Until recently, the processes and methods used by designers have been rather traditional. As times have changed, so too have the tools used by designers to bring their inspirations into reality and develop their concepts. Now, the majority of results of the design process can be attributed to intelligent products or services. We are rapidly advancing towards an era of Industry 4.0, which is radically transforming the creative process. Data can now be part of the creative process in new and innovative ways. Many businesses in a wide range of fields are already using data to provide personalised experiences to millions of people through their products. The ever-growing influence of data management has not yet been fully appreciated in the field of design. Information derived from data allows the designer to understand context, learn and evolve with the consumer and create unique experiences. In this research paper, a new way of working is defined and new models to follow are developed.

big data, design process, methodology, creativity.

1 Introduction

Today, the objects which present greatest complexity of design are smart objects. We now have an enormous range of devices available to us which have internal computer technology and are partially or fully connected via the internet. We use these devices differently than we did even just a few years ago. All smart products are connected, making objects or people identifiable, locatable, directable and/or controllable, allowing us to complete our tasks and generating huge amounts of data. New technological advances are drastically changing the creative processes used to make smart objects and the ways in which these objects are used. As yet, there are no known methodologies which both make use of big data integrated into design’s creative process and provide solutions considered to be of genuine creative value. Our proposal, therefore, becomes increasingly important; the present study is intended to identify the determining factors in this evolution, including the shifting role of the designer brought about by emerging technologies. The current role of big data will be contextualised and an analysis of how big data can add value to the
creative process, the evolution of the creative process and its methodological application will be presented.

2 How big data is revolutionizing our environment

The rapid evolution that we are able to observe in the current context of Industry 4.0 supposes that it will be possible to include artificial intelligence in every object, in such a way that central agents will be able to communicate with every object, and every object with one another. We are able to see that in many sectors (healthcare, agriculture, education, industry, finance, security, marketing, etc.) data, and the information they generate, are being exploited to predict future scenarios (figure 1). Data have always offered a means to analyse past events, but the situation is now changing. Quantitative change has led to a qualitative change. It was in sciences like astronomy and genetics that the data explosion was seen for the first time in the 2000s.

Figure 1. Value potential of big data. Source: US Bureau of Labour Statistics; McKinsey Global Institute analysis.

Researchers in the fields of health and technology are collaborating, attempting to change our current reality through experimentation with artificial intelligence (AI) and machine learning using big data. The computers and algorithms that they use are capable of processing colossal amounts of data, much more quickly than human scientists or medical professionals. Thereby identifying patterns and making predictions which improve the diagnosis of diseases and informing the planning of treatments, improving public health and safety. Innovation is occurring at an ever-increasing speed and it is predicted that more advances will be made in the fields of medicine and economics in the next forty years than were made in the previous four thousand. Based on the extraordinary impact that improvements in healthcare systems could have for so many people and their potential to save lives and money, healthcare has become a key area for investment and development in AI and machine learning. Many businesses, like IBM and Microsoft are carrying out their own healthcare projects based on AI, just as many start-ups and smaller organizations have begun their own initiatives to develop medical assistance tools. The study conducted by McKinsey ("How big data can revolutionise pharmaceutical R&D", 2017), estimates that big data could save up to $100 billion per year in medication and pharmacies as a result of the increased efficiency of clinical trials and research, a more informed decision-making process and new tools which would aid insurers, regulators, doctors and consumers to make better decisions. There have already been strong indicators of big data’s potential to aid the monitoring and prediction of disease epidemics around the world as Google Flu Trends demonstrated in 2009 (Author, 2017) or the algorithm that identified the Ebola outbreak nine days before the World Health Organization. The computer studied social media, news reports and government websites to identify the outbreak’s existence. As with
any algorithm, the more data that it is provided, the more it learns and thus the better its prediction will be. Although tools such as that used to identify outbreaks are not yet perfect, it is clear that it has great potential.

3 The use of Big data and the creative industries

Creativity has recently become an important subject of reflection, analysis and controversy – possibly even revolution. It is considered from economic (Hawkins 2005), sociological (Joas 1996; 2012) and psychological (De Bono 2006; Csikszentmihalyi 1996) perspectives and has become part of debates ranging from industry and urbanization to social class and education among other issues. However, since the publication of Richard Florida's (2010) “The Rise of the Creative Class” in 2002, creativity has become an increasingly popular topic in the social sciences, provoking countless studies into the creative classes. It is not currently possible to understand the creative classes outside of the context provided by two other expressions: the “creative economy” and the “creative industries”. Fourteen sectors of the creative economy which have a significant artistic element exist in most countries. These include: advertising, architecture, the arts, craftsmanship, design, fashion, publishing, cinema and video production, television, recreational software development, music, the performing arts, photography, IT services, etc. However, Hawkins (2005) suggests that creativity exists in almost every area of collective life. Gaggioli, Riva, Milani & Mazzoni (2013) indicate that the sociocultural analysis of creativity has also emphasised the role of financial, economic and historical factors in the development of creative progress. Technological advances like big data and the internet of things (IoT) are likely to fundamentally change how we live and work in a new open and online world (Greengard, 2015). For the potential of these advances to be fully exploited, they must form the basis of digital technology:

…the increasing integration between devices, and the nature and quality of our reception and interpretation of this content. It is the case, then, that ‘the digital revolution’ pivots on user experience and the effective use of design” (Design Commission, 2014).

Economic, social, cultural and political decisions are increasingly being influenced by big data, but a disparity still exists between the creative industries and users ability to determine how big data is collected and how it is used. The amount of data we generate has grown exponentially (Helbing & Balietti, 2011) from 150 exabytes in 2005 to 4,423 in 2015, meaning that important opportunities may exist if these sources can be exploited effectively (Dove & Jones, 2014).

The evolution of the creative process

Creativity is a complex concept which is very mysterious for the majority of people. It has been advocated that although people have difficulty pointing out exactly what product creativity is it would seem to be identifiable by the majority (Amabile & Kidd, 1983). The approach to the appreciation of creativity drives an ongoing interest in researching the relationship between product creativity and science during the creative process. According to this research, creativity will be seen as an essential component of design (Chakrabarti, 2006), aided through data and using an adaptive, integrated model. A literary review has been carried out identifying the contributions and potential gaps in creative processes throughout history. The analysis shows certain deficiencies in the creative processes as expressed by Guilford (1950), who noted that there was "considerable consensus on the four phases comprising the creative process", which is traditionally recognised as preparation, incubation, illumination and verification. However, Guilford, unsatisfied with the above description, wrote: "that such an analysis is very superficial from the psychological point of view". It does not reveal anything about the mental operations involved. Guilford identified several factors that influence creativity, including problem sensitivity, the abilities to generate a large number of ideas, transform one’s mind-set, reorganise, deal with complexity and evaluate. Following over fifty years of research, our understanding of the cognitive processes of creativity has grown substantially, incorporating radical innovations at an extraordinary pace. Many researchers have based studies into creativity on the four-phase model which remains relevant today. (Busse & Mansfield, 1980;
Cagle, 1985; Goswami, 1996; Ochse, 1990; Osborn, 1953; Stein, 1974; Taylor, 1959; Taylor, Austin, & Sutton, 1974). Following and analysis of over 100 creativity and design processes, about half of which are included in this research, possible characteristics include: (1) Creativity is deemed to involve adaptation to the requirements of reality. (2) It is the quality of being original or novel. (3) Definitions are wide-ranging. (4) The product of creativity is a qualitative or structural advance. (5) The product of creativity is unpredictable even to the creator. Researchers including Brown (2008) indicate that computational creativity may reinforce the creative process due to higher precision and the use of computable constraints. The study of creativity may be supported by computer science with the creation of support tools enabling collaboration, difficulty management, history and rationale maintenance and facilitating exploration. (Lubert, 2005; Shneiderman, 2007). One of the most recent updates of the four-phase model corresponds to Amabile (1996) which incorporated a new vision, describing the creative process in several phases: (a) identification of the problem, (b) preparation (collection and reactivation of information), (c) generation of responses and (d) validation and communication of responses. Key to Amabile’s proposal is the suggestion of a final decision-making stage performed after a result is obtained, which makes it possible to end a process if the outcome is successful, suspend it if unsuccessful or return to an earlier phase, allowing iteration. Amabile’s proposal forms an important part of the present study, conceiving of the creative process as one in continual evolution. Guilford (1950), among others, submitted that the creative process might be analysed by breaking it down into its component sub-processes and examining these. The theories put forward by Guilford and Amabile form the foundation of this study.

4 Can big data improve the design process, offering better solutions to users more quickly?

In the current industry of the Internet of Things, it is understood that everything is connected and is capable of collecting and sharing data about how it is functioning. Ries (2011) refers to a new generation of services, products and systems which aims to alter users’ behaviour. Chakrabarti (2006) suggests that developments like the qualified self (ISO13407, 1999) and wearable technology may help find solutions to major challenges faced by society. Parameters which are nearly invisible to human perception, can be measured with the help of advanced analytical tools like machine learning, which means that through data analysis techniques, such as predictive analytics, events can be predicted before they occur and become a problem. Predictive analytics is used, for example, to foresee serious mechanical or structural faults: placing sensors in machines, motors or infrastructure such as bridges to monitor data and detect changes that could become problematic in the future. Artificial Intelligence (AI) allows us to collect and process a huge quantity of data, obtain better results and make better decisions in a more systematic and organised manner (Solares, 2017). Algorithms, neural networks and reasoning patterns, which are in theory similar to those used by humans, are applied in AI (Nilsson, 1980). How would we approach a new project if all of the collected data were available to us? Currently, the use of correlations is growing. Aviva, a large insurer, has used credit reports and consumer marketing data to approximate blood or urine tests applicants (The impact of big data on the future of insurance, 2016), allowing it to identify those which have a higher risk of suffering from conditions, such as high blood pressure, diabetes or depression. Aviva’s method uses data related to the subject’s lifestyle which include hundreds of variables: hobbies, web pages visited, hours of television watched, as well as income level, Aviva’s model of predictive analytics, developed by Deloitte Consulting, has shown positive results in identifying health risks. A few years ago, Google began its first trials of driverless cars in California. As tests are carried out, the car analyses each obstacle that it encounters and finds a solution instantly. The car then shares its information with all of the other cars operated by Google. From that moment on, the new obstacle will no longer pose a problem. The Google car is equipped with sensors, processors and communication devices. The connected car will be just one of millions of devices sending and receiving information to and from the cloud every second. Considering the integration
of the data into the design process, based on the examples above, it can be seen that data can have two clear directions. The first describes the use of data gathering through software applications and behaviours. Usage data, mainly with qualitative component, are based on correlations, generating data of an abstract nature through predictive analysis. The nature of this data will allow it to be used as creative material, providing high-value insights in the early stages of the creative process. The second direction, according to Google car’s example, describes a method for detailed and remote observation using sensors. The use of sensors provides a rich and detailed understanding of performance. The data obtained here are concrete, giving flexibility and new opportunities to collect quantitative data. Such data can be useful for both validation and improvement, allowing the design to be optimised even further. Speed & Oberlander (2016) indicate that there are three types of data used in the design process, which are: (1) Design from data: Systems are designed by people, so show quantifiable qualities of humans, computers, their contexts and their conditions. (2) Design by data: Systems are designed by humans and account for the data-flow through the system. (3) Design with data: Systems autonomously designed by other systems.

The existence of two separate forms of data, “abstract” and “concrete” data, is proposed by Uu & Zhu (2016). Abstract data is conceptual, not existing in reality, while concrete data exists, and can be collected and processed. However, in the present study a more specific classification, as proposed by Author (2017) will be used (Figure 2): (1) Concrete data: Produced by processing existing data sets. (2) Abstract data: The recontextualization of existing data to be used in predictive analytics, giving additional insight into, and aiding exploration and understanding of the data. Author affirms that, in accordance with the above definition of data use, abstract data will facilitate the development of novel concepts in the design process, while concrete data will aid in defining and improving design. Studying data in the creative process will allow us to learn how users use products, services or systems, what problems they encounter and what characteristics they ignore. CTO of Teradata, Stephen Brobst suggests that this will improve processes, stating that collecting all kinds of data is not practical, nor is constantly asking for it and ruining the user experience. Data-driven design aims to engage users in real-world usage contexts. Through a combination of different data sources and the ability to probe remotesly, it is possible to build empathy with users in the field. The availability of AI systems and easy access to large amounts of data during the design process will mean that designers will find fewer unwanted surprises at the end of the process, leading to better products that can be marketed much more quickly.

**5 The model: Data-driven design process**

Design has begun to adopt processes and methodologies used in other disciplines with the intention of focusing the design process on the user, providing both users and markets with valuable solutions. We have outlined what the impact of insights derived from data analysis could mean to the normal operations of many companies worldwide. With the integration of sensors and data collection mechanisms, the flow of data has dramatically increased, facilitated by the Internet of Things. The exploitation of this data is propelling innovation, creating and connecting ecosystems and providing...
many opportunities for businesses. The present research proposes that it will also be possible for design to exploit data through the use of a new, more advanced model. Many authors have concluded that new methods must be developed to advance design further. Research ranging from Guilford to Amabile last century to the most recent studies, have indicated the need to develop more advanced models. Julian (2002) states that it is a common belief that a prescriptive model of the design process and methods is necessary, an approach that Doesburg and Gropius (as cited in Julian, 2002) were proponents of from the early 1900s. It was not, however, until the middle of the 20th century that the study of design methods became relevant, faced with an increasingly complex design process. Based on the research presented in the previous sections and the need for an advanced design model adapted to the new reality influenced by big data presented herein, it is understood that while large data sets can improve design by stimulating creativity in its initial phase, design can provide greater understanding of the data, driving innovation, such is the hypothesis upon which the present study is based and is is represented in the data-driven design model proposed by Author (2017). The data-driven design model aims to bring the fields of data science and creativity together, building synergies and interaction, while improving effectiveness and efficiency throughout the lifecycle of the process.

Following the research presented above, the present study is based on the double diamond model, which is considered an advanced model which unifies the common features of design's creative process caused by its evolution. According to the Design Council, every discipline of design shares the same creative process, which it refers to as “The Double Diamond” (“The Design Process: What is the Double Diamond?”, 2015). Each specialisation within the field of design has different focuses and ways of working, but they all have some points in common, as can be seen in the double diamond diagram. These consist primarily of four different phases which are shared by the majority of models of the creative process, as can be seen in the summary (Lubart, 2001): Discover, Define, Develop and Deliver. The Design Council stated that “in all creative processes a number of possible ideas are defined (divergent thinking), before refining and reducing them to the best idea (convergent thinking)”. This can be represented in the form of a diamond. The double diamond indicates that this pattern of divergence and convergence happens twice, both to define the problem and as part of
the creation of the solution. The model illustrated in figure 3, based on prior studies and adapted from the "double diamond" model is intended to be an evolution; responding to the flexible and changing environments, aiding creativity. The result is a dynamic model that can adapt quickly to the requirements of the process and, clearly, the market. In the initial discovery phase, the Data-Driven Design model (DDD model) proposes the collection of all available data, extracting knowledge from data. Having access to large sets of data during the design process is assumed to aid creativity and as such allow a greater number of potential solutions. Such an abundance of data grants the designer freedom to explore more concepts and new perspectives or analyses while paying closer attention to certain facets of the process without losing the central focus. The design process is potentiated by the data collected from the thousands of connected devices in use today; transmitting information about their use and functioning.

Through the integration of concrete and abstract data, as in the Data Driven Design process (Author, 2017) (Figure 3), we are able to perform analyses to identify trends, in turn generating abstract data which may be used in predictive analytics, helping identify future performance scenarios or support a product, service or system continued development. The proposed model is more developed, transversal and flexible, although further research will be needed to ascertain its potential impact. Following this methodology, the data collected at the start of the process could be concrete (shown in the upper section of the diagram) or abstract (shown in the lower part). During the second phase, definition, analyses are performed to identify higher-level patterns, which can be used to define the design problem. It is now when the designer must give equal weight to the quantitative and qualitative aspects of their work. For example, if concrete data show that users perceive a problem that is not supported by data, it may be necessary to re-evaluate the situation and ask different questions in order to determine the actual problem. This is represented in the model by its bi-directionality: the iterative flow of the process. Conversely, abstract data may provide us with a more conceptual interpretation of a problem that must be solved, as the analysis is predictive and based on correlations that will help us define the present to improve the future, as shown in the example of Aviva and Deloitte. In the subsequent phases of Develop and Deliver, the process is similar to the double diamond with the proposed difference that the final solution evolves based on data collected after its implementation or the product’s release. This provides early feedback, allowing the solution to evolve and improve, or for an alternative solution to be developed. As well as integrating big data, the model improves traditional linear models via iteration, becoming a more agile and flexible model, allowing the final solution to be continually improved, reducing risks. The implementation of the data driven design model is a step forward in the design profession, which aids creativity and strengthens our capacity for invention of high creative quality through the use of data. Asta Roseway (Labarre, 2016), principal research designer at Microsoft, states that the designer’s role therefore will be:

"to act as the ‘fusion’ between art, engineering, research, and science. The ability to think critically while working seamlessly across disciplines, blending together their best aspects, is what will make the design professional a ‘Fusionist’. The challenge and reward for the Fusionist will be in her ability to communicate, comprehend, and connect all parties through design" (Labarre, 2016).

This statement captures the essence of what the designer’s role in the future will be.

6 Discussion
It was found that traditional models consider design methodologies to come to an end with the launch of a product, service or system that has been tested several times and is ready for the market. However, the DDD-model studied, with the integration of iteration in the final decision-making phase, allows the design process to remain "alive", as pointed out by Amabile, who states that it is possible to stop the process because a successful outcome has been achieved, to suspend it for an unwanted outcome or to return to any of the previous phases and continue working again. Consequently, it is not understood as a process that ends when the solution has reached the market,
but it is understood initially allowing the most important data to be tracked to obtain solutions at
the earliest opportunity, and then subsequently to develop improvements corresponding to data of
other priority levels. This aims to provide a better user experience. The most remarkable result that
emerges from the research is that the combination of a deep understanding of the user and a deep
learning of the big data is a step forward in the design process compared to traditional models.
It was found that data correlations used in the initial phase of the process stimulate creativity by
increasing efficiency and effectiveness on, introducing new patterns of innovation. There is evidence
to suggest the hypothesis that the model proposed can provide greater understanding of the data.
Given that our findings are based on a limited number of creative processes and models studied, the
results from such analyses should be treated with caution. But recent studies show that data is
already being used during product development, indicating that the model presented may have
great potential for future product, service or system development within creative industries. A more
recent and important example that makes use of big data is the Autodesk automotive project Hack
Rod. In order to develop the chassis for their racing car, the Hack Rod team fitted hundreds of
sensors to the chassis of a test vehicle, a so called “digital central nervous system” which would
provide data on the physical forces the driver and car were subject to. Based on the data collected, a
new chassis was designed using design software. The Hack Rod is an example of the intersection of
qualitative design and quantitative data science. While the model proposed is still in preliminary
stages and requires testing and implementation to verify if will be viable, we are hopeful that further
research will confirm our hypothesis. The data driven design model’s use of big data in the initial
stage makes the model more agile and flexible, helping to alleviate Design Fixation, which negatively
affects the start of the design process due to reliance on familiar method to the exclusion of new
ones that may be more suitable (Jansson, 1991). Mitigating design fixation will allow designers to
create innovative solutions. In “A Step Beyond to Overcome Design Fixation”, Moreno, Blessing,
Yang, Hernández & Wood (2014) indicate that utilizing big data and AI allow usage to be compared,
and experiences to be analysed based on correlations brought to light through data analysis,
allowing designers to gain insight into problems and implement solutions.

7 Conclusion
Current advances show that smart objects in the era of AI will change how the design process is
carried out. The rapid and continuous changes in society have provoked the creation of new creative
methodologies and processes, as have the new patterns of innovation to which the designer must
adapt. In this context, the designer’s expertise would shift form creativity itself to facilitating
creativity. Our study is intended to open a debate about the space created and the opportunities
which arise around the creative industries, as well as serving as the basis for an exploration of the
emergent space of design generated by emerging technologies which use big data. This includes the
application of data in the design process with the objective of improving it and serving as a tool for
the industrial designer, but it must be emphasised that the use of data is not a substitute for
creativity. New opportunities are available to designers thanks to big data. As has been argued, data
can be a determining factor in design’s creative process, but it is essential to consider that data
analysis does not explain why there is a problem, only that there is one. Data allow us to define the
problem, but we use the power of creativity to solve it. Direct contact with the user is still essential,
as it will now be necessary to collect data related to emotion, feelings, reactions and interpretations.
We are currently unable to imagine the potential of data and must rely on instincts. It may now no
longer be necessary, but the unquantifiable value of creativity cannot be disregarded. Creativity
should continue guiding the creative process, so that its application may represent real value for
design. Big data, which provides us with more reliable user data obtained in the field, if used
responsibly, can be a useful tool to make rational decisions and can make the design process more
effective. Accommodating the integration of data and creativity will be an important evolution and
advancement for design. Applying these methodologies to the creative industries and their
subsequent evolution are the basis of thought responding to needs, the entire process being applied
via creativity, balancing intuition with reason and design with science. The background research for this paper included an analysis of empirical studies and literature in the fields design and models of design and the creative process carried out through history. Based on the arguments and evidence presented in the present study, the following statement can be made: integrating big data (which is based on near infinite data) into the design process will allow easy access to a huge quantity of ideas and information; it represents a tool of great potential for designers, strengthening and supporting human creativity, creative results and innovation. As mentioned by Norman (2017):

“We need to think more about the design of human-machine teamwork. And we need to continue to expand the concept and tools of design, from design as specification, to design for use, to design that includes new business models” (Norman, 2017).

As such, the objective of integrating AI systems into the creative process of design is to aid it and that it may be more effective. In this situation, the designer would not lose their control over the process, on the contrary, their individuality and the personal nature of their idea would be reflected. The model being proposed is still in its nascent stages and requires full testing and implementation to ascertain its viability. It could be implemented through an online platform to aid data management. Post factum studies of the proposed model would also be necessary to determine whether the user experience could be optimised. In practice, given the appropriate approach and making use of artificial intelligence, the data-driven design model allows data to be reused intelligently, as well as serving as a base for computational creativity systems; becoming a wellspring for innovation. This model’s potential resides in the integration of data used iteratively, allowing continual internal feedback within the system, the designer to evolve the solution and establish levels of solutions to be implemented, becoming an “entity into which the designer inscribes value and from which the user infers value” (Zingale & Domingues, 2015). It is the designer's responsibility to create a flexible environment so that iteration may occur as fluidly and quickly as possible. The digital explosion and smart objects have shown us that there are no constants, nor certainties and that designs must evolve as the end users’ needs do.

As such, this study contributes to improving how we understand the use of big data, establishing objectives for future research. Viewing the future development of design from a strategic and anticipatory perspective represents a different way of facing the new scenario of Industry 4.0. In summary, I am inclined to think that traditional models of design are becoming obsolete in a new, changing, and flexible environment where immediate response and reaction are crucial: where design is a means of creating innovative solutions, guided by big data.

8 References

Author (2017) Conference paper


About the Author:

**J.C Quiñones**, is a Design Researcher at the University of Málaga whose expertise lies in product design, his research focuses on the evolution of the creative process through big data, studying the impact of digital technologies on creative activities.