peers as a crucial factor for creativity (Neumann, 2007), the fostering of individual creativity is important too (Erren et al., 2017).

One important stream of research views creativity as involving the novel combination and/or recombination of elements that have never been combined before (Lee et al., 2015; Schumpeter, 1939). In this regard, Fleming (2001) maintains that the recombination of previously combined components and the combination of new components that have not been combined before could lead to creativity. "The combination process can be regarded as an innovation process that links knowledge with different distances in the knowledge base" (Zeng et al., 2017, p. 56). Atypical combinations of knowledge while maintaining the advantages of conventional knowledge could also lead to innovativeness (Uzzi et al., 2013). Carayol, Lahatte, and Llopis (2017) propose a measurement of novelty which uses the frequencies of pairwise combinations of articles' keywords for the exploration of new research questions. This study indicates that the combination does not always offer remarkable benefits for creativity, however pairwise keyword novelty is strongly related to the articles' citation impact (Carayol et al., 2017).

Koestler (1964) suggests the term 'bisociation' for human intellectual creativity. He explains this term as follows: "the creative act does not create something out of nothing, like the God of the Old Testament; it combines, reshuffles, and relates already existing but hitherto separate ideas, facts, frames of perception, associative contexts" (Koestler, 1981, p. 2). A similar idea is introduced by Salganik (2017) called 'ready-made'. Ready-made characterizes art "where an artist sees something that already exists in the world and then creatively repurposes it for art" (Salganik, 2017, p. 7). Salganik (2017) also introduces another term called 'custom-made' which is defined as the art that was intentionally created.

Schubert (2013) employed bisociation and proposed 'title term bisociation' in bibliometrics as a tool for detecting emergent areas. Schubert and Schubert (1997) posit that emergent areas or new connections occur if "two frequent but so far not co-occurring terms begin to co-occur regularly" (p. 132). Schubert and Schubert (1997) analyzed the terms in the titles of documents in *Inorganic Chemistry Acta* and found 14 new connections. They note that "using Koestler's 'bisociation' concept, some potential 'creative foci' were identified in the form of pairs of title terms, around which some new ideas may emerge" (Schubert & Schubert, 1997, p. 133).