DIFFUSION OF CREATIVE DESIGN: GATEKEEPING EFFECTS

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Abstract This paper presents computational experiments with a multi-agent framework of design to explore the idea that gatekeeping structures can determine how new solutions are created and spread in a society. These experiments support the idea that creativity transcends the individual domain. Situational factors such as the role of gatekeepers may determine how and who is considered creative in a society.

1. Introduction

Designers are interested in gaining a deeper understanding of creativity and innovation (von Stamm 2003). These two phenomena can be seen as complementary dimensions of a differentiation cycle that gradually reduces through commoditisation (Schumpeter 1939). Whilst design practitioners can be considered change agents of their societies, a deeper understanding on the micro-macro link between creativity and innovation is necessary. Creativity is increasingly considered as occurring in the interaction between the individual generator of an idea and a group of evaluators (Sawyer et al 2003). However, most studies define the specification of a solution -and not its social impact- as the outcome of the creative process (Runco and Pritzker 1999). On the other hand, innovation studies tend to exclude the generative process and focus on diffusion using an aggregate unit of analysis. In diffusion studies the term 'innovator' does not refer to the creator of a solution but to the initial category of adopters followed by early, late adopters and laggards in the S-shaped or sigmoid curve of diffusion (Rogers 1995).

This paper focuses on a key aspect of the link between generation and diffusion of creative design: the role of gatekeeping. Invention is an exemplary type of creative design where the role of gatekeepers is manifest (Lemelson-MIT 2004). An invention is first devised by an individual or a team who present it for evaluation at least at three social levels: a group of authorised experts who assess its novelty and feasibility, a population that adopts (and adapts to) it, and fellow practitioners who develop further solutions made possible within the new design space. Although creativity is an ambiguous term, its definition includes at least expert judgement, popularity, and peer recognition (Runco and Pritzker 1999; Simonton 2000). Inventions and inventors can be considered creative by the combination of these processes. H-creativity indeed implies that some sort of social agreement is necessary to distinguish a creative designer from the rest (Boden 1994). Certain aspects of this evaluative process are believed to emerge in a bottom-up direction through social interaction. Other top-down determinants are controlled by institutional structures such as patenting and intellectual property legislation (Australian Designs Office 2004).

Gatekeepers are individuals authorised to qualify the merits of creative solutions including their novelty. Apart from patent examiners, other types of gatekeepers in creative design include venture capital firms, exhibition and museum curators, journal and magazine editorial committees, and competition juries, amongst others. In most cases, approval or endorsement of gatekeepers is indeed necessary to turn an invention into an available product or design artefact. Nonetheless, little is known about the role of gatekeeping in a) promoting or deterring the generation of creative solutions and b) initiating their diffusion and the ascription of the 'creative' label to their creators. In a rigorous study of patterns of creative figures Gardner (1994) suggests that the hierarchical structure of a field has an

important effect on the ascription of prominence and creativity. The evidence suggests that in more hierarchical fields (i.e. "where a few powerful critics render influential judgments about the quality of work") it is easier for a small number of creators to emerge and gain recognition and influence (Gardner 1994). This paper presents computational experiments with a multi-agent framework of design to explore the idea that gatekeeping structures can determine how new solutions are created and spread in a society.

2. Artificial Societies

A framework of design as a social activity is formulated in this paper where the focus is on the interaction between designers and adopters, i.e. the impact that artefacts have in a social group and the social conditions within which individuals create. This framework is based on a systems view of creativity where interdependent stakeholders are taken into consideration. The DIFI (Domain-Individual-Field Interaction) (reference – Csikszentmihalyi 1998) model addresses the roles that the individual, the field and the domain play in the definition of creativity. Emphasis is on the interaction between agent, social, and epistemological levels of analysis respectively (Feldman et al 1994).

The implementation of this conceptual framework is carried through the modelling of artificial societies (Gilbert and Doran 1994). Multi-agent systems are used as a simulation tool to study the link between individual actions and social structures. However, the rational agency paradigm that dominates the computational modelling of behaviour is based on a reductionist view where social interaction is limited to the sum of individual mental states (Wooldridge 2000). Whilst this describes well the micro level of agency, it does not account for the emergence of explicit second-order structures, which can be expected to be qualitatively different (Anderson 1972). Evidence from experimental and field studies suggests that human behaviour is a function of the complex interaction of individual and social structures (Ross and Nisbett 1991).

The rational agency paradigm does not account for explicit representation of circular emergence (Conte et al 2001). In ant colonies a form of collective intelligence is said to emerge bottom-up as an aggregate effect of simple rules of reactive behaviour. However, such fixed reactions to environmental cues are insufficient to represent the behaviour of more complex organisms such as humans. Instead, humans seem to be aware of the emergent structures collectively developed by the social group (O' Laughlin and Malle 2002), which feed back into individuals determining their behaviour particularly when faced with new situations (Argyle et al 1981).

In this paper, a socio-cognitive agent architecture is implemented that addresses the combination of individual and situational factors in a system of generation and evaluation of designs. Individual factors are those that differentiate individuals such as abilities and preferences. Situational factors are those that determine external factors such as time and environmental conditions.

3. Adopters, Opinion Leaders and Designers

In our multi-agent system of design, members of an adopter population evaluate available design solutions and take adoption decisions. In this process individual thresholds of perception and preference are complemented by social interaction where opinions are exchanged amongst adopters. At the implementation level, Figure 1 shows a group of adopter agents where elements of the adoption process become part of the group structure. Decision components include perceptions, preferences, requirements, and choices. Group structures emerge from agent interaction and mediate their interaction with the environment. These structures are shared by agents at different times causing them to exhibit different degrees of normalised behaviour. Perceptions may become collectively biased, preferences may be emphasised by groups at different times, and socially permissible actions may be established.

One of the effects of this type of social behaviour is the emergent formation of opinion leaders, i.e. adopter agents that exert influence over the adoption decisions of others. Structures of dominance

emerge where the most influential adopters acquire the role of gatekeepers to the domain. Gatekeepers in this model are responsible for considering available solutions for their inclusion into the repository of their societies. Need to say something about repositories here from Feldman 1994
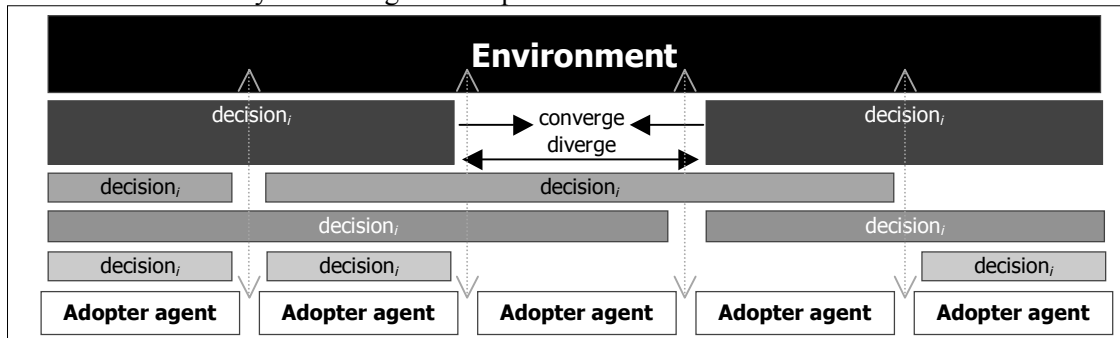

Figure 1 Socio-cognitive architecture where decision components become part of group structures

Designer agents create and transform solutions that are adopted by the population and are considered by gatekeepers for their inclusion in the repository. Some of the resulting phenomena of interest are the size of adopter groups (a measure of popularity) and the number of entries to the repository (a measure of critics' endorsement). The design process consists of generating alternative solutions by learning (a measure of knowledge) or by imitating other designers (a measure of peer-recognition). Lastly, adopter groups manifest their satisfaction with their adoption choices (a measure of quality). In the literature creativity is defined by such components as aesthetic appeal, novelty, quality, unexpectedness, peer-recognition, influence, intelligence, learning, and popularity (Runco and Pritzker 1999). In this framework, creativity is defined by a set of complementary processes including adoption of a solution by a population, nomination by specialists and colleague recognition.

Designers are considered creative by their social group when their designs reach large adopter groups, their artefacts are selected by gatekeepers, other designers imitate their artefacts, they transforms the design space by formulating knowledge, and their adopters have high satisfaction levels. Experimentation in this framework consists of exploring the effects that both individual and situational factors have on determining the performance of designers.

A formal description of these framework elements including artefact representation and adoption functions is given elsewhere (Sosa and Gero 2004). The following sections concentrate on the mechanisms of social interaction, influence, and gatekeeping.

3.1 SOCIAL INTERACTION

During a system run adopters rely on social interaction to validate their perceptions, spread preferences and in general to conduct their adoption decisions. To this end different social spaces are defined as social networks where adopters interact (Wasserman and Faust 1994). At initial time adopter agents are randomly assigned a location (node) and random neighbourhoods (links) on each space. These social spaces have different rules of interaction. Two aspects addressed in this paper are social tie strength (T) and neighbourhood size (H).

Social ties are interaction links between nodes in a social network where nodes represent the relationship between adopter agents in that particular social space (Wasserman and Faust 1994). The strength of social ties is determined by the probability that associated nodes may interact over a period of time (Granovetter 1973). Strong social ties exist between nodes in a kinship network, whilst weak ties exist in networks where casual encounters occur between strangers or acquaintances. H is determined by the number of links from a node, also called ego-centred networks (Wasserman and

Faust 1994). In our framework we implement a basic notion of tie strength as a probability $0.0 \leq T \leq 1.0$ that the link between a possible pair of adopter agents will remain at the next time step (Marsden and Campbell, 1984). $T \approx 0.0$ brings higher social mobility, i.e. adopter agents are shuffled more often and get to interact with different adopters over a period of time. In contrast, $T \approx 1.0$ bonds adopters together causing a decrease in social mobility, i.e. adopter agents interact within the same groups for longer periods of time.

3.2 INFLUENCE

At initial time agents are randomly assigned extroversion thresholds in every social space (Eysenck 1991). An adopter agent is assigned different thresholds in different social spaces. Extroversion values are not fixed during a system run but change as a result of exerting influence over other agents.

In the first social space in this framework adopter agents exchange individual preferences. Within a second social space percepts are traded and a third space is set where agents exchange adoption decisions. In all spaces H has a constant initial value (H = 2) which varies during a system run according to the influence that an adopter exerts on others. Influence and neighbourhoods are increased when an adopter agent transmits its opinions to other adopters.

Exchange between any pair of adopters starts by a comparison of their extroversion thresholds. In the social space where preferences are exchanged, in a pair of adjacent neighbours the adopter agent with the highest extroversion of the pair influences the less extrovert adopter on the criterion with highest preference. A negotiation process occurs by which the influenced adopter increases its preference by a difference between their preferences. However, if the chosen artefact of both adopters is the same and their preferences too similar, the more extrovert changes its focus of attention by shifting its preference to another criterion. This is a way to implement uniformity-avoidance and novelty-seeking behaviour, i.e. "x is an adopter's top preference until x becomes commonplace". Within other social spaces different content is exchanged following a similar approach. The exchange of percepts and adoption choices in their corresponding social spaces takes place in the same form.

The distribution of influence in an adopter population is measured by the Gini coefficient γ, a summary statistic of inequality (Dorfman 1979). When $\gamma \approx 0.0$, influence is more distributed among adopters. In contrast, $\gamma \approx 1.0$ indicates that influence is concentrated by a few adopters and more stable dominance hierarchies exist. Figure 2a shows adopters (rectangles) in a group with low γ where influence is distributed. In contrast, in Figure 2b a hierarchy of influence exists in a group with high γ.
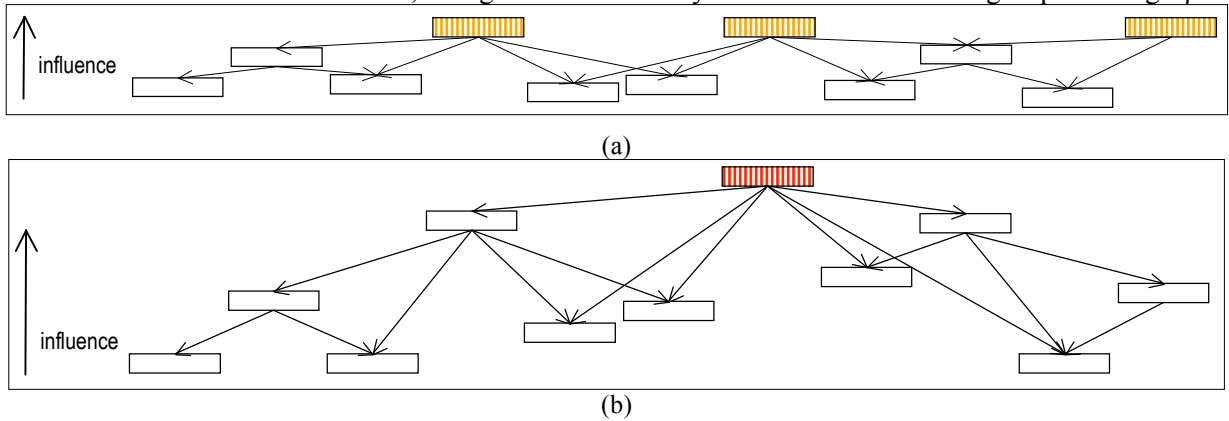

(a)

(b)

Figure 2 Influence structures with different distributions. In (a) Gini coefficient $\gamma \approx 0.0$, whilst in (b) $\gamma \approx 1.0$

In this way adopter agents exchange components of their individual adoption process. However, even if an influential adopter is successful in spreading its opinions in one social space, adoption

decisions in a group need not converge since adopters with equal top preferences may still perceive artefacts differently and therefore reach different adoption decisions. Similarly, adopters may share percepts but have different preferences and equally reach different adoption decisions.

3.3 GATEKEEPING

Adopter populations collectively define opinion leaders as a result of their aggregate interaction. At initial time the set of opinion leaders is empty. As a result of social interaction over time, adopter populations form social structures. These structures can be determined by various exchange processes. This paper focuses on influence hierarchies between adopters. Adopters that gain a dominance level of two standard deviations above the mean are nominated as opinion leaders. An adopter population may have characteristics that enable many agents to gain opinion leadership temporarily or may have characteristics that generate only a limited number of stable opinion leaders. In Figure 2a three adopters become opinion leaders, whilst in Figure 2b one influential adopter gains this role.

Opinion leaders become gatekeepers of the field due to their ability to nominate artefacts for entry into the domain, i.e. a repository of artefacts that defines the material culture of a population (Feldman et al 1994). Since the number of gatekeepers is by definition a small ratio of the adopter population, they are more likely to spend more real and computational resources in analysing available artefacts. With an adopter background, gatekeepers follow the standard adoption decision process described above but also gain access to more detailed critique criteria.

The repository of artefacts is initialised with an entry threshold $\varepsilon = 0$. During a system run ε is increased supporting a notion of group progress by which the entry bar is raised with every entry. Two possible entry modes are addressed in this paper. Gatekeepers can nominate artefacts that either increase the population's entry threshold ε or perform well in different criteria than existing entries.

4. Gatekeeping Effects

The following experiments address the role of social ties in the formation of influence structures in a population and the associated effects on creativity and innovation. A series of simulations are run where the initial configuration of adopters and designers is kept constant (i.e. control random seeds) and T is the independent variable. MonteCarlo runs are conducted to explore the range T = 0.0 to 1.0 in ten increments over 7500 iterations in populations of 10 agents, i.e. where agents remain in their social location at all times and where agents change social locations at all times, respectively. Preliminary runs showed that dependent variables stabilise between 2500 and 5000 iterations. The resulting dataset is then filtered in order to exclude outliers, i.e. values 1.5 standard deviations from the mean. All the following results represent means of 30 simulation runs.

Each simulation run is initialised in a converged state to avoid biases in the form random initial artefact configurations. Therefore at iteration step 0, adopters perceive no differentiation between artefacts and all abstain from adopting. It is only after a designer first modifies an artefact when adoption commences. Parameter relationships are analysed with Pearson correlation with a significance value $p < 0.05$, given by a sample size of 30 cases for each experiment.

4.1. DOMINANCE HIERARCHIES

The results of varying T from 0.0 to 1.0 show that influence concentration increases with social tie strength, i.e. in societies with strong ties, a few opinion leaders become dominant. In contrast, as social ties become weaker, social mobility increases and agents have contact within a varying neighbourhood causing influence structures of dominance to be more distributed ($\gamma \approx 0.0$). Figure 3 shows a scatter plot of the power-law relation of tie strength T and Gini coefficient γ with fitness $r^2 = 0.927$. Whilst cases with very strong social ties yield a high Gini coefficient, in most cases it is comparatively low. Figure 3a plots the full range on the axes with the non-linear distribution of data points. Figure 3b shows the

same plot but on a double-logarithmic scale. The same distribution now shows itself to be linear, a characteristic signature of a power-law. It is particularly interesting to obtain a pattern of self-organised criticality (Bak 1996) by linear increments of an independent variable in this framework. These types of patterns are prevalent in biological and social phenomena and have been found to characterise relations such as the frequency of words in natural language, the growth of cities, metabolism, and the topology of the World Wide Web (Strogatz 2003).

A power law relates influence distribution to social tie strength raised to a constant power. The general form takes $y = x^a$, where y and x are variables, and a is a constant exponent. In this experiment the power law coefficient is -0.37. Social groups with strong ties T ≈ 1.0 reach a mean Gini coefficient γ = 0.44. As T decreases marginally, there is a sudden drop of influence hierarchies rapidly going below γ = 0.39. However, once this threshold is crossed, even a significant decrease in T does not pull γ < 0.38. This pattern of the relationship between tie strength and influence hierarchies is a typical result of complex, dynamical systems consisting of many constituents where a critical state can be reached without any exogenous control at which point a system changes radically its behaviour or structure (Bak 1996). In the critical state, a small local perturbation may spread to the whole system and form an avalanche. In this case this point consists of a minimum of social mobility.
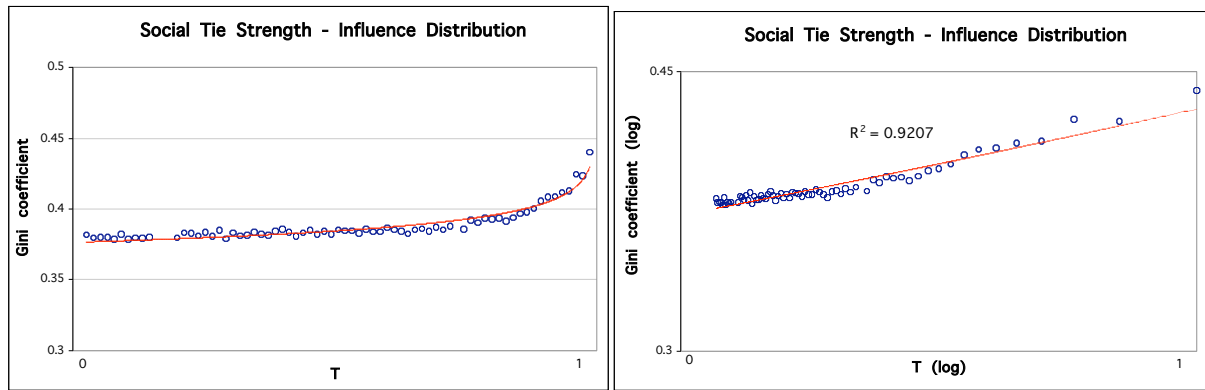

Figure 3 A power-law function is observed between social tie strength (T) and Gini coefficient.

This result suggests that in most cases influence hierarchies can be expected to be rather flat, the exception being only when adopter agents tend to remain in stable social positions. In social groups with strong ties there is lower mobility and the spread of ideas occurs in a hierarchical structure of influence between adopters. As a result, in groups with strong links influence hierarchies guarantee that a few individuals become dominant in the spread of ideas. In contrast, in weaker social settings adopters can be expected to influence their peers to a lesser degree. Influence is more diffused in groups with weak social ties. Small amounts of social mobility in societies of strong ties rapidly reduce disparities. As tie strength decreases further, influence becomes more egalitarian up to a point at which even large changes in social tie strength and mobility do not have a significant impact.

4.2. DOMAIN EFFECTS

The formation of dominance structures shows unexpected effects in adoption and design behaviour. On the one hand an inverse correlation is shown between tie strength T and number of entries to the repository. Lower values of T are correlated with larger repositories as shown in Figure 4 (Pearson = 0.6706 N = 30 p = 0.001).

In societies with weak social ties a mean of 97 artefacts with a standard deviation of 43.4 are selected by gatekeepers, whereas in societies with strong social ties a mean of 16 artefacts with a standard deviation of 11.7 are selected. From the results of the previous experiment it can be seen that in

societies with strong ties, a constant set of adopter agents tends to remain in the role of gatekeepers. Namely, gatekeeping is more stable and controlled by a small unchanging group of influential experts. Therefore, interpretations in which the evaluation of artefacts is based remain constant over time. As a consequence repositories tend to be smaller. In contrast, in societies with lower tie strength T and therefore where influence is distributed rather than concentrated there is a higher change rate of gatekeepers. The gatekeeping group is constantly composed of different adopters. Consequently, more diverse evaluations mean a larger number of artefacts are included in the repository.
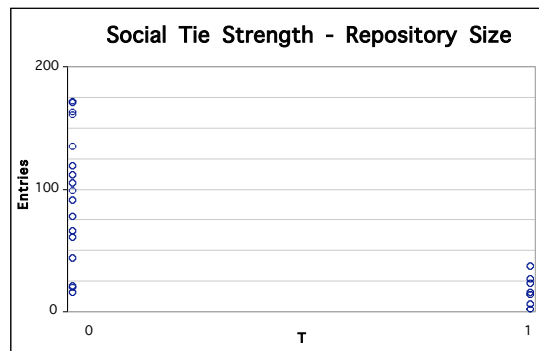

Figure 4 Social spaces with weak social ties tend to produce larger domains.

A principle of tie strength and repositories can be stated in this framework as follows: In fields where social ties are strong and influence is concentrated, an unvarying group of gatekeepers generates smaller artefact repositories. In fields where social ties are weak and influence is more distributed, there is a high rotation of gatekeepers and this generates a larger and less predictable domain size. Social groups where individuals have stronger links produce more stable gatekeeping, i.e. the process of selecting artefacts for a collective repository remains in the same hands for long periods of time. One direct result is that such repositories are of smaller size than in equivalent societies where social ties are weaker. The artefacts of designers that operate within weaker social spaces are more likely to be recognized by experts of the field.

4.3. DIFFERENTIATION EFFECTS

The differentiation of design artefacts is measured through the Strategic Differentiation Index (SDI) (Nattermann 2000). SDI is an aggregate measure of artefacts' differences as perceived by adopters. These experiments show that SDI is inversely correlated with T. Designer agents operating on tight social spaces where influence structures are rigid tend to generate more similar artefacts whilst the same designers operating on wider distributed influence social spaces have a tendency towards higher differentiation (Pearson = 0.5755 N = 30 p = 0.004).

This effect on design behaviour can be explained by the normative nature of strong social ties. Societies where a few influential opinion leaders exist, the adoption choices can be expected to be more similar. As a result, designers engage in aggressive competition to improve their artefacts. In contrast, in societies with weaker links, adoption opinions are expected to diverge and provide designers with a wider range of preferences. In such cases, different artefacts are adopted.

4.4. PROMINENCE EFFECTS

Lastly, effects on the size and nature of adopter groups are addressed. Results show that T is positively correlated with adopter group size as shown in Figure 5a (Pearson = 0.608 N = 26 p = 0.001). The standard deviation of adoption in weak ties (1718.74) is also significantly higher than in strong ties

(726.53). This illustrates that weak social ties increase abstention and make adoption less predictable. This is a consistent result with the notion that in more rigid societies there is a higher agreement of adoption opinions.

Adoption variance, on the other hand, is given by the distribution of adopters by designer agent. When adoption variance ≈ 1.0 most adopters choose the artefacts of one designer whereas when adoption variance ≈ 0.0 adopters distribute their choices amongst all designers. The strength of social ties T is correlated with adoption variance as shown in Figure 5b (Pearson = 0.6796 N = 26 p = 0.001). Namely, in social spaces with weak ties adoption choices tend to be more distributed across designers. In contrast, $T \approx 1.0$ increases total adoption and concentration of choices around a few designers.
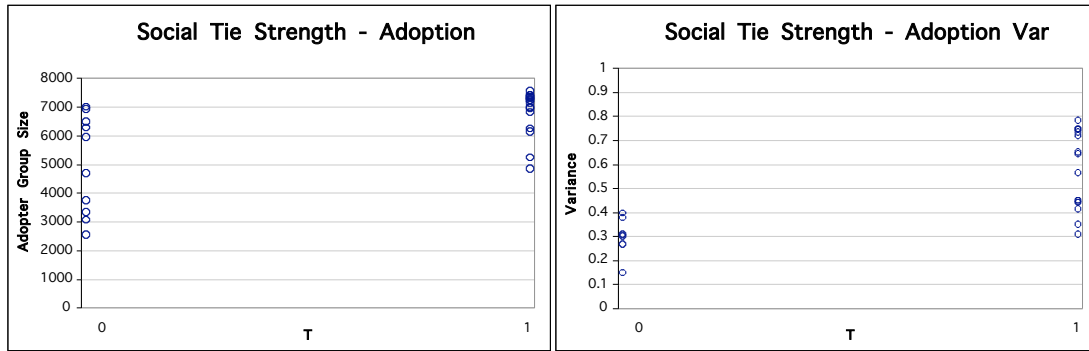

Figure 5 Social spaces with strong social ties (T $\approx$ 1.0) tend to produce more aggregate adoption and more concentration of adoption choices around a few designers.

5. Discussion

The experiments presented in this paper support the idea that creativity transcends the individual domain. Patterns of creative figures show that characteristics external to the individual may determine how and who is considered creative in a society. Graham, Einstein, Picasso and Freud have been characterised as extraordinary creators. Whilst their personality traits and abilities have little in common (Gardner 1993), similarities exist between the structures of the fields within which they operated. Namely, a few powerful critics rendered influential judgements about the quality of their work (Gardner 1994).

Our experiments with a multi-agent framework confirm this observation. When the tie strength between members of a population is high, adoption is more likely to concentrate on one designer. That is, keeping everything else constant and varying only the way in which adopter groups interact makes one designer more likely to become more prominent than the rest. Moreover, when prominence is more concentrated the behaviour of designers is also more differentiated as an effect of the strength of ties in the adopter population. On the other hand our experiments suggest that in societies where ties between agents are stronger, the domain tends to contain fewer entries.

The findings obtained from this framework point to a better understanding of creativity and innovation. However, they need to be validated against evidence from empirical observations. This is a difficult task given the methodological limitations to experiment with these variables in real cases of invention and innovation. However, these results can be compared to other relevant and well understood phenomena. In particular the observed power-law of social tie strength and influence hierarchies is consistent with the distribution of wealth in 120 countries plotted in Figure 6 (UNDP 2003). Specifically, the social conditions throughout a large number of cases yield a similar income distribution with the exception of cases where high inequality exists. The difference occurs at a critical point at

which small variations have a large impact on the outcome. If a pattern of this type exists in the gatekeeping process, it would help to explain the exceptionality of historical creative figures. In such case creativity could perhaps be understood as the combination of exceptional individual and situational conditions.
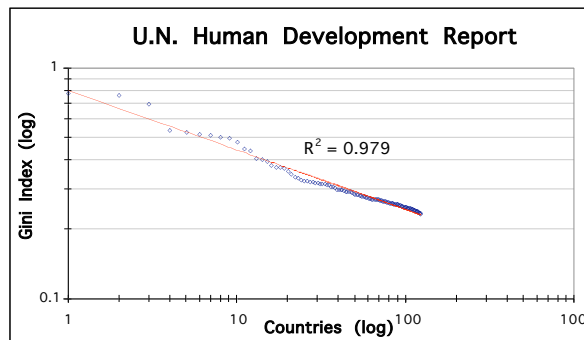

Figure 6 Power-law function of wealth distribution across countries (after UNDP 2003).

Differences in the hierarchy of influences and their possible effects on creativity and innovation may exist between different fields or at different stages of development within a field. In early stages of field formation, when influence is more distributed, it may be harder for a single designer to be recognised as creative. As the field advances and gatekeeping hierarchies develop, the distribution of prominence may become more concentrated. With the arrival of a new paradigm, hierarchies in the field may collapse reinitiating the cycle of effects on prominence (Kuhn 1974).

A corollary of these experiments is that in studying prominent designers, it seems necessary to consider the properties of the field within which they operate.

Acknowledgements

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