

What makes musical improvisation creative?

Article (Accepted Version)

Jordanous, Anna and Keller, Bill (2012) What makes musical improvisation creative? *Journal of Interdisciplinary Music Studies*, 6 (2). pp. 151-175. ISSN 1307-0401

This version is available from Sussex Research Online: <http://sro.sussex.ac.uk/41568/>

This document is made available in accordance with publisher policies and may differ from the published version or from the version of record. If you wish to cite this item you are advised to consult the publisher's version. Please see the URL above for details on accessing the published version.

Copyright and reuse:

Sussex Research Online is a digital repository of the research output of the University.

Copyright and all moral rights to the version of the paper presented here belong to the individual author(s) and/or other copyright owners. To the extent reasonable and practicable, the material made available in SRO has been checked for eligibility before being made available.

Copies of full text items generally can be reproduced, displayed or performed and given to third parties in any format or medium for personal research or study, educational, or not-for-profit purposes without prior permission or charge, provided that the authors, title and full bibliographic details are credited, a hyperlink and/or URL is given for the original metadata page and the content is not changed in any way.

What makes musical improvisation creative?

Anna Jordanous¹ and Bill Keller²

¹ Centre for e-Research, Department of Digital Humanities, King's College London

² Department of Informatics, University of Sussex

Background in musical improvisation and creativity. What makes musical improvisation creative? And what exactly is it that justifies one improviser being described as more creative than another? For a clearer understanding, it is a practical necessity to use an approach such as those of Berliner (1994) and Gibbs (2010), who make the study of improvisational creativity more tangible by identifying key constituent parts, rather than treat creativity as ineffable (Bailey 1993).

Background in computational linguistics. The log likelihood ratio statistic can be used to compare two sets of texts (corpora) to examine word distribution patterns (Rayson & Garside 2000, Dunning 1993). Using this statistic, words are identified which are associated with academic papers on creativity. Lin's similarity measure (Lin 1998) is then used as a basis for clustering words with similar meanings using the algorithm Chinese Whispers (Biemann 2006). Analysis of the clusters reveals fourteen key components of creativity.

Aims. To model creativity in musical improvisation by identifying components of creativity using computational linguistics techniques and understanding how each contributes to creativity in improvisation.

Main contribution. The paper presents an empirical, language-based approach to understanding creativity in musical improvisation. This approach is based upon treating creativity as having common features that transcend different types of creativity but that vary in importance depending on the type of creativity. Fourteen key components of creativity are identified from an analysis of a corpus of texts on creativity. A study is then conducted to investigate the relative importance of each of these components in musical improvisation. All fourteen components are considered relevant to some degree, but particular significance is attached to three of them: the ability to communicate and interact, the possession of relevant musical knowledge and skills, and emotional engagement and intention. It is notable that the products of improvisation are relatively less important than these process-based aspects.

Implications. The work provides a model of musical improvisational creativity as a set of guidelines or benchmarks for evaluating how creative a musical improviser is. Such a detailed understanding helps improvisers identify what areas to work on in order to develop their creativity (Gibbs 2010).

Keywords: improvisation, musical improvisation creativity, empirical methods, log likelihood ratio statistic, computational linguistics, creativity evaluation

• *Correspondence:* Anna Jordanous, Centre of e-Research, Department of Digital Humanities, King's College London, 26-29 Drury Lane, London WC2B 5RL;

tel: 0044 207 848 1988, e-mail: anna.jordanous@kcl.ac.uk

• *Received:* 5 November 2012; *Revised:* 10 July 2013; *Accepted:* 5 February 2014

• *Available online:* 10 March 2014

• doi: 10.4407/jims.2014.02.003

Introduction

There is currently much interest in how creativity is manifested in musical performance and improvisation. The Research Centre for Musical Performance as Creative Practice (CMPCP) was established by the AHRC in 2009 to investigate creativity in musical practice. In music education, there has been interest in a better understanding of how to assess and develop the creativity of musical improvisers (Gibbs 2010).

Adopting an analytic approach to creativity is vital for firm grounding of research into creative practice: 'only when the field is analyzed and organized - when the listener can be sure he knows what the speaker is talking about - will the pseudo aspect of the subject of creativity disappear' (Rhodes 1961, p.310). Kaufman (2009) argues that creativity can and should be studied and measured, but the current lack of a standard definition causes problems for measurement. This impacts particularly on assessment and development of improvisational creativity. A more precise, objective account of creativity specifies and justifies standards for evaluating creativity (Plucker et al. 2004, Kaufman 2009, Jordanous 2012).

Creativity can be seen as an *essentially contested concept* (Gallie 1956): it is subjective, abstract and can be interpreted in a variety of acceptable ways, so that a fixed 'proper general use' is elusive (Gallie 1956, p. 167). It is more productive to acknowledge that different interpretations exist than to argue for a single interpretation. Then we can refer to 'the respective contributions of its various parts or features' (Gallie 1956, p. 172). Thus, different types of creativity manifest themselves in different ways whilst sharing certain characteristics or 'family resemblances' (Wittgenstein 1958). We need to identify what those 'family resemblances' are and which are most pertinent to musical improvisation creativity.

Is musical improvisation creativity the same type of creativity as creativity in general? Or is it distinct from artistic creativity, or scientific creativity? Creativity researchers take a hybrid view (Plucker & Beghetto 2004, Baer 2010), acknowledging that some aspects of creativity transcend domains and others are specific to that domain. Hence **both** general elements of creativity **and** elements specific to musical improvisation should be investigated to better understand musical improvisation creativity.

This paper presents an empirical approach to understanding creativity in musical improvisation, guided by the above considerations. Key to this empirical approach is that such an understanding can be derived from a contextual analysis of the language used to talk about creativity and creative practice. Using techniques from statistical natural language processing, texts on general creativity were analysed to reveal fourteen distinct themes or components. These components may be understood as a set of 'family resemblances' that may be emphasized to a greater or lesser extent in different manifestations of creativity. To interpret these components in the context of creativity in musical improvisation, a study was conducted to identify the perceived relative importance of the fourteen components. Study participants wrote about a number of different aspects of musical improvisation. Their responses were analysed

to determine how often each of the fourteen components was mentioned. From this analysis, the relative importance of each of the fourteen components could be determined in the context of musical improvisation.

Background: Musical improvisation as a creative domain

George Lewis has referred to improvisation as ‘the ubiquitous practice of everyday life’, communicating meaning and emotion such that while improvising, ‘one hears something of oneself’ (Lewis 2011). Bailey (1993) proposes that the creative process exists at a level beyond that which can be expressed in words, and that ‘musical creativity (all creativity?) is indivisible’; however Pressing (1987) advocates making more tangible connections between improvisation and creativity. In pursuing a clearer understanding overall, it is most productive to follow the lead of those such as Berliner (1994) and Gibbs (2010), who make the study of improvisational creativity more tangible by describing it in terms of subprocesses (Berliner 1994) or components (Gibbs 2010).

What, then, are these components or subprocesses that comprise or contribute to creativity? Several suggestions have been made, from various perspectives. Biasutti and Frezza (2009) adopt a view similar to the confluence approach in creativity research (Sternberg & Lubart 1999, Mayer 1999, Ivcevic 2009). On this view creativity as a whole is understood by breaking it down into smaller, constituent parts. Biasutti and Frezza (2009) identify seven dimensions of improvisation. Five concern improvisational processes: anticipation, emotive communication, flow, feedback and use of repertoire. The remaining two dimensions are for abilities: musical practice and basic skills. Focusing on jazz improvisation, Johnson-Laird (2002) adopts a different viewpoint, identifying five different parts of creative processes (forming the ‘NONCE definition of creativity’): ‘Novel for the individual, Optionally novel for society, Nondeterministic, dependent on Criteria or constraints, and based on Existing elements’ (Johnson-Laird 2002, p. 420).

Issues of choice and liberty are raised by Lewis (2011), in terms of having a choice of what expressive actions to perform in improvisation and when to perform them. Neural evidence (Csikszentmihalyi 2009; Friis-Olivarius et al. 2009; Berkowitz & Ansari 2010) shows that brain activity during improvisation relates to brain activity when making choices. Lewis (2011) contends that this neural evidence demonstrates that one is never fully in control during improvisation.

Improvisation and creativity are often conflated by authors rather than being distinguished as different behaviours (e.g. Sawyer 1999, Thom 2003, Johnson-Laird 2002, Biasutti and Frezza 2009, Gibbs 2010). Gibbs (2010) equates ‘creative’ with ‘improvisational’ musicianship in musical improvisation education. She highlights invention and originality as two key components for creative improvisation (Gibbs, 2010). The word ‘improvisation’ derives from the Latin *improvisus*, or “unforeseen”/“unexpected” Sawyer (1999). Sawyer sees this unpredictability as ‘the

most salient characteristic' of improvisation (Sawyer 1999, p. 193), also placing emphasis on use of structures and the generation of products (Sawyer 1999, p. 194).

Influenced by Sawyer's work, Biasutti and Frezza (2009) see unpredictability and use of structures as two opposite ends of a spectrum. The more that creativity is embedded in the improvisatory process, the greater the level of unpredictability demonstrated. Similarly, '[t]he more the structure, the less the creativity, and vice versa' (Biasutti & Frezza 2009, p. 238). Berliner describes how musical improvisers need to balance the known and unknown, working simultaneously with planned conscious thought processes and subconscious emergence of ideas (Berliner 1994). Berliner examines how musical improvisers learn from studying those who precede them, then develop that knowledge to produce a unique style. Thom (2003) notes that the use of too much domain knowledge in a computational model of improvisation would inhibit creativity.

The Four Ps view of creativity (Rhodes 1961, MacKinnon 1970) identifies four aspects of creativity: the creative Person, the Process(es) employed, the creative Product(s) and the Press (environment) that hosts and influences creativity. Encompassing the contributions made to creativity by the Press, as well as the contributions made by an individual Person, the importance of improvisation as a group rather than solo activity is often emphasised (Biasutti & Frezza 2009, Barrett 1998, Sawyer 1999, 2006, Walker 1997). Sawyer (1999) criticises 'creativity researchers' (Sawyer 1999, p. 201) for adopting a focus on the individual and their processes rather than the group.

From these various reflections we see useful contributions on creativity in musical improvisation but no overall consensus on how that creativity is manifested. The same situation arises in creativity research more generally (Kaufman 2009, Hennessey & Amabile 2010). A multitude of research exists on what constitutes creativity, from the early to mid 20th century (e.g. Poincaré 1929, Guilford 1950) to contemporary investigations (e.g. Plucker et al. 2004, Hennessey & Amabile 2010). However, no standard definition of creativity has yet been agreed upon (Rhodes 1961, Torrance 1988, Sternberg & Lubart 1999, Boden 2004, Plucker et al. 2004, Hennessey & Amabile 2010). Problems with defining and understanding creativity are widely documented and investigated, often without satisfactory resolution. Several higher-level views of creativity exist, often inconsistent with each other. For example, it may be contended that creativity is centred around cognitive function (e.g. Boden 2004) or alternatively that it is embodied and situated in an interactive environment (e.g. Csikszentmihalyi 1988). Other tensions exist where narrow views of creativity have later been widened in perspective. For example, rather than focusing purely on creative geniuses, there are benefits to looking at 'everyday' creativity, of which genius is a special case (Rhodes 1961, Boden 2004, Bryan-Kinns 2009). Similarly, P-creativity, creativity that produces work that is novel to the person being creative, encompasses H-creativity, creativity that produces original work not encountered before in society (Boden 2004).

In summary, it can be seen that various proposals have been made about what constitutes creativity, both in the general case and in the specific case of creativity in

musical improvisation. However, no consensus has been reached. The work reported in this paper responds to this situation, not by adding yet another definition to the wealth of existing definitions of creativity, but by providing an empirically grounded conceptual model of creativity that is drawn from the various perspectives available. As noted above, it is critical to remember that creativity is domain-specific to some extent but also has some elements that occur in all manifestations of creativity (Plucker & Beghetto 2004, Baer 2010). Hence this paper offers a model of musical improvisation creativity, constructed by:

1. combining different perspectives on creativity to identify overriding key themes or components of creativity;
2. identifying the relative importance of each of these components in the context of musical improvisation creativity.

Identifying key components of creativity

Our point of departure is to identify key themes or components that collectively help us understand the general concept of creativity: aspects of creativity that commonly appear across various types of creativity. A set of words that appear to be highly associated with discussions of creativity is identified from a corpus of academic papers on the topic. Using a measure of lexical similarity, these words are then clustered to reveal a number of common themes or constituent components. Further analysis of these themes results in a set of fourteen key components.

Corpus data

A small, but representative sample of academic papers discussing the nature of creativity was assembled. This ‘creativity corpus’ comprises a sample of 30 academic papers that examine creativity from a variety of standpoints, ranging from psychological studies of creativity to computational models or standpoints from Arts and Humanities or other disciplines. The papers in the creativity corpus are listed in Appendix A and elsewhere (Jordanous 2010, 2012).

All selected papers are written in Englishⁱ and cover a wide range of years (1950-2009) and academic disciplines. A paper was included if it was considered particularly influential, as measured by the number of times it had been cited by other academic authors. For papers published in very recent years and which have therefore not yet accrued many citations, selection was based on intuitive judgement. Academic papers were used as the source of information for several reasons. These included: the ability to locate and access time-stamped textual materials over a range of decades; an appropriate format for computational textual analysis; access to citation data (as a measure of how influential a paper is on othersⁱⁱ) and the availability of provenance data, such as the paper’s author and intended audience (from the disciplinary classification of the journal).

The creativity corpus is relatively small and necessarily selectiveⁱⁱⁱ in terms of the papers that are included. As such it constitutes just a small fraction of the many academic works on creativity that have been published in the last 60 or so years. Indeed, the 30 papers in the creativity corpus cannot be regarded as fully representative of the wide range of academic positions on creativity that have been discussed in the literature over the decades. However, it is not the intention to provide a fine-grained analysis or detailed of the language used in the full range of academic literature on creativity. Nor is it necessary to provide a comprehensive lexicon or dictionary of creativity, drawn from this complete literature. The goal is rather to identify the broader themes or concepts that recur in our understanding of creativity. For this purpose, what is required is a sufficiently representative sample of the academic discourse on creativity. This sample can be used to identify the way in which word use reflects key themes that persist across different perspectives.

In order to identify words that appear to be highly associated with creativity, rather than simply ubiquitous, it is necessary to provide a baseline for comparison with data drawn from the creativity corpus. A further corpus of 60 academic papers on topics unrelated to creativity was therefore assembled (a ‘non-creativity corpus’). For each paper in the creativity corpus, the two most-cited corresponding non-creativity papers were retrieved. These were the two most cited papers in the same academic discipline^{iv} and with the same year of publication, but which contained none of the words *creativity*, *creative*, *creation*, etc.

Natural language processing of the corpora

The assembled corpus data was processed using the RASP natural language processing toolkit (Briscoe et al. 2006) to perform automated lemmatisation and part-of-speech tagging. Lemmatisation permits inflectional variants of a given word to be identified with a common root form or ‘lemma’. For example, *performs*, *performed* and *performing* all occur in the creativity corpus as distinct morphological variants of the verb, *perform*. Each of these morphological variants should be counted as an instance of the same word rather than as separate vocabulary items. Lemmatisation software enables this by mapping such variants to a common root. As a further refinement, each lemma was mapped to lower case to ensure that capitalized word forms (e.g. *Novel*) were not counted separately to their non-capitalized forms (*novel*).

Using RASP, each word was also automatically assigned a part-of-speech tag identifying its grammatical category (i.e. whether the word was a noun, verb, preposition, etc.). Such tagging is helpful because it allows us to distinguish between different uses of a common orthographic form. For example, the use of *novel* as a noun in the phrase *a good novel* can be properly differentiated from its use as an adjective in the phrase *a novel idea*. The data was further simplified and filtered so that only words of the four ‘major’ categories (i.e. noun, verb, adjective and adverb) were represented. Note that the major categories are the bearers of semantic content. They may be distinguished from minor categories or ‘function words’, such as pronouns (*something*, *itself*) prepositions (e.g. *in*, *upon*) conjunctions (*and*, *but*) and

quantifiers (e.g. *all, more*). As the latter have little independent semantic content they are of limited interest for the present study and may be removed from the data. Finally, the resulting data were processed to produce two lists of words and associated frequency counts: one list for all those words occurring in the creativity corpus and one for all words in the non-creativity corpus.

Finding words likely to be associated with creativity

A standard, statistical measure of association was used to identify those words strongly associated with discussions of creativity. The log-likelihood ratio (or G-squared statistic) is a measure of how well observed frequency data fit a model or expected frequency distribution. The statistic is an alternative to Pearson's chi-squared (χ^2) test and has been advocated for corpus analysis as it does not rely on the (unjustifiable) assumption of normality in word distribution (Dunning 1993, Oakes 1998, Kilgarriff 2001). This is a particular issue when analysing relatively small corpora as in the present case.^v The log likelihood ratio is more accurate in its treatment of infrequent words in the data, which often hold useful information. By contrast, the χ^2 statistic tends to under-emphasise such outliers at the expense of very frequently occurring data points.

The use of the log-likelihood ratio in the present work follows that of Rayson & Garside (2000) and Jordanous (2010). Given two corpora (here, the "creativity corpus" and the baseline "non-creativity corpus") the log-likelihood ratio score for a given word is calculated as follows:

$$LLR = 2 \sum_{i \in \{1,2\}} O_i \ln \left(\frac{O_i}{E_i} \right)$$

where O_i is the observed frequency of the given word in corpus i and E_i is its expected frequency in corpus i . The expected frequency E_i is given by:

$$E_i = \frac{N_i \times (O_1 + O_2)}{N_1 + N_2}$$

where N_i denotes the total number of words in corpus i . To identify words likely to be associated with creativity, any word with a log-likelihood score less than 10.83, representing a chi-squared significance value for $p=0.001$ (one degree of freedom), was removed from the data. The log-likelihood statistic tells us only whether the observed distribution of a word is unexpected (and to what extent). It does not in itself tell us whether a word is more or less frequent than expected in the creativity corpus. To identify words likely to be associated with discussion of creativity therefore, it was necessary to select just those words with observed counts higher than that expected in the creativity corpus.

Finally, to avoid problems of very rare words disproportionately affecting the data, any word occurring fewer than five times was removed from consideration. This

resulted in a total of 694 extracted words: a collection of 389 nouns, 205 adjectives, 72 verbs and 28 adverbs that occurred significantly more often than expected in the creativity corpus. Table 1 lists the 20 words with the highest LLR scores.^{vi}

Table 1. The top 20 results of the log-likelihood ratio (LLR) calculations. A significant LLR score at $p=0.001$ is 10.83.

Word (and part of speech tag)	LLR
thinking (N)	834.55
process (N)	612.05
innovation (N)	546.20
idea (N)	475.74
program (N)	474.41
domain (N)	436.58
cognitive (J)	393.79
divergent (J)	355.11
openness (N)	328.57
discovery (N)	327.38
primary (J)	326.65
originality (N)	315.60
criterion (N)	312.61
intelligence (N)	309.31
ability (N)	299.27
knowledge (N)	290.48
create (V)	280.06
experiment (N)	253.32
plan (N)	246.29
agent (N)	246.24

Finding key ‘building blocks’ for creativity

To identify common, recurring themes or factors in the discussion of creativity, the creativity words were clustered according to a statistical measure of *distributional similarity* (Lin 1998). Intuitively, words that tend to occur in similar linguistic contexts will tend to be similar in meaning (Harris 1968). The notion of linguistic context here is not fixed and might plausibly be modelled in a variety of different ways. For example, two words could be considered to inhabit the same context if they appear in the same document or sentence, or if they stand in the same grammatical relationship to some other word (e.g. both occur as object of a particular verb or modifier of a given noun). In practice it has been shown that modelling distribution in terms of grammatical relations leads to a tighter correlation between distributional similarity and closeness of meaning (Kilgarriff and Yallop 2000). For example, evidence that the words *concept* (LLR=189.90) and *idea* (LLR=475.74) are similar in meaning might be provided by occurrences such as the following:

1. The *concept/idea* involves (subject of the verb *involve*)
2. applied the *concept/idea* (object of the verb *apply*)

3. the fundamental *concept/idea* (modified by the adjective *fundamental*)

Distributional data of this kind were obtained from the written portion of the British National Corpus (Leech 1992). The corpus had previously been processed toolkit (Briscoe et al. 2006) to identify grammatical relations of various kinds (e.g. *subject-of*, *object-of*, *modified-by*, etc.). For each word in the creativity corpus a list of all of the grammatical relations in which it participated was then extracted, together with corresponding counts of occurrence.

Distributional similarity of two words is measured by the similarity of their associated lists of grammatical relations. A variety of different methods for calculating similarity have been investigated in the literature, including standard techniques such as the cosine measure (Manning & Schütze 1999). The present work adopts an information-theoretic similarity measure introduced by Lin (1998). This measure has been widely used in language processing applications to discover near-synonyms and has been shown to perform particularly well in comparison to other similarity measures (Weeds & Weir 2003, McCarthy & Navigli 2009). Similarity scores were calculated between all pairs of creativity words of the same grammatical category. That is, scores were obtained separately for pairs of nouns, pairs of verbs and so on.

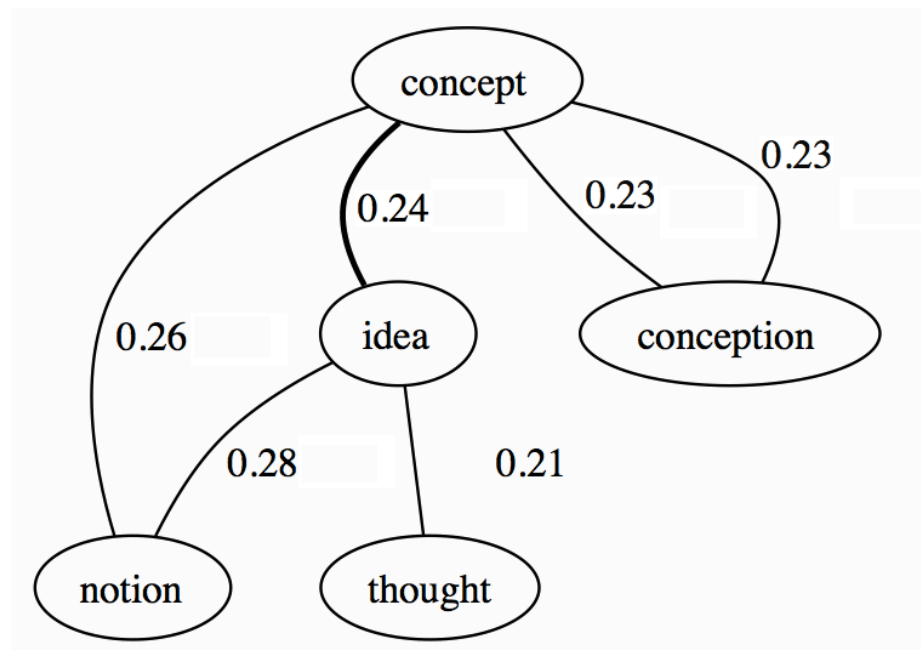


Figure 1. Graph representation of the similarity of the nouns *concept* and *idea* and closely semantically related words. Each word is drawn as a node in the graph, linked together by a weighted edge representing the similarity of the two words (maximum similarity strength is 1.0).

The word similarity data can be visualised as a graph or network, where similar words are linked together and the links weighted by similarity scores (for any score > 0). An example of such a graph is shown in Figure 1. Graphical representations of similarity data like that shown in the figure provide a useful basis for further analysis. The graph clustering software *Chinese Whispers* (Biemann 2006) was used to automatically identify word clusters in the dataset. This algorithm iteratively groups together graph nodes according to how closely they are linked together. By grouping words with similar meanings, the number of data items was effectively reduced and themes in the data could be recognised more readily from each distinct cluster.

The clustering results were inspected manually to help eliminate noise in the data and to focus on the key themes or concepts, rather than the individual words. Themes discovered through clustering were further analysed in terms of the *Four Ps* of creativity (as discussed earlier) to identify alternative perspectives and reveal subtler (but still important) aspects of creativity. For example, *novelty* is commonly associated with the results of creative behaviour (*product*), but we can also recognise as creative a novel approach to a task (*process*). Similarly, if a product is novel in a particular environment (*press*), then that product may well be regarded as creative by those in that environment. Viewing *novelty* from the perspectives of *product*, *process* and *press* uncovers these subtle and interlinked distinctions. From the clustering analysis and manual inspections described above, it was possible to progress towards the identification of a set of fourteen key components of creativity, shown in Figure 2 and defined in Appendix B.

No claim is made that the fourteen components constitute a necessary and sufficient definition of creativity. Creativity manifests itself in different ways across different domains (Plucker & Beghetto 2004) and the components will vary in importance and emphasis, accordingly. So, creative behaviour in mathematical reasoning has more focus on finding a correct solution to a problem than is the case for creative behaviour in, say, musical improvisation (Colton 2008, Jordanous 2012). It is also interesting to observe that some of the identified components appear logically inconsistent with others in the set. For example, the theme of autonomous, independent behaviour (*Independence and Freedom*) conflicts with the apparent requirement for social interaction (*Social Interaction and Communication*). The set of components is therefore presented as a collection of dimensions (attributes, abilities and behaviours) that contribute to our overall understanding of creativity. The components may be viewed as a set of *building blocks* for creativity that may be arranged in different ways and with different emphases to suit different purposes.

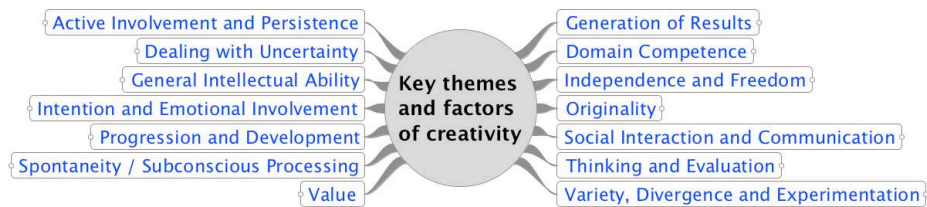


Figure 2: Fourteen key components of creativity derived from an analysis of the language used to talk about creativity in a sample 30 academic papers on the subject.

Identifying how creativity is manifested in musical improvisation

The fourteen building blocks of creativity represent a collection of recurring themes or factors in discussions of the general nature of creativity. To understand the special nature of creativity in the domain of musical improvisation, the relative importance of these fourteen components was quantified. A study was run in which a group of subjects with a range of musical expertise and experience were questioned to identify what they regarded as most important in the context of creativity in musical improvisation. The results of the study were then used to provide relative weightings for the fourteen key components.

A group of 34 subjects was recruited to the study. Study participants came from a variety of different backgrounds though were generally musicians and had different levels of expertise in and experience of various musical styles.^{vii} Each was asked about his or her musical experience and training as well as the type of improvisation they had experience of. From the 34 subjects, 15 considered themselves to be professional musicians, 8 semi-professionals and 8 amateurs. The remaining 3 were non-musicians who had experience of listening to musical improvisation and were therefore able to give an informed but different perspective. The length of time for which individuals within the group considered that they had been practising musicians ranged from 22 - 40 years, with a mean of 20.2 years, median of 19 years and standard deviation of 14.5 years. Similarly, the subjects were asked about their experience of musical improvisation. In this case, 10 of the subjects considered themselves to have attained a professional standard, 10 semi-professional and 9 amateur. The remaining 5 considered themselves to have no direct experience of practising musical improvisation. The length of time for which individuals considered that they had been practising musical improvisers ranged from 10 - 40 years, with a mean of 15.1 years, median of 12 years and a standard deviation of 14.3 years.

Each subject was emailed a questionnaire to fill in and return. The questionnaire required the participant to think about the following groups of words in the context of musical improvisation and to briefly describe what these words meant to them in this context:

1. thinking / thought / cognitive.
2. process / processes.

3. innovation / originality / new / novel.
4. divergence / divergent.
5. openness.
6. ideas / discovery.
7. accomplishments / contributions / production.
8. intelligence / skills / ability / knowledge / talent.
9. problem / problem-solving.
10. personality / motivation.
11. creativity

Each of these words included in the questionnaire occurred in the creativity corpus significantly more often than might be expected by chance, as measured by the log-likelihood ratio. The words were collected together into ten different groups of related items and these groups presented to the subjects in different, randomized orders. The ten groups were always followed by the target word *creativity*. This presentation was designed to familiarise the participants with the process of thinking about words relating to creativity in the context of musical improvisation before presenting them with the target word. Presenting *creativity* as the last word to consider meant that the participants had ten short practice trials before tackling the word this study was most interested in.

After completing the questionnaire, the participants were asked to read a debrief document which briefly outlined the purposes of the questionnaire and introduced this research project. Participants were then asked the following final questions:

Are there any words which you feel are important for describing creativity in musical improvisation that have not been mentioned so far? If so, what are these words and why are they important?

Participants returned both the completed questionnaire and the debrief document for analysis and were encouraged to pass on any further comments or questions they had.

Building a model of creativity in musical improvisation

Participants reported that they enjoyed completing the questionnaire and became fully absorbed in providing responses. This is borne out by analysis of the length of the responses to each of the groups of words in the questionnaire. As shown in Figure 3, the average length of responses ranged from 171 words (*process/processes*) to just under 293 words (*personality/motivation*). However, there is no noticeable drop off in the length of the responses given by participants for the final word *creativity*, which is around the average for the 11 items. This suggests that subjects did not suffer any undue fatigue in completing the questionnaire. In terms of their content, the responses to the ten 'practice items' focused narrowly on the relevant word or group of words. While it had been hoped that some useful additional data might be given in the responses to these ten items, in practice they appeared of limited use except as practice trials for the eleventh question. At the end of the study, 29 of the subjects

took the opportunity to volunteer additional comments about words they associated with creativity in musical improvisation. This prompted further discussions with 6 of the participants and provided useful contextual information.

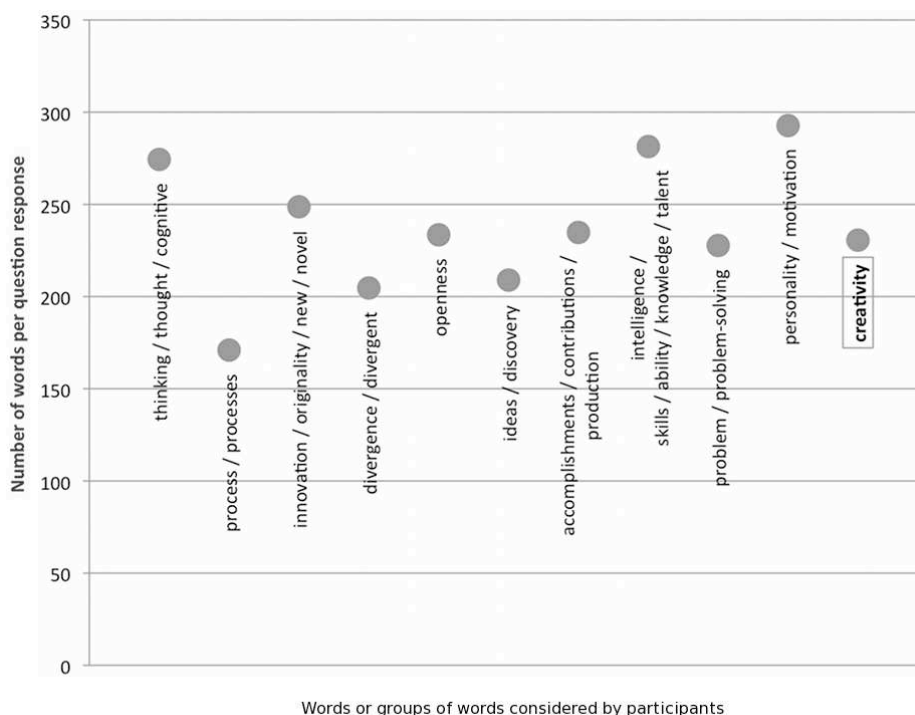


Figure 3: Responses for each question ranged from a mean length of 171 to 293 characters, with an overall mean of 237 characters. Responses for ‘creativity’ were a mean of 231 characters long.

The responses provided by the participants to the question about the word *creativity* and to the final questions, together with any follow-on comments were considered with respect to the fourteen key components of creativity, using response tagging for a quantitative analysis. For each response provided by a participant, where comments were made that mapped to a component (or components), this part of the response was annotated to indicate that this component(s) had been mentioned. Negative as well as positive mentions were recorded. For example, the response “*Originality or doing something different with known elements*” was tagged as: “*Originality or doing something different{originality} with known elements{domain competence}*”.

After tagging all of the responses, tags for each component were totalled together. Hence each of the fourteen components could be allocated a score that quantified the perceived importance of that component in the questionnaire data, given as the count of all positive mentions of that component minus the count of all negative mentions of that component:

$$I_C = pos_C - neg_C$$

where, I_C is the perceived importance of creativity component C , pos_C is the number of positive mentions that were tagged as illustrative of C and neg_C is the number of negative mentions tagged as illustrative of C .

The results of this analysis of the participants' responses are summarised in Figure 4. All components were mentioned by participants to some degree. Two components were occasionally identified as having a negative as well as positive influence. For example, over-reliance on domain competence was sometimes seen as detrimental to creativity, though in general domain competence was considered to be very positive factor. Of the fourteen components, those considered most important for musical improvisation were: *Social Interaction and Communication*, *Domain Competence* and *Intention and Emotional Involvement*. The importance counts were converted to weights by calculating the percentage of comments for each component in the sum total of all comments for all components (see Table 2).

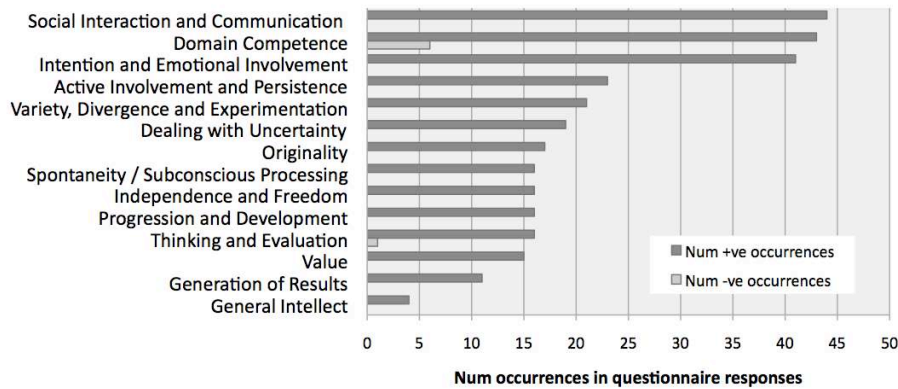


Figure 4: Importance and relevance of creativity components to improvisation.

In this way, a model of creativity in musical improvisation is generated through the identification of fourteen key components of creativity and the analysis of these in the context of musical improvisation. The components (building blocks of creativity) are presented in Figure 2 and in Appendix B. Table 2 presents a quantified measure of each component's relative importance in musical improvisation creativity.

The model of musical improvisation creativity: Discussion

It is possible to use this model of creativity in musical improvisation to reflect on our original questions: what makes musical improvisation creative, and what exactly is it that justifies one improviser being described as more creative than another? Key aspects of creativity in musical improvisation have been identified: the ability to communicate and interact socially, the possession of relevant musical and

improvisational skills and knowledge, and emotional engagement and the intention to be creative. It is notable that the products of musical improvisation appear to be relatively less important than these process-based aspects. Furthermore general intelligence is less important than specific musical improvisation expertise and knowledge.

Table 2: Converting the I_c values into weights representing component importance.

Component	I_c	weight percentage
Social Interaction and Communication	44 - 0 = 44	14.9%
Domain Competence	43 - 6 = 37	12.5%
Intention and Emotional Involvement	41 - 0 = 41	13.9%
Active Involvement and Persistence	23 - 0 = 23	7.8%
Variety, Divergence and Experimentation	21 - 0 = 21	7.1%
Dealing with Uncertainty	19 - 0 = 19	6.4%
Originality	17 - 0 = 17	5.8%
Spontaneity / Subconscious Processing	16 - 0 = 16	5.4%
Independence and Freedom	16 - 0 = 16	5.4%
Progression and Development	16 - 0 = 16	5.4%
Thinking and Evaluation	16 - 1 = 15	5.1%
Value	15 - 0 = 15	5.1%
Creation of Results	11 - 0 = 11	3.7%
General Intellect	4 - 0 = 4	1.4%
	295	100.0%

In terms of the development of creativity in improvisation, it would seem most fruitful to concentrate on improving an individual's ability to communicate and interact with the musicians around them (as well as others in a social environment, such as the audience). Demonstrating a definite intention and an emotional involvement in what is being done is also highly important for creative, musical improvisation. Knowledge and competence in relevant musical skills is a further area to concentrate effort on. This includes technical ability on the instrument, as well as knowledge of scales, chords or structures. At the same time, the improviser should not be over-reliant their technical knowledge. Other factors that contribute to creativity in musical improvisation include the ability to be autonomous, free and independent, though as noted above, this is tempered by the need to communicate and interact in a group setting.

Other authors on musical improvisation have previously noted the importance of group communication, interaction and involvement. The model of creativity presented here thus provides empirical evidence to support what has already been proposed in

the literature. The earlier discussions on musical intention and on making choices are also supported by this paper's results, both in terms of the high importance of intention and emotional involvement and in the balance between autonomy and freedom, on one hand, and spontaneity and subconscious processing, on the other.

Several respondents strongly associated or conflated improvisation with creativity in the context of musical improvisation, supporting a similar conflation often made by authors in related literature (as discussed above). Such an association was not observed in the responses for the other ten items in the questionnaire. For example:^{viii}

"improv the only way I feel that I can be truly creative during live performance"[sic]

"The word creativity in relation to improvisation is critical, and is the defining word I would use to describe improvisation"

[creativity:] *"The very background impetus for an improvisation. This is what is expressed in every part of an improvisation"*

"Improvisation is fundamentally about creativity"

"Improvisation is creative by its very nature"

This intertwining of musical improvisation and creativity underlines the importance of understanding and developing creativity, in the pursuit of improving musical improvisation skills. Musical improvisation is seen as a highly creative activity; hence to understand the creative aspects of this activity helps better understand improvisation itself. Interestingly several of the participants offered their own definitional takes on creativity in musical improvisation, despite not explicitly being asked to do so. These offerings serve to illustrate the range and variety of aspects considered important to creativity in musical improvisation, as well as the inclination of these participants to better understand creativity by deconstructing it into componential parts. Examples include:

"Originality or doing something different with known elements - producing something new which hasn't been heard before"

"being yourself. Not conforming to the norm"

"doing whatever you feel like, following creative impulses"

"about our ability to organize our thoughts and go with the flow or thoughts in real time"

"give expression to and trust the heart"

"Improvising so (1) as to surprise, to be inventive, (2) to seem of worth (= a response like 'now that IS good!'), and (3) still to have a connection or link to the basic line, the tune on which the improvisation is being developed"

Evaluating the model of musical improvisation creativity

The aim of this work is to develop a comprehensive and empirically grounded understanding of what it means to be creative in musical improvisation. The work has been conducted in the scope of a wider project examining creativity in computational systems, by modelling what it means for a computer system to be creative (Jordanous 2012). Hence to evaluate the model offered in this paper, the creativity of three musical improvisation systems was analysed and assessed using the current model, other models of creativity that have been previously proposed and through an opinion poll.^x The different systems were rated numerically by judges according to how well they met each of the criteria. These ratings were then weighted according to the percentages given in Table 2. Qualitative data was also collected from the judges' comments. Further details can be found in Jordanous (2012).

The results and feedback obtained in this analysis gave an informed comparison as to which systems were more creative and in what ways. It also found that for further improvements on the creativity of these systems as musical improvisers, greatest gains can be made in all three systems by improving performance in Social Interaction and Communication, Intention and Emotional Involvement and Domain Competence, i.e. the components found to be most important for musical improvisation creativity. The system authors considered the results in terms of how accurately they captured the creativity of their system, as they perceive it, and how useful the feedback proved to be for learning about and developing the system's creativity. Feedback showed that authors found the model of musical improvisation presented in this paper provided detailed and useful information about a system's creativity; it was generally regarded as accurate except in some small details.

To compare the proposed model of musical improvisation creativity against other models and against human intuition, the creativity evaluations generated from this model were contrasted with those obtained using other models and also with the results of an opinion survey. The survey was carried out across 111 people who were asked how creative they thought each system was.

All of the evaluations agreed upon which of the computational systems were considered to be the most and the least creative. However, they differed markedly in terms of the formative feedback provided. This was particularly evident in terms of identifying a system's creative strengths and any weaknesses that should be improved upon. The model offered in this paper gave the most detailed and targeted feedback, though it also required the most information to be collected.

An additional finding of the opinion survey supported the need identified in the literature for standards or consensus of opinion to refer back to, when performing creativity evaluations (Rhodes 1961, Torrance 1988, Plucker et al. 2004, Hennessey & Amabile 2010). Several people noted a preference to be supplied with a definition of creativity, or guidelines for evaluation, rather than relying purely on their own intuitive understanding.^x

Conclusions

This work investigates creativity in musical improvisation with the aim of obtaining deeper insight into how such creativity is manifested in practice and providing more tangible strategies for creative development. To better understand how musical improvisation is creative, it is necessary to have both a general understanding of creativity and an appreciation of what is particular to creativity as manifested in musical improvisation. Creativity can be thought of as the combination of various aspects that transcend different creative activities to some extent. The relative importance of each aspect increases or decreases according to the type of creativity being engaged with. In order to understand musical improvisation creativity therefore, this paper first identifies componential common aspects of creativity which can be used as ‘building blocks’ to construct an understanding of creativity. The relative importance of each of these building blocks is then considered in the context of interest here: musical improvisation creativity.

In this way, the paper presents a detailed, comprehensive, cross-disciplinary model of creativity in musical improvisation. The model consists of fourteen key, common components of creativity (identified using empirical natural language processing methods and statistical techniques) and a representation of each component’s importance for musical improvisation creativity (identified through analysis of improvisers’ opinions). In particular, the following are highlighted as key for creative musical improvisers: the ability to communicate and interact socially, the possession of musical skills and improvisational competence, and the demonstration of intention and emotional involvement in the improvisational process. With a detailed understanding of what makes musical improvisation creative, improvisers and their teachers can focus on what they should work on to improve their creativity (Gibbs 2010). Future work in applying this model of musical improvisation creativity for educational purposes would be interesting to explore and could prove very fruitful in improvisers’ creative development.

The model of musical improvisation creativity presented here has been used to evaluate computational musical improvisers in terms of how creative they are, identifying why one system is perceived as more creative than another and indicating how to improve each system’s creativity (Jordanous 2012). In comparison with other creativity models, the proposed model of musical improvisation creativity agreed with other models in terms of the relative creativity of each system, while providing the most detailed, targeted feedback for how to improve the creativity of each system (based on more comprehensive and focused information gathering requirements for this model). This model also helps resolve issues encountered when asking people to evaluate the creativity of musical improvisation systems: people were unsure how to perform this evaluation task, questioning what it entailed for musical improvisation to be creative.

To better identify how to develop one’s own creativity, how to evaluate creativity or how to learn from the creativity of others, it is highly beneficial to have a greater and more tangible understanding of the various relevant aspects involved. A key

conclusion drawn from the work presented in this paper is that the understanding and evaluation of creativity requires clear standards to use as guidelines or benchmarks, to guide our efforts in appropriate directions and to help target feedback for greater understanding and future development of creativity. The model in this paper offers the standards needed to meet this requirement.

References

- Baer, J. (2010) Is creativity domain-specific? In J.C. Kaufman and R.J. Sternberg, editors, *The Cambridge Handbook of Creativity*, chapter 17, 321–341. Cambridge University Press, New York
- Bailey, D. (1993) *Improvisation: Its nature and practice in music*. Da Capo Press, New York
- Barrett, F.J. (1998) Creativity and improvisation in jazz and organizations: Implications for organizational learning. *Organization Science*, 9(5): 605–622
- Benjamini, Y. & Hochberg, Y. (1995). Controlling the false discovery rate: a practical and powerful approach to multiple testing". *Journal of the Royal Statistical Society, Series B* 57 (1): 289–300. MR 1325392.
- Berkowitz, A.L. & Ansari, D. (2010) Expertise-related deactivation of the right temporoparietal junction during musical improvisation. *NeuroImage*, 49(1):712–719
- Berliner, P.F. (1994) Thinking in jazz: the infinite art of improvisation. *Chicago Studies in Ethnomusicology*. The University of Chicago Press, Chicago, IL
- Biasutti, M., & Frezza, L. (2009) Dimensions of Music Improvisation. *Creativity Research Journal*, 21(2), 232–242
- Biemann, C. (2006) Chinese Whispers: an efficient graph clustering algorithm and its application to natural language processing problems. In *Proceedings of TextGraphs: the First Workshop on Graph Based Methods for Natural Language Processing*, 73–80, Morristown, NJ. Association for Computational Linguistics
- Boden, M.A. (2004) *The creative mind: Myths and mechanisms*. Routledge, London, UK, 2nd edition
- Briscoe, E., Carroll, J., & Watson, R. (2006) The second release of the RASP system. In *Proceedings of the COLING/ACL 2006 Interactive Presentation Sessions*, Sydney, Australia
- Bryan-Kinns, N. (2009) Everyday creativity. In *Proceedings of the 7th ACM conference on Creativity and Cognition (Introductory Address)*, Berkeley, CA
- Butler, C. (1985) *Statistics in Linguistics*. Blackwell, Oxford, UK
- Colton, S. (2008) Creativity versus the perception of creativity in computational systems. In *Proceedings of AAAI Symposium on Creative Systems*, 14–20
- Csikszentmihalyi, M. (1988) Society, culture, and person: a systems view of creativity. In R.J. Sternberg, editor, *The Nature of Creativity*, chapter 13, 325–339. Cambridge University Press, Cambridge, UK
- Csikszentmihalyi, M. (2009) The creative person and the creative system (keynote address). In *Proceedings of the 7th ACM Creativity and Cognition conference*, 5–6, Berkeley, CA
- Dunning, T. (1993) Accurate methods for the statistics of surprise and coincidence. *Computational Linguistics*, 19(1):61–74
- Friis-Olivarius, M., Wallentin, M., & Vuust, P. (2009) Improvisation - the neural foundation for creativity. In *Proceedings of the 7th ACM Creativity and Cognition Conference*, 411–412, Berkeley, CA

- Gallie, W.B. (1956). Essentially contested concepts. In *Proceedings of the Aristotelian Society*, 56, 167–198
- Garfield, E. (1972) Citation analysis as a tool in journal evaluation *Science* 178: 471–479
- Gibbs, L. (2010) Evaluating creative (jazz) improvisation: Distinguishing invention and creativity. In *Proceedings of Leeds International Jazz Conference 2010: Improvisation - jazz in the creative moment*, Leeds, UK
- J. P. Guilford (1950) Creativity. *American Psychologist*, 5: 444–454
- Harris, Z. (1968) *Mathematical Structures of Language*. Wiley, New York
- Hennessey, B.A. & Amabile, T.M. (2010) Creativity. *Annual Review of Psychology*, 61:569–598
- Ivcevic, Z. (2009) Creativity map: Toward the next generation of theories of creativity. *Psychology of Aesthetics, Creativity, and the Arts*, 3 (1): 17–21
- Johnson-Laird, P.N. (2002) How Jazz Musicians Improvise. *Music Perception*, 19(3), 415–442
- Jordanous, A. (2010) Defining creativity: Finding keywords for creativity using corpus linguistics techniques. In Proceedings of the *International Conference on Computational Creativity*, 278–287, Lisbon, Portugal
- Jordanous (2012) *Evaluating Computational Creativity: A Standardised Procedure for Evaluating Creative Systems and its Application*. PhD thesis, University of Sussex, UK
- Kaufman, J. C. (2009) *Creativity 101*. The Psych 101 series. Springer, New York
- Kilgarriff, A. (2001) Comparing corpora. *International Journal of Corpus Linguistics*, 6(1):97–133
- Leech, G. (1992) 100 million words of English: the British National Corpus (BNC). *Language Research*, 28(1):1–13
- Lewis, G.E. (2011) Improvising with creative machines: Reflections on human-machine interaction (keynote talk). In Proceedings of the *2nd International Conference on Computational Creativity*, xii–xiii, Mexico City, Mexico
- Lin, D. (1998) An information-theoretic definition of similarity. In *Proceedings of the 15th International Conference on Machine Learning*, 296–304, Madison, WI
- MacKinnon, D. W. (1970) Creativity: a multi-faceted phenomenon. In Roslansky, J. D., editor, *Creativity: A Discussion at the Nobel Conference*, 17–32. North-Holland Publishing Company, Amsterdam, The Netherlands
- Manning, C. & Schtüze, H. (1999) *Foundations of Statistical Natural Language Processing*. MIT Press, Cambridge, MA
- Mayer, R.E. (1999) Fifty years of creativity research. In R.J. Sternberg, editor, *Handbook of Creativity*, chapter 22, 449–460. Cambridge University Press, Cambridge, UK
- McCarthy, D. & Navigli, R. (2009) The English lexical substitution task. *Language Resources and Evaluation: Special Issue on Computational Semantic Analysis of Language*, 43(3):139–159
- Oakes, M.P. (1998) *Statistics for Corpus Linguistics*. Edinburgh University Press, Edinburgh, UK
- Plucker, J.A. & Beghetto, R.A. (2004) Why creativity is domain general, why it looks domain specific, and why the distinction doesn't matter. In Sternberg, R.J., Grigorenko, E.L. & Singer, J.L., editors, *Creativity: From Potential to Realization*, chapter 9, 153–167. American Psychological Association, Washington, DC
- Plucker, J.A., Beghetto, R.A., & Dow, G. T. (2004) Why isn't creativity more important to educational psychologists? Potentials, pitfalls, and future directions in creativity research. *Educational Psychologist*, 39(2):83–96
- Poincaré, H (1929) Mathematical creation. In *The Foundations of Science: Science and Hypothesis*, [Original French version published 1908, tr. G. B. Halsted], vol: Science & Method, Chapter III, Book I, 383–394. The Science Press, New York

- Pressing, J. (1987) Improvisation: Methods and models. In Sloboda, J.A., editor, *Generative Processes in Music: The Psychology of Performance, Improvisation and Composition*, chapter 7, 129–178. Oxford University Press, Oxford, UK
- Rayson, P. & Garside, R. (2000) Comparing corpora using frequency profiling. In *Proceedings of ACL Workshop on Comparing Corpora*, Hong Kong
- Rhodes, M. (1961) An analysis of creativity. *Phi Delta Kappan*, 42(7):305–310
- Sawyer, R.K. (1999) Improvised conversations: Music, collaboration and development. *Psychology of Music*, 27:192–205
- Sawyer, R.K. (2006) Group creativity: musical performance and collaboration. *Psychology of Music*, 34(2):148–165
- Sternberg, R.J. & Lubart, T.I. (1999) The concept of creativity: Prospects and paradigms. In Sternberg, R.J., editor, *Handbook of Creativity*, chapter 1, 3–15. Cambridge University Press, Cambridge, UK
- Thom, B. (2003) Interactive improvisational music companionship: A user-modeling approach. *User Modeling and User-Adapted Interaction*, 13:133–177
- Torrance, E.P. (1988) The nature of creativity as manifest in its testing. In Sternberg, R.J., editor, *The Nature of Creativity*, chapter 2, 43–75. Cambridge University Press, Cambridge, UK
- Walker, W.F. (1997) A Computer Participant in Musical Improvisation. *Conference on Human Factors in Computing Systems (CHI'97)* (pp. 14–17)
- Weeds, J. & Weir, D. (2003) Finding and evaluating nearest neighbours. In *Proceedings of the 2nd Conference of Corpus Linguistics*, Lancaster, UK
- Wittgenstein, L. (1958) *Philosophical Investigations*, eds. Anscombe, G.E.M., Rhees, R. & Von Wright, G.H. (2nd edition). Basil Blackwell, Oxford, UK

ⁱ Converted to British English spellings for standardisation.

ⁱⁱ Whilst not a perfect reflection of a paper's influence, citation data is often used for measuring the impact of a journal (Garfield 1972) or an individual researcher's output (Hirsch 2005).

ⁱⁱⁱ Due to practical issues with extracting text from older PDF documents for text processing.

^{iv} As categorised by the literature database *Scopus* (<http://www.scopus.com/>), last accessed 27th January 2012.

^v At around 300K and 700K words respectively, the creativity and non-creativity corpora are very small compared to the British National Corpus (\approx 100M words) and tiny in comparison to recent, web-derived text collections of billions of words.

^{vi} Multiple testing will give rise to a relatively large proportion of false positives (words that by chance appear associated with creativity). It is possible to correct for this effect (Benjamini, Y. & Hochberg, Y., 1995). However, it is important to note that the present work aims to identify key themes or concepts based on a clustering of the words extracted from the creativity corpus. Crucially, we are not interested in the individual words *per se* and can tolerate a proportion of “false discoveries” in the data prior to clustering without invalidating the results.

^{vii} Nationalities ranged across European, American and Asian continents, although the majority of participants were recruited from UK-based contacts. Participants collectively had experience improvising in a wide range of genres, including jazz, folk and world music.

^{viii} All quotes are verbatim and may occasionally contain grammatical or spelling inaccuracies.

^{ix} We would like to see our model of musical improvisation creativity applied to describe, inform and evaluate the creativity of human musical improvisers, especially by those involved in music education or in research on developing creativity in improvisation.

^x This may be due to unfamiliarity with or biases against computational creativity. Most participants reported positive or at least neutral views on computational creativity; this may not stop subconscious biases affecting evaluations (Moffat & Kelly 2006) but would reduce overt negative biases. Difficulties may also arise in objectively rating a subjective concept like creativity, though participants generally reported feeling confident about their responses.

Appendix A: The 30 papers in the creativity corpus

- T. M. Amabile. The social psychology of creativity: A componential conceptualization. *Journal of Personality and Social Psychology*, 45(2):357-376, 1983.
- M. A. Boden. *Precis of The Creative Mind: Myths and mechanisms*. Behavioural and Brain Sciences, 17(3):519-570, 1994.
- D. T. Campbell. Blind variation and selective retentions in creative thought as in other knowledge processes. *Psychological Review*, 67(7):380-400, 1960.
- S. Colton, A. Pease, and G. Ritchie. The effect of input knowledge on creativity. In *Proceedings of Workshop Program of ICCBR-Creative Systems: Approaches to Creativity in AI and Cognitive Science*, 2001.
- M. Csikszentmihalyi. Motivation and creativity: Toward a synthesis of structural and energistic approaches to cognition. *New Ideas in Psychology*, 6(2):159-176, 1988.
- M. Dellas and E. L. Gaier. Identification of creativity: The individual. *Psychological Bulletin*, 73(1):55- 73, 1970.
- Dietrich. The cognitive neuroscience of creativity. *Psychonomic Bulletin & Review*, 11(6):1011-1026, 2004.
- G. Domino. Identification of potentially creative persons from the adjective check list. *Journal of Consulting and Clinical Psychology*, 35(1):48-51, 1970.
- W. Duch. Intuition, insight, imagination and creativity. *IEEE Computational Intelligence Magazine*, 2(3):40-52, 2007.
- S. Findlay and C. J. Lumsden. The creative mind: Toward an evolutionary theory of discovery and innovation. *Journal of Social and Biological Systems*, 11(1):3-55, 1988.
- M. Ford. A theory of individual creative action in multiple social domains. *The Academy of Management Review*, 21(4):1112-1142, 1996.
- J. Gero. Creativity, emergence and evolution in design. *Knowledge-Based Systems*, 9(7):435-448, 1996.
- H. G. Gough. A creative personality scale for the adjective checklist. *Journal of Personality and Social Psychology*, 37(8):1398-1405, 1979.
- J. P. Guilford. Creativity. *American Psychologist*, 5:444-454, 1950.
- Z. Ivcevic. Creativity map: Toward the next generation of theories of creativity. *Psychology of Aesthetics, Creativity, and the Arts*, 3(1):17-21, 2009.

- K. H. Kim. Can we trust creativity tests? A review of the Torrance tests of creative thinking (TTCT). *Creativity Research Journal*, 18(1):3-14, 2006.
- L. A. King, L. McKee Walker, and S. J. Broyles. Creativity and the five-factor model. *Journal of Research in Personality*, 30(2):189-203, 1996.
- R. R. McCrae. Creativity, divergent thinking, and openness to experience. *Journal of Personality and Social Psychology*, 52(6):1258-1265, 1987.
- S. A. Mednick. The associative basis of the creative process. *Psychological Review*, 69(3):220-232, 1962.
- M. D. Mumford and S. B. Gustafson. Creativity syndrome: Integration, application, and innovation. *Psychological Bulletin*, 103(1):27-43, 1988.
- M. T. Pearce, D. Meredith, and G. A. Wiggins. Motivations and methodologies for automation of the compositional process. *Musicae Scientiae*, 6(2):119-147, 2002.
- J. A. Plucker, R. A. Beghetto, and G. T. Dow. Why isn't creativity more important to educational psychologists? Potentials, pitfalls, and future directions in creativity research. *Educational Psychologist*, 39(2):83-96, 2004.
- R. Richards, D. K. Kinney, M. Benet, and A. P. C. Merzel. Assessing everyday creativity: Characteristics of the lifetime creativity scales and validation with three large samples. *Journal of Personality and Social Psychology*, 54(3):476-485, 1988.
- G. Ritchie. The transformational creativity hypothesis. *New Generation Computing*, 24(3):241-266, 2006.
- G. Ritchie. Some empirical criteria for attributing creativity to a computer program. *Minds and Machines*, 17:67-99, 2007.
- L. Rubenson and M. A. Runco. The psychoeconomic approach to creativity. *New Ideas in Psychology*, 10(2):131-147, 1992.
- M. A. Runco and I. Chand. Cognition and creativity. *Educational Psychology Review*, 7(3):243-267, 1995.
- K. Simonton. Creativity: Cognitive, personal, developmental, and social aspects. *American Psychologist*, 55(1):151-158, 2000.
- J. R. Suler. Primary process thinking and creativity. *Psychological Bulletin*, 88(1):144-165, 1980.
- Wiggins. A preliminary framework for description, analysis and comparison of creative systems. *Knowledge-Based Systems*, 19(7):449-458, 2006.

Appendix B: Defining the 14 components of creativity

1. Active Involvement and Persistence - Being actively involved; reacting to and having a deliberate effect on a process. The tenacity to persist with a process throughout, even at problematic points.

2. Dealing with Uncertainty - Coping with incomplete, missing, inconsistent, uncertain and/or ambiguous information. Element of risk and chance, with no guarantee that problems can or will be resolved. Not relying on every step of the process to be specified in detail; perhaps even avoiding routine or pre-existing methods and solutions.

3. Domain Competence - Domain-specific intelligence, knowledge, talent, skills, experience and expertise. Knowing a domain well enough to be equipped to recognise gaps, needs or problems that need solving and to generate, validate, develop and promote new ideas in that domain.

4. General Intellect - General intelligence and intellectual ability. Flexible and adaptable mental capacity.

5. Generation of Results - Working towards some end target, or goal, or result. Producing something (tangible or intangible) that previously did not exist.

6. Independence and Freedom - Working independently with autonomy over actions and decisions. Freedom to work without being bound to pre-existing solutions, processes or biases; perhaps challenging cultural or domain norms.

7. Intention and Emotional Involvement - Personal and emotional investment, immersion, self-expression, involvement in a process. Intention and desire to perform a task, a positive process giving fulfillment and enjoyment.

8. Originality - Novelty and originality — a new product, or doing something in a new way, or seeing new links and relations between previously unassociated concepts. Results that are unpredictable, unexpected, surprising, unusual, out of the ordinary.

9. Progression and Development - Movement, advancement, evolution and development during a process. While progress may or may not be linear, and an actual end goal may be only loosely specified (if at all), the entire process should represent some developmental progression in a particular domain or task.

10. Social Interaction and Communication - Communicating and promoting work to others in a persuasive, positive manner. Mutual influence, feedback, sharing and collaboration between society and individual.

11. Spontaneity/Subconscious Processing - No need to be in control of the whole process; activities and thoughts may inform a process subconsciously without being fully accessible for conscious analysis. Being able to react quickly and spontaneously during a process when appropriate, without needing to spend time thinking about options too much.

12. Thinking and Evaluation - Consciously evaluating several options to recognize potential value in each and identify the best option, using reasoning and good

judgment. Proactively selecting a decided choice from possible options, without allowing the process to stagnate under indecision.

13. Value - Making a useful contribution that is valued by others and recognised as an influential achievement; perceived as special; 'not just something anybody would have done'. End product is relevant and appropriate to the domain being worked in.

14. Variety, Divergence and Experimentation - Generating a variety of different ideas to compare and choose from, with the flexibility to be open to several perspectives and to experiment with different options without bias. Multitasking during a process.

Biographies

Anna Jordanous is a post-doctoral researcher at the Centre of e-Research, Digital Humanities, King's College London. Currently working on a project to explore the cultural value of electronic music, Anna has conducted research in digital humanities, computational creativity, music informatics, research evaluation and technology-enhanced learning/research. Her doctoral research (2012) posed the question: How should we evaluate the creativity of computational systems? With a background combining musical performance and study of Artificial Intelligence and computer science, she has published work on musical improvisation programs, computational musicological analysis and artificially intelligent accompaniment systems. As a musician, Anna plays and performs regularly, including occasional small-group jazz improvisation with her co-author Bill and other colleagues.

Bill Keller is a Senior lecturer in Computer Science and Artificial Intelligence in the Department of Informatics, The University of Sussex. He holds an MA in Cognitive Science and a PhD in Computational Linguistics from the University of Sussex and has published on a wide range of topics in Natural Language Processing. His early work concerned approaches to the semantics of natural language and in particular that of quantification in noun phrases. He has conducted research into the formal and computational properties of grammatical and lexical knowledge representation formalisms and investigated techniques for automated learning of natural language syntax and the lexicon. His current research interests include probabilistic approaches to semantics as well as interdisciplinary work on alignment phenomena in natural dialogue. Bill is a self-taught musician who enjoys playing in a variety of musical settings.