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Regulators as 'agents': power and personality in risk regulation and a role for agent-based simulation

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Abstract

We critically examine how evidence and knowledge are brokered between the various actors (agents) in regulatory decisions on risk. Following a précis of context and regulatory process, we explore the role power and personality might play as evidence is synthesised and used to inform risk decisions, providing a review of the relevant literature from applied psychology, agent-based simulation and regulatory science. We make a case for the adoption of agent-based tools for addressing the sufficiency of evidence and resolving uncertainty in regulatory decisions. Referring to other environmental applications of agent-based decision, making we propose how an agent model might represent power structures and personality characteristics with the attending implications for the brokering of regulatory science. This critical review has implications for the structuring of evidence that informs environmental decisions and the personal traits required of modern regulators operating in facilitative regulatory settings.

Keywords: agent-based simulation, personality, power, risk, regulation

Introduction

Modern regulation and public risk.

Regulatory decision-making is undergoing a revolution in the UK. Proposals for modernising regulation within Government in the 1990s (Cabinet Office, 1999) are now being delivered through programmes and legislation on 'better' and 'risk-based' regulation (Blackman, 1998; Gunningham and Grabosky, 1998; Pollard, 2001; Strategy Unit, 2002; Hampton, 2005; Hutter, 2005; Pollard et al., 2008; Gunningham, 2009). The premise is that a step change in decision quality can be delivered, with the regulation of public risk being targeted towards higher risks, and with decisions being more open to external scrutiny and challenge. Alongside, we observe a renewed emphasis on evidence in government decision-making; set within a historic climate of low public trust in policy decisions (Powell, 1999; House of Lords, 2000; HM Government, 2005; House of Lords, 2006). Departments and agencies have submitted evidence strategies to Government for review.

Over the last ten years, substantive work has been conducted by government on the handling of risk and uncertainty (OXERA, 2000; Strategy Unit, 2002; POST, 2004; BRC, 2006). The UK has published a national security assessment (2008), and an update (2009), and Government departments and their agencies are now expected to prioritise risks across their public service remits and direct resources accordingly. Government departments and agencies have also published 'risk management frameworks' (e.g. HSE, 2001) that set out the technocratic processes of risk management and options appraisal for managing risks within their organisational remits (Strategy Unit, 2002).

However, some hold the view that these frameworks fail to capture the nuances of regulatory decision-making in practice (RCEP, 1998; Powell, 1999; Slater et al 2006).

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Making evidenced-based decisions on public risk not only involves the assembly of a technically sound assessment of risk, but is also a process of social interaction requiring feedback, negotiation, power play, brinkmanship, compromise, and dialogue (de Bruijn and Koopmans, 2005). Take the role that science plays in informing regulatory decisions. In its simplest form, regulatees procure scientific studies, among other evidence they may gather, in support of their operations; and regulators review these scientific assessment in the legislative context, may commission their own studies and then advise on a course of action in light of multiple lines of evidence, the aggregate of which must be assessed and weighed. Numerous actors are often present in these processes, especially for the regulation of complex operations such as nuclear operating facilities, waste facilities, integrated refineries for example. These actors may include professional advisors (consultants), academic researchers, technical laboratory staff, international experts, regulatory scientists, policy specialists and front line regulators. Evidence, as it is assembled, is not only secured under different auspices and mechanisms (contracts, research projects, consultancy, independent advice, reviews of the prior art), but also brokered between actors within and between the key parties. This is the subject of our research. We are interested in the brokering of evidence among the actors in regulatory decisions and to explore whether these processes can be represented with agent-based tools. Specifically we seek to explore the influence that power structures and key personalities might have on the brokering and acceptance (or not) of the evidence and knowledge that supports decisions on risk. Here, we review relevant contributions from the psychology, agent-based simulation and regulatory science literatures. Ultimately we seek to better understand how can we represent and learn from the behaviour of regulatory decision makers; notably the influence of power and their dispositions, specifically their personality and propensity to trust, in a structured fashion. Further, how can we then use this knowledge to progress toward better regulation? Prior research has made

some progress in characterising agents with psychological properties, however, there are considerable opportunities for using this technology to study decision making processes. This paper represents the first phase of a funded research programme that aims to bring together the fields of decision making and agent systems. In the sections that follow, we first explain what we mean by risk-based regulation and the brokering of evidence that support decisions on risk. We discuss the potential influence that personality and power structures may have on this process. Finally, we propose how we might investigate these influences using agent-based simulation technologies.

Risk-based regulation and the brokering of scientific evidence

State regulation is often viewed as the implementation of policy, being progressed through frameworks of due process and legislative documents (acts, regulations, annexes, statutory guidance) with specific outcomes in mind. Much of regulation is concerned with preventing harm to people and the environment. Within Europe, European Community (EC) institutions set the framework of Council legislation on Member States. In the environmental field, Directives are used as legal instruments, because of the flexibility they offer. Once agreed, Directives are transposed into national law through acts of Parliament and delegated secondary legislation (Bell and McGillivray, 2000). Conventional regulation has been criticised for being resource intensive and overly-prescriptive (Kirk et al, 2005); potentially inhibiting innovation and the development of new technologies (Wiener, 2004); creating an unfair competitive advantage by paying inconsistent attention toward regions and areas; and reducing the benefit regulatory resources can bring by imposing too large an administrative burden (Hampton, 2005). In response, modern, risk-based regulation seeks to allocate regulatory resources in proportion to the risks and interventions they require (BRC, 2006; Environment Agency, 2005; Hutter, 2005). Much of regulatory activity requires the issuing

of permits, licences and authorisations, usually supported by conditions, where failure to meet these results in some sanction. Risk assessments are used to inform the drafting of these conditions, many of which specify risk management measures to prevent harm occurring as the condition of the permit. What can meaningfully be said about the significance of risks depends on the extent and quality of the evidence that underpins the risk analysis, and one's confidence in it. In practice, evidence is brokered between many actors, or 'agents' in the decision. Research can be procured or elicited from the research base; used alongside targeted, site-, or policy-specific studies; used to develop new lines of evidence that may support or contradict a line of reasoning; and in concert, is applied to develop an overall weight of evidence about a risk decision – for example, whether or not to extend an environmental permit for an integrated petroleum refinery, say; or whether to produce guidance on the consumption of alcohol within certain 'safe' limits.

Three contexts: radioactive waste, carcase disposal and salt

Consider for example, three decision contexts that feature high on the public risk agenda: (i) the presentation of a post-closure, environmental safety cases for radioactive waste repositories, (ii) the disposal of animal carcasses produced during exotic disease outbreaks; and (iii) deliberations about expert advice of the consumption of salt in the human diet. Each decision requires the regulator to draw on a complex evidence base to generate knowledge that can inform a policy or regulatory decision. Later we will return to these contexts and explore how agents-based approach might be applied.

The importance of managing nuclear waste safely has been widely documented (e.g. IAEA 1994; HSE, 1999). An extended international debate over what constituted "good practice" in performance assessments for disposal facilities led to the development of risk criteria for disposals, based on the principles of sustainability. These currently require (in the

UK) that the performance of a waste repository does not generate exposures for humans that exceed an annual incremental risk of a 'serious radiological detriment' (health effect) of greater than one in a million. In England and Wales, the Environment Agency (EA) is responsible for the authorisation of radioactive waste disposal. In accord with public policy, repository operators undergo a periodic review of their permit by preparing a post-closure environmental safety case for the regulator, in which they are required to make good use of scientific evidence and knowledge. The assessment and management of future human actions and risks in these post closure risk assessments, given the longevity of radioactivity, poses a considerable intellectual challenge in terms of the availability and reliability of evidence and knowledge, and it places a substantive burden of proof on the operator to evaluate future risks up to 100 000 years forward in time. The use of reasoned argument, future scenarios and, structured approaches to the 'evolution' of the repository over time, are encouraged alongside the use of quantitative field and modelled data in support of the operator's safety case. Once the safety-case has been formally submitted and all relevant parties have been consulted, the regulatory officer must make a recommendation for authorisation, or the re-authorisation for existing facilities. This is a hugely complex task involving multiple decision agents associated with the regulate, the regulator, and a large suite of other key stakeholders including local community representatives. Figure 1 provides a generalised summary of the key actors and flows of evidence involved in the regulatory review of a post-closure safety case used to support the decision on whether (or not) to reauthorise disposals at radioactive waste repository in the UK (after Yearsley et al., 2001).

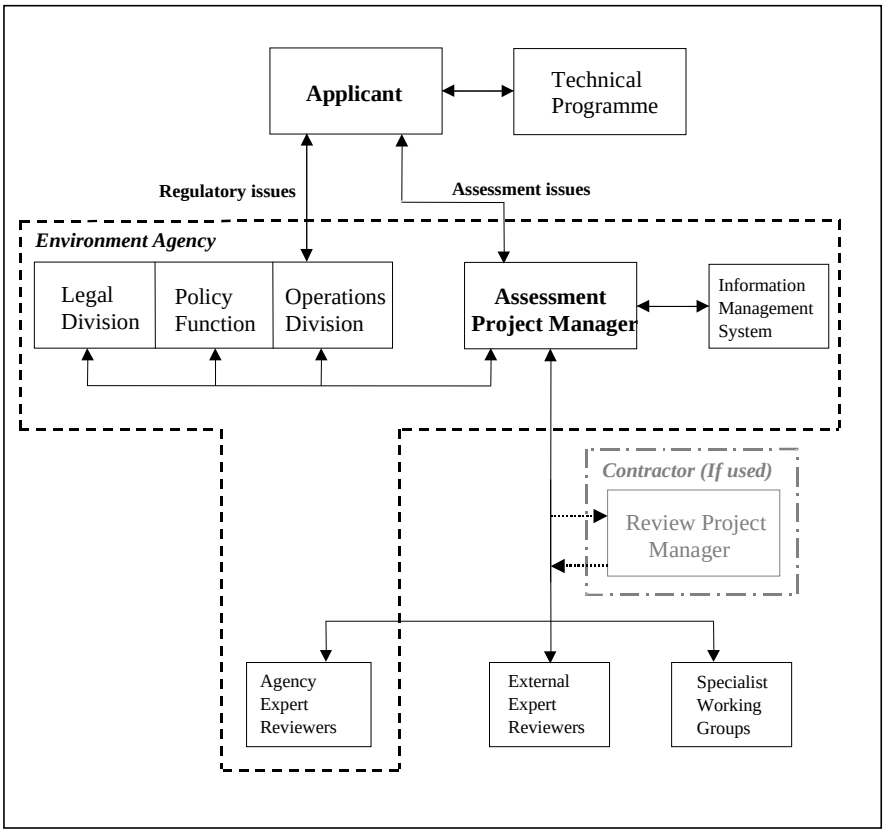

Figure 1. An example structure of the institutional sub-components involved in the decision on reviewing post-closure safety cases. Individual boxes are often populated by an array of domain experts. In this case, representatives of the regulator's policy function make recommendations to the Government Department and ultimately the Secretary of State regarding the reauthorisation of a facility (adapted from Yearsley, 2001).

In Great Britain, the Department for Environment, Food and Rural Affairs (Defra) are responsible for coordinating the disposal of diseased animal carcases. This requires Defra to have a working knowledge of the potential pathways that could lead to exposure of humans, animals and the environment to pathogens, chemicals and other hazards associated with carcase collection, disinfection and disposal (Pollard *et al.*, 2008). Much of the risk assessment work is carried out ahead of time and is disseminated in the form of guidance notes for operational staff in the form of a generic contingency plan. In the event of an outbreak, the regulator uses this information in collaboration with expert advice from a

number of different parties (e.g. health departments and their agencies, veterinary officials, environment agencies, emergency planners and other professional partners) to inform their decisions on the most appropriate suite of disposal options.

High concentrations of dietary salt have been reported to result in a significant increase in high blood pressure (Korhonen et al 1999), which is linked to coronary heart disease. Reducing salt intake has been reported to reduce average blood pressure levels in a clinical dietary control, in both sexes (Sacks et al 2001). In the UK, the Food Standards Agency (FSA) has set voluntary targets for reducing the average salt intake by adults to six grammes per day, based on recommendations made by a Scientific Advisory Committee on Nutrition (SACN). Because these targets are voluntary, their primarily aim is to encourage retailers and manufacturers to reduce salt in food products. As an incentive, the FSA publish 'league tables' based on attempts made by organisations to meet this target. The FSA also runs major public heath campaigns, with other organisations, aimed at reducing the amount of salt in 'social cooking'; and they recruit and train local peer facilitators to make the public more aware, generally, of the large amounts of salt that is added to their food.

Many regulatory decisions, such as those above, are informed by various lines of evidence about the risk in question. These rarely point in the same direction because it may prove difficult to establish causal mechanisms within complex systems, and evidence lines may have different levels of theoretical and empirical support. Evidence thus requires a structured synthesis (Figure 2) so that an overall weight of evidence can be applied to the characterisation (significance and confidence) of the risk (Lowell et al 2000; Pollard et al 2008). This practice frequently involves inputs from fundamental and applied scientists, scientific consultants, highly specified domain experts, advisory committees, expert referees, various publics with local or specialist knowledge, industry sector specialists with their scientific advisors, technical policy development specialists, and so on.

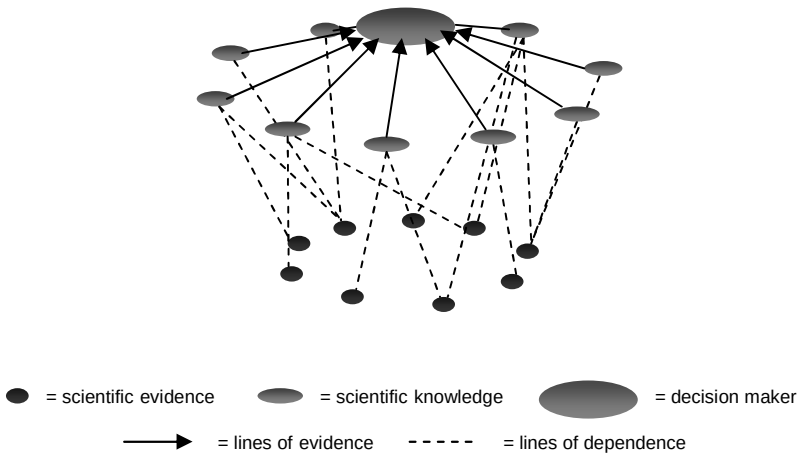

Figure 2. A conceptual simplification of the brokering of evidence and knowledge.

Actors in this process (Figure 2) secure different sources of primary scientific evidence (e.g. experimental or field data), assemble knowledge from it (e.g. the predicted future behaviour of contaminants discharged to an aquatic environment) and pass knowledge on the a decision maker who must consider the evidence on a specific issue (e.g. the risk of harm to a specific ecosystem) in concert. This occurs through a sequence of transactions between agents (people), to an ultimate decision maker for an assessment of the significance of the risk and a decision whether to accept the risk or not, and how to manage it. The brokering of evidence and knowledge in practice is far less idealised and inherently uncertain due to information gaps, the existence of competing theories and the presence of manifold scientific uncertainty (Powell, 1999). Risk-informed decision-making is thus value-laden, not least because decision participants, agents, make value judgements regarding the sufficiency and credibility of available information. Moreover, individuals do not make stable decisions under uncertainty. Decisions made are to some degree biased by participants' perceptions of the decision environment (Slovic et al 1982; Slovic, 2000). Further, risk characterisation itself requires a discussion of values with a pre-requisite discussion of risk appetite (Tuler et al 2005). Under these conditions, unfettered assessments and assembly of the direction,

strength and weight of evidence that constitute an assessment of the risk, may not be possible. Current technocratic risk management frameworks fail to account for this and, in doing so, may compromise the level openness and transparency that they attempt to infer.

We are interested in constructing a richer description of this brokering process. In the discussion that follows, we refer to evidence as 'raw data' and to knowledge as 'interpretations' of the evidence that inform an assessment of the significance of the risk. For example, environmental regulatory officials must frequently evaluate the risks posed by new operational plant or the incremental risks of changes to plant design and or layout. A regulatory officer may need to decide, for example, on the reliable performance of an in-plant wastewater treatment works for the biological treatment of pharmaceutical residues in process streams prior to discharge to receiving surface water. Raw data on the treatment performance on individual unit processes must be received from the operator, processed so to evaluate the risk of exceeding environmental quality standards, and then used to establish compliance criteria in consultation with the operator. Often this data, and the risk assessment, will be supplied by the operator and their professional advisors (environmental consultants, say) in support of a modification to the plant. Agents within this process must receive, process, and pass-on evidence and knowledge to other actors. Ultimately, the local regulatory official must make a decision about whether to issue a permit to an upgraded in-house wastewater plant, say. If the two nodes at the bottom represent an operator and a consultant, the square dotted arrows can represent the evidence they gather. If the node at the top of this figure represents a regulatory officer (decision maker), the solid arrows can represent the scientific knowledge presented to the regulator after the operator and consultant has placed the scientific evidence in context of the risk question being asked. Then the round dotted arrows represent the outcome; the confidence the regulator has in approving the authorisation of an environmental permit, say. At each step, a recipient may wish to accept

or reject the scientific evidence and knowledge provided, usually by determining how sufficient and dependent different sources of scientific evidence and knowledge are. Interactions between agents in these discussions are critical. Evidence is often brokered with a 'tag' – a supporting case for its acceptance (or not) that passes between parties. The rejection of evidence, or that matter the indecision over evidence submitted, has severe cost implications for regulatees, in that they may need to procure additional studies or delay improvements. Thus the characteristics of the agents themselves and the power they exercise may have influence on the brokering of evidence, its acceptance and the construction of compelling cases that attend technical assessments of risk. Wardman's (2008) risk government model suggests the dispositions and behaviour of decision makers are important to the decision making process and its outcomes.

The following sections explores these facets and critically assess how a decision maker's power and personality may determine whether or not they engage in dialogue with the provider of evidence and/or knowledge, and whether this is likely to be conducive to the resolution of decision uncertainty and thereby imbue confidence that there is sufficient evidence to support (or refute) the risk question being posed. We focus on one aspect of each: personality as a characterisation of dispositions, and the exercise of power as an example of decision makers' behaviour.

The role of power

A taxonomy of power

Power is the ability to control one's environment and the behaviour of those within it (Dahl, 1957; French and Raven, 1959; Kanter, 1979). In the context of brokering evidence and knowledge, power is realised by an individual's capacity to include or exclude information, contingent on their view of its' validity and relevance to the decision. Power

structures represent the influences people have, and thus the distribution of power, by reference to individual status and the period for which they hold power. A substantive literature exists on the dynamics of power (e.g. French and Raven, 1959; Morgan, 1986; Paton, 1984; Stephenson, 1985; Liao, 2008a; 2008b). Here we focus on French and Raven's (1959) taxonomy of five forms of power (Figure 3): legitimate, referent, expert/informational , reward and coercive; defined below. These describe the sources of power that a participant may exercise, and the influences they hold within a power structure (Belaya et al 2008).

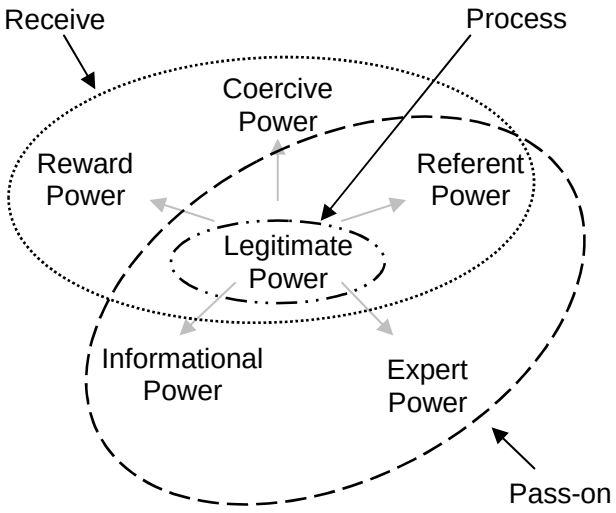

Figure 3. French and Raven's (1959) five forms of power related to the brokering of evidence and knowledge

This taxonomy plays out in authentic regulatory decisions as the various agents to the decision exchange, sort and validate evidence in support of risk characterisation. The first aspect of an agent's power to influence the brokering process is their ability to 'receive' scientific evidence and knowledge, and relates to their legitimate power. Legitimate power refers to an individual's position within a power structure and is usually equated with authority (Handy, 1999). The power resides with the position held, rather than with the individual (Belaya et al 2008). Here, the recipient agent has a legitimate right to influence

and oblige others to comply with a course of action. For example, a regulatory inspector is legally empowered to inspect and gather environmental compliance data. Legitimate power is only as strong as it is supported, and additional 'guaranteeing' sources of power can reinforce it. For example, providing site inspectors with access to reward power, coercive power and referent power may further strengthen their legitimate power.

Reward power is relevant to an individual's ability to offer an incentive (Belaya et al 2008) and may be obvious in the case of an inspecting officer's ability to encourage the submission of compliance data. Less obvious might be the rewards offered for the delivery of timely information.

Coercive power is relevant to an individual's ability to punish those who do not comply. Although this may provide a regulator with short term gains, it may also prove to be ineffectual in the long run (Rahim et al 2001) and is less in keeping with modern views over facilitative regulation. In general, the expression of coercive power may result in resentment and resistance because it is fuelled by the respondent's desire for the reward and the fear of having it withheld (Molm, 1997). The mere perception that a recipient agent has coercive power may be sufficient to yield information. However, if coercive power is abused, it can evoke conflict, resulting in a regulator being reprimanded; for example, via judicial review.

Referent power will also aid a recipient agent's capacity to receive evidence and knowledge. Referent power helps build compliance and, in contrast to legitimate power, resides with the personality of the individual. It takes time to establish. For example, an inspecting officer's role is supported when they maintain a long-standing relationship with the operator, and requires the officer to communicate a sufficiently convincing reason why an operator should comply with a specific request. If the officer is successful in establishing this relationship, s/he can be considered to hold a degree of referent power; thereby facilitating access to evidence and knowledge in support of a decision. However, if the relationship

between an operator and an officer is brief and the officer has only a small window of opportunity to establish referent power, this opportunity may be lost. Hence, referent power is only as effective as the extent to which recipients become exposed to it.

The second aspect of an agent's power to influence the brokering of evidence and knowledge is their ability to 'process' it. Here, we mean the synthesis of evidence in the context of the risk characterisation – how significant in the risk and, by extension for unacceptable risks, what measures should be imposed to secure reductions to a level of residual risk? Again, legitimate power is the first point of call. An individual's influence will depend on the extent their role allows, or expects them to partake in the gathering, processing, analysis, or third party review of evidence and knowledge. French and Raven's (1959) other four forms of power have minimal impact on a participant's ability to influence on the processing of scientific evidence and knowledge.

The final aspect is an agent's ability to 'pass-on' the evidence and knowledge provided to them to other agents. The original recipient now becomes the provider as s/he 'receives and accept' information and then passes it on to other agents in the decision process, usually labelled with some statement of its validity and/or their confidence in it. The ability to pass-on evidence is intertwined with the ability to receive it because power operates both relationally and reciprocally. For example, a recipient's legitimate power may allow them to reject information, but whether this happens or not depends on whether they perceive the provider to have expert and/or referent power. Expert power, for example, can only be inferred upon agents by those on whom it will be exercised, and must be explicitly and implicitly recognised to exist. As such, expert power is said to be the most socially acceptable form of power (Handy, 1999). Hence, placing this in the context of our study, if a provider has expert power then it can be assumed that the recipients will be receptive to the scientific knowledge provided. However, if for any reason the recipient becomes aware of

‘credibility gaps’ associated with the evidence and knowledge provided to them, the provider’s expert power can become discredited (Handy, 1999). When expert power is no longer perceived to exist in the providing agent, the recipient agent may reject the evidence and knowledge provided they have legitimate power in which to do so. Hence, a provider’s ability to pass-on scientific evidence and knowledge with credibility will also depend on whether the recipient is receptive.

In summary then, the brokering of evidence and knowledge can be viewed as being mediated through a power structure, whereby agents with a range of interests have varying degrees of authority to determine the flow, acceptance, and transfer of information to inform decisions on risk. The power relationships are designed to ensure the right people are best placed to exercise the appropriate type of power at the right time (Figure 1). However, power requires a balance between parties, it operates relationally and reciprocally and it is subjective. It depends on whether the agent is in a position to exercise power, as well as their personality, since personality can also influence the mechanisms through which power might be enacted and decision making occurs.

The role of personality

The five factor model

Personality research is concerned with the psychology of the whole person (Epstein, 1996). In this section, we review a widely used model of personality and discuss its application to the regulatory decision process. One of the most popular measures of personality is the five-factor model (Costa and McCrae, 1992). This has been accepted by scholars (e.g. Barrick et al 1998; Denissen and Penke, 2008; Digman, 1990; Goldberg, 1990; Hong et al 2008; John, 1990; John and Srivastava, 1999) and encompasses the most significant variations of human personality (Ivancevich and Matteson, 1999; Robbins, 2003).

The model comprises five personality traits. Neuroticism is the extent to which people are nervous, anxious and prone to stress. Extroversion refers to tendencies to be sociable, assertive and experience positive emotions. Openness to experience concerns preferences for novelty and creativity. Agreeableness is the extent of co-operation, trust and tender-mindedness. Conscientiousness describes preferences for order, goal focus and achievement striving. Since personality is reasonably stable over time (Costa and McCrae, 1992; Johnson, 1999), it provides useful information about how individuals will approach decision making and the exercise of power. Extensive studies have demonstrated how the personality traits relate to an individual's typical behaviour. For example, there is widespread evidence for links between personality and workplace behaviour (e.g. Back et al 2006; Berry et al 2007; Burke and Witt, 2004; Flaherty and Moss, 2007; Lee et al 2005). Insights from this field could also help to explain the influences that personality has on the brokering of evidence and knowledge, and on an agent's ability to uphold certain responsibilities for the processing of information.

There are also important interactions between personality and situations that influence behaviour. The person-by-situation approach has been the source of much debate (e.g. Bem, 1983; Blass, 1991; Bowers, 1973; Endler, 1984; Eysenck and Eysenck, 1980; Johnson, 1999; Reynolds and Karraker, 2003; Saucier et al 2007; Shoda, 1999; Ten Berge and De Raad, 1999; Ten Berge and De Raad, 2002), with some questioning how valid and novel it really is (e.g. Funder, 1996; Johnson, 1999). This said, it has become increasingly popular within modern personality research, and scholars generally agree in the value of its approach (e.g. Borkenau et al 2006; Fleeson, 2007; Graziano et al 2007; Kammrath et al 2005; Withey et al 2005). In recognition of this, scholars such as Mischel have examined the role that situational forces have on the emergence of behaviour (Mischel, 1999; Shoda, 1999). These authors argue for characterising personalities by stable patterns of behaviour, and by distinct and

stable patterns of situation-behaviour relations (Shoda et al., 2002). This combined '*if… then…*' approach has allowed researchers to create so called 'behavioural signatures' that are predictive of patterns of variability across different situations (Mischel, 1999; Mischel and Shoda,, 1995; Shoda, 1999; Shoda et al 2002). This allows researchers to specify how traits play out with increasing precision under different situations (Ten Berg and De Raad, 1999).

Distinct *if… then…* behavioural signatures might be sued to explain the influence personality has on the brokering of evidence and knowledge within risk decisions. If so, these traits could be assigned to agents and represented in a modelled system. Consider the influence that the five factor model could exert on the brokering process in the context of knowledge sharing (e.g. Bakker et al 2006; Liu, 2008; Mooradian et al 2006) as this is central to regulatory decision-making. Bakker et al (2006) separate knowledge sharing into the phases of exploration and exploitation. The former describes the point at which agents discuss and work together to solve a problem; the latter the phase in which knowledge is integrated (Bakker et al 2006). Analogously, we refer to the exploitation phase as the act of 'receiving and accepting' evidence and knowledge and the exploration phase as the act of 'engaging in dialogue'.

Knowledge exchange and trust

A considerable amount of work has been undertaken into what constitutes knowledge, where it is derived from and how it can be effectively nurtured, transferred and assimilated (Major and Cordey-Hayes, 2000). Knowledge is invariably dynamic, context specific and intangible. Bhagat et al. 2002 (in Claver-Cortes et al., 2007) argue that knowledge originates from unique experiences and organisational learning, and is present not only in written documents but also in the routines, tasks, processes, practises, rules and values of organisations. This type of knowledge is tacit and as such it is hard to verbalise because it is

expressed through action based skills and cannot be reduced to rules and recipes or easily captured, stored and distributed (Sahota et al., 2007). Metcalfe and Gibbons (1989) suggest that the "knowledge base" of an organisation comprises the individual human resources and mechanisms of interaction. Subsequently, close attention has to be paid to the people, culture, organisational structures, and information technology because knowledge is rooted in human experience and social context (Havens and Knapp, 1999). Pyoria (2007) argues that knowledge intensive organisations should value human relations above technology and create an atmosphere of passion and enthusiasm and a culture of innovativeness and creativity.

Earl (1994) suggests that knowledge management requires a combination of technological and social action; that is organisations must develop ways of ensuring that the organisational culture is conducive to knowledge sharing. Henry (1995; in Gererdo et al., 2002) argues that although individuals bring resources to the group, they may not use these effectively unless asked to do so. Therefore it appears that however much effort it spent implementing an organisational structure that encourages knowledge sharing, knowledge ultimately resides with individuals (Gerardo *et al.*, 2002). Knowledge processes are then concerned with micro-social interactions among individuals (Gererdo *et al.*, 2002). This focus on individual cognitive activity as the central element in an organisation's acquisition and processing of information is critical to our discussion of an agent's actions during the act of "receiving and accepting" and the act of "engaging in dialogue". There are many other factors that affect knowledge sharing, such as: (i) the properties of knowledge (e.g. the degree of articulation and aggregation; Blacker, 1995; Nonaka and Takeuchi, 1995; Spender, 1996); (ii) organisational culture (Wasko and Faraj, 2005); and (iii) interpersonal relationships (Hansen, 1999; Levin and Cross, 2004). However, the most common facet referred to is the influence of trust (e.g. Abrams et al 2003; Levin et al 2006; Mayer et al 1995; McEvily et al 2003) which has obvious implications for the credibility of evidence and knowledge.

Rotter (1971) defined trust as "*the generalized expectancy held by an individual that the word, promise, oral or written statement of another individual or group can be relied upon*". In its literal sense, we refer to trust as a recipient agent's belief that the evidence and knowledge provided is both reliable and sufficient. Mayer et al (1995) posited the "*higher a trustor's propensity to trust, the higher the trust for the trustee prior to availability of information about the trustee*". These definitions suggest that trust will indicative of a person's willingness to engage in sharing knowledge (e.g. Davenport and Prusak, 1998; Uzzi, 1997) and depend on the recipient's propensity to trust. Propensity to trust is related to dispositional trust - the general willingness to trust others (Mayer et al 1995), which is neither focused on specific others nor dependent on specific contexts (Mooradian et al 2006).

Interpersonal trust, on the other hand, is a measure of how trustworthy participants perceive others to be. It is determined by the situation and is multi-dimensional (e.g. McAllister, 1995; Rempel et al 1985; Abrams et al 2003). Abrams et al (2003) define interpersonal trust as "*the willingness of a party to be vulnerable*" (Dirks and Ferrin, 2001; Gambetta, 1988; Kramer and Tyler, 1966; Mayer et al 1995), suggesting that participants display more interpersonal trust and knowledge sharing behaviour when they are more willing to accept vulnerability. In this regard, Evans and Revelle (2008) describe vulnerability as a ratio of costs (e.g. betrayal) and benefits (e.g. reciprocity) where the uncertainty over gains or losses motivates (or discourages) trusting behaviour. These authors suggest that those with a propensity to trust are more inclined to establish interpersonal trust and engage in knowledge brokering and networking (Becerra and Gupta, 2003; Evans and Revelle, 2008; Swan et al 2002).

Studies have also linked personality to trust and knowledge sharing (e.g. Evans and Revelle, 2008; Martins, 2002; Mooradian et al 2006). Evans and Revelle (2008) demonstrated that trust, rather than trustworthiness, predicted whether a recipient would

return money in a standard economic investment game. They demonstrate that the tendency to 'trust' was positively correlated with extroversion and negatively with neuroticism, and that 'trustworthiness' was positively correlated with agreeableness and conscientiousness. Only agreeableness was related to the amount of money invested, with more money being invested under the send-only condition compared to the simultaneous condition. It was suggested that agreeableness motivated more interpersonal trust under greater levels of risk and uncertainty (Evans and Revelle, 2008), possibly motivated by the opportunity to cooperate rather than compete (Liao and Chuang, 2004). Hence, although propensity to trust may translate as a propensity to engage in interpersonal trust, this will depend on whether the situational context motivates agents to do so.

Managing uncertainty

Scholars also explain that the uncertainty associated with information that is brokered may account for a large proportion of an agent's motivation. Hodson and Sorrentino (1999), explain that the composite of a person's approach to uncertainty (Sorrentino et al., 1992) and certainty (Cherry and Byrne, 1977) allows them to deal with the complexities of information-processing. Investigating the relationship with the five factor personality traits, only openness to experience was found to be positively related to a person being uncertainty orientated, suggesting that given the choice, these individuals are more likely to approach uncertainty in the hope of resolving it (Hodson and Sorrentino, 1999). Thus, research suggests it is possible to predict whether a recipient agent would be unwilling to "receive and accept" evidence and knowledge without first engaging in dialogue, by knowing whether: (i) the level of uncertainty associated with the evidence and knowledge motivates them to do so; (ii) they have prior knowledge that causes them to believe that the provider is trustworthy (e.g. having sufficient expert power); or (iii) they lack prior knowledge but have the

propensity to trust. Failing this, and assuming a recipient has sufficient legitimate power, an exploration phase would proceed an exploitation phase. During the exploration phase propensity to trust, interpersonal trust, and willingness to engage in knowledge sharing will play a role. For risk-based decisions, the most enduring characteristic being brokered is the level of uncertainty associated with evidence and knowledge (see Bradshaw and Borchers, 2000).

In summary, personality research suggests that whether agents will be motivated to carefully and systematically process information will, in part, depend on their 'behavioural signatures' by reference to the five factor model and their uncertainty orientation. In the context of brokering evidence and knowledge for regulatory decisions, the recipient agent must determine whether they agree with the providing agent over the sufficiency of the evidence and knowledge to support a decision. Unlimited time and resources might permit success to be measured in terms of how conducive dialogue is to the resolution of uncertainty. Indeed, some regulatees may recognise certainly uncertainty resolution in these decisions as a key factor in the occasional delays experienced in securing regulatory approvals for contentious or complex developments. Thus there would appear to be some merit in exploring whether issues of power, personality and uncertainty resolution could be explored in a more systematic way, perhaps through using agents-based tools.

Regulatory actors as 'agents'

Applying agent-based models within regulation

An understanding of decision makers' personality and exercise of power is useful to effective development and communication of regulatory decisions. However, opportunities for examining the range and combinations of personality, power, and different decision contexts in real-world regulatory decision contexts are limited. One approach to developing a

498 construct for decisions and exploring behaviour is by representing ‘agents’ in a computer
499 model (Zhang and Zhang, 2007). A computer agent is autonomous with the ability to
500 function independently; goal directed with a capacity to assess the outcome of its behaviour
501 relative to its goals; and flexible with the ability to recognise traits of other agents and learn
502 from its environment. Hence, an ‘agent’ can be perceived as being a discrete component with
503 a set of characteristics and rules that set its decision making capability (Macal and North,
504 2006). Proponents of agent based modelling claim it offers insights otherwise unobtainable
505 by using conventional research methods. Applications of the approach include modelling
506 behaviour in knowledge-based jobs such as trawling strategies (Beecham and Engelhard,
507 2007), stock markets, supply chains (Macal and North, 2006), and waste management
508 (Courdier et al., 2002). The key advantage of an agent-based model is its capacity to describe
509 and simulate complex systems (Courdier et al., 2002; Chaturvedi et al., 2000; Kurahashi and
510 Terano, 2005). Environmental decision contexts, complex by their very nature, have been
511 tackled using agent based approaches to negotiating on groundwater demand management
512 (Feuillette at al., 2003), optimising the effectiveness of greenbelt in periurban settings
513 (Brown et al., 2004), improving forest ecosystem management strategies (Nute et al., 2004)
514 and recently for modelling pine beetle infestation (Perez and Dragicevic, 2010). By
515 combining knowledge of individual and strategic choice, automated decision makers can
516 reflect the complex interaction of humans when making decisions under uncertainty, taking
517 account of the behaviour of others. These tools have allowed researchers to vary the
518 components of the decision-making environment, and of the actors themselves, to generate a
519 greater understanding of how group decisions are secured. Scholars working in the field of
520 artificial intelligence have modelled the influence personality human decision making
521 (Alavizadeh et al., 2008; Canuto et al., 2005; Ghasem-Aghaee and Ören, 2007; Nassiri-
522 Mofakham et al., 2008, 2009) and power (e.g. Prada and Paiva, 2009; Marreiros et al., 2008;

Cincotti and Guerci et al., 2005). However, applications to the regulatory environment and the human interactions between parties engaged in the brokering of evidence and knowledge have to date been limited.

How might such a model be constructed, verified and validated? Figure 4 illustrates the hierarchical relationship between power and personality as it relates to a recipient's belief in the sufficiency of the information being provided to support a decision. One might envisage a representation, albeit grossly simplified compared to the realities of social interaction in these contexts, in which conditional weights might be applied to traits and sub-traits and a power/personality weight be derived. This might then be used to modify a recipient's initial belief about the sufficiency of the scientific evidence and knowledge provided.

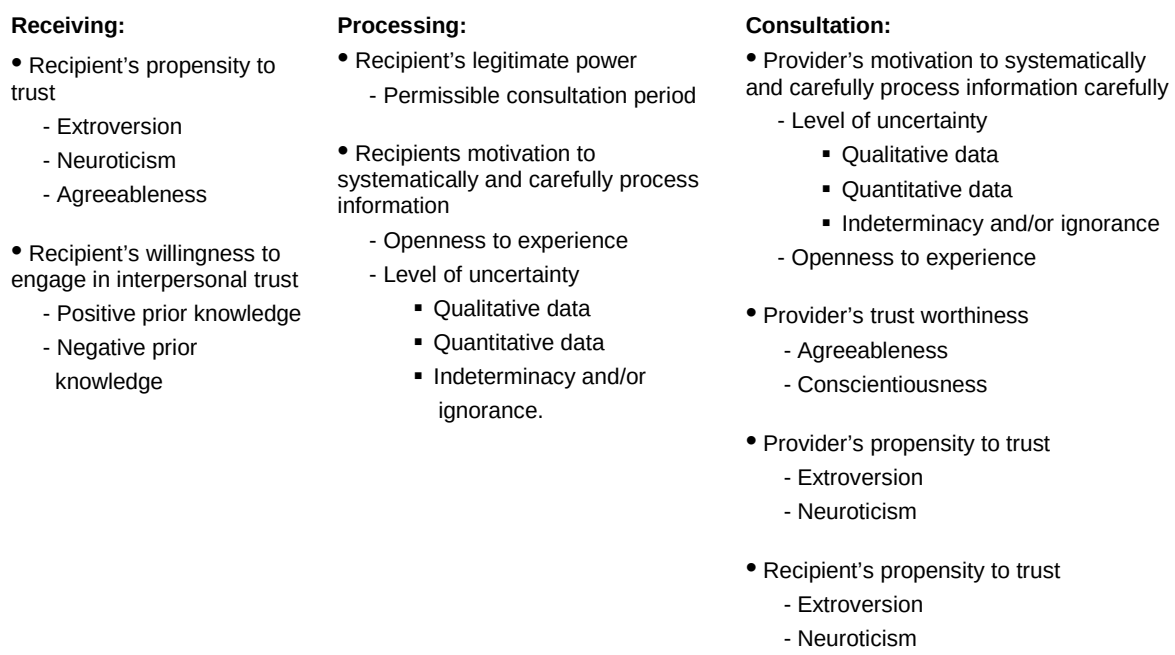

Figure 4. Logic supporting the influence personality and power has on the brokering of evidence and knowledge.

Here, we assume that the recipient agent is an intelligent customer for the evidence brokered, and is fully aware of what the guidance of the use of science in regulatory decision-making requires of them. Therefore we focus on the influence power and personality may have on a recipient's ability to manage uncertainty in this evidence and knowledge and interact with other agents accordingly. Dependency and necessity are assumed to be less subjective; perceived as hard and fast rules less likely to change modify the recipient's belief. We suggest there is some scope here to develop a dynamic agent-based model capable of exploring the potential influence power and personality have on risk regulation. Clearly, we do not claim this could offer predictive insight; rather we believe this will provide a means of exploring different scenarios; providing scope for better more improved regulatory and policy decisions; and in particular, illustrate how the influence of power and personality might play out in each of these of our example decision contexts introduced above.

For example, in the disposal of radioactive waste, a key role for the Environment Agency (EA) as regulator is to determine how sufficient and valid is the information provided by the operator is to the post-closure risk assessment (Figure 1). The trust established between the Agency and the operator, and between the internal and external expert advisers may influence judgements made on the sufficiency of the available information. If the Agency perceives the operator to be trustworthy, holding a degree of referent power, then they will be more inclined to accept the operator's line of argument in support of the long term safety of a facility. However, this may also depend on how trustworthy the Agency perceives alternative sources to be; and what degree of expert power the internal and/or external consultants are considered to hold. Hence, the decision making process entails extensive dialogue, not only between the Agency and the operator and the internal and external consultants, but also between the consultants and the operator. Moreover, much of the information being brokered will be qualitative and value laden, so the capacity to progress

decisions in a climate of considerable uncertainty is critical to securing a recommendation (in this case to the Secretary of State) within a bounded timeframe. The level of trust established between parties influences the brokering process. There are also important implications here for the personal competencies and skill sets of regulators, regulatory scientists, company representatives and lead consultants.

For the disposal of animal carcases organisations operate within an emergency response situation. Time constraints and good practice dictate that much of the risk assessment work is carried out in advance. In the event of an outbreak a key role for Defra is to determine the best course of action to minimise the risks of onward exposure, making good use of available guidance and expert advice. Hence, they must have a working knowledge of exposure routes, and the risks they pose, and access to expertise that can contextualise this knowledge during an outbreak. It is imperative Defra can trust expert advice so they can act quickly. Moreover, the level of interpersonal trust between the multiple actors involved here consultants may influence the extent to which referent, coercive, reward, expert and informational power can be established.

With respect to expert advise on salt in the diet, a primary role of the FSA is to determine the best course of action to minimise harm. Accountability for public risk here lies with the manufacturers and the public themselves and so the FSA's role is to educate the general public and encourage food manufactures to act responsibly. To achieve this, the FSA must maintain expert power and informational power in passing on (communicating) the current scientific evidence and knowledge. Hence, it is essential that the FSA be perceived as being factual and trustworthy, particularly to the general public so that published league tables and public health campaigns have the desired effect and the FSA can therefore establish reward and coercive power with manufacturers.

These brief explorations above illustrate the importance of regulators being both scientifically competent and facilitative in their discussions with regulatees, in keeping with the tenets of modern regulation. Enforcement authorities must be competent communicators, capable of making clear what they expect. Moreover, they must maintain an open and fluid communication with operators, because misunderstandings and poor communication might otherwise undermine the quality of decisions made.

Conclusions

Personality and power have a marked influence on group decision making. However, the influence they have on risk regulation through the brokering of scientific evidence is less understood and rarely examined in the practical context of regulation, as opposed to regulatory design. The application of agent-based tools may be an opportunity to learn from the influence of power and personality in a structured fashion so as to improve our design for better regulation. Insights from the literature have been presented as they relate to the brokering of scientific evidence and knowledge in regulatory decisions. We believe these are important, not only for conventional state regulation, but for the increasing application of hybrid regulatory models involving public and private sector interventions (see van der Heijden, 2009 on building regulations, for example). This paper has set out a critical review and set a forward agenda for our research. Future manuscripts in preparation discuss developments of our model and will evaluate the output from these simulations.

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