UNIVERSITY OF SOUTHAMPTON

Trust in Human Supervisory Control Domains

Melanie J. Ashleigh

Doctor of Philosophy

Faculty of Engineering and Applied Science

Department of Civil & Environmental Engineering

April 2002

UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF ENGINEERING AND APPLIED SCIENCE

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

Doctor of Philosophy

TRUST IN HUMAN SUPERVISORY CONTROL DOMAINS

By Melanie Jane Ashleigh

This thesis examined trust in the contextually specific domain of Human Supervisory Control, (HSC). Study one, established that control engineers conceptualise trust according to the context within which they are working and give more emphasis to making trust observable. Study two, identified important common contextually specific constructs of trust relevant to HSC domains and showed that differences in levels of trust existed across three bespoke groups of elements. Study three, confirmed construct validity in the three most important trust factors from study two and established a link between type of system interface, team location, level of trust and team performance. Study four, showed that these same constructs were important in developing trust in team interaction and a matrix of trust factors was validated based on emotive, cognitive and behavioural dimensions. It is argued that trust is a resultant perceptual state that is reinforced by varying the critical factors within a socio-technical system and should not be considered out of context.

It is shown that to ensure a trusting status, effort is required to maintain continuous visual and tangible feedback between human-human and human-system interfaces in an attempt to reinforce a perceived desired common goal. By adapting the Perceptual Control Theory framework, a practical model of trust has been developed that provides a relevant measuring tool that may be used to enhance trust in HSC and other applied engineering domains.

List of Contents

List of Tables.

List of Figures.

List of Appendices.

Acknowledgements

First thank you to God my creator for giving me the opportunity, strength courage and perseverance to complete this thesis – there were times when I never thought I would.

Thank you Roy for believing in me and putting up with me through the worst part.
A special thank-you to both my families - I love you all
To my family at church (you all know who you are), thank you for your prayers and support over the last year – it helped so much!

Dr. and Princess Debs – you are the best – I love you – thanks.

Thanks to Dr. Mike Riley for supporting my work over the last year and for enduring the endless pages of psycho speak. As an engineer I know it was painful for you – but we got there in the end!
A big thank you to the boys at BEG; Dave, Davey-boy and Lewis – what would I have done without you?
Finally, thank you to all the staff at BG Transco for the development of software and helping to generate the real-world parameters for the simulated control task. A special thank you to Dave Futers for looking after me during my stay at Killingworth. Also to Peter Chambers and all the control-room engineers from BG Transco North and South and all the guys from NGC who participated in this research.

To my children, *James and Katie* and my

grand daughter, *Charleigh*.

Persevere in all things……….

'Let the process go on until endurance is fully developed'. James 1:4.

1 Chapter One: Literature Review

"Perhaps there is no single variable which so thoroughly influences interpersonal and group behaviour as does trust. On this point ancient and modern observers typically agree. Trust acts as a salient factor in determining the character of a huge range of relationships. Trust is critical in personal growth and development as well as task performance." Golembiewski & McConkie, (p.131, 1975).

1.1 Introduction

Continuous fluctuation in and across organisations, together with escalation of automated systems within industry, including shifts in distribution of labour and greater variety in working patterns, has caused massive changes in our working relationships. These changes in working structures have subsequently increased the demand for synergy and mutual trust within and between teams. The impact of economic and technological changes over the last decade has also led to a greater complexity in working relationships, again emphasising the importance and need for trust to exist if organisations are to function effectively and achieve success, (Arrow, 1974; Dunphy & Bryant, 1996, Kramer & Tyler, 1996; Shaw, 1997). Reducing transaction costs (Luhmann, 1980), whilst developing a competitive advantage for any organisation is also an important goal, but can only be achieved through the capabilities that are embedded in the skills and knowledge of its members, (Amit & Schoemaker, 1993). Trust is seen as a vital component that can enhance this ability and as such provide the unique edge that organisations are striving for in order to enhance co-ordination and efficiency, (Bradach & Eccles, 1989).

In nearly every field of the social science literature, from sociological and psychological perspectives to economic, political and scientific debates, trust is a ubiquitous concept, (Gambetta, 1988; Lewicki & Bunker, 1996). With the increase in network organisations (Miles & Snow, 1995) and collaborative projects between independent industrial organisations and academic institutions, it appears that people are more willing to take risks in the expectation that through mutual collaboration we can become more productive. Are we therefore becoming more co-operative and trusting in our negotiations? This thesis proposes that the restructuring of organisations and the ways of working has emphasised the need for more co-operative and trusting practices. Although it is acknowledged that the level of awareness is beginning to rise in terms of what needs to be achieved, there is still little evidence in practical terms of what strategies to adopt and how they can be implemented into working practices in order to facilitate and monitor trust.

There seems to be some incongruity between the notion of trust as an inherent ingredient in any successful relationship, and the lack of trusting behaviour we generally observe in today's society (Tyler & Kramer, 1996). Within the UK this conflict emanating from our socialisation into rational choice (Good, 1988) was used to direct political, social and welfare policies during the eighties, leading society to embrace the notion of self-interest. Therefore, in societal terms, trust as a social construct seems to have been eroding rather than developing over the years. People have been encouraged to maximise individualism and materialism at the expense of facilitating collectivism in the wider community. In organisations where restructuring has led to mass redundancy and/or temporary contracts, employee and employer loyalty is diminishing. Tyler & Kramer (1996) argue that as our world is evolving, *'society is socialising us to negate our reciprocal obligations and in every domain we* *now cannot count on loyalty to others as a basis of reciprocity therefore the element of trust may be eroding away with it'*, (p. 3,1996). In order for trust to exist there needs to be an anticipated future interaction, as a basis for negotiation, and co-operation, (Axelrod, 1984; Williamson, 1993). Growth of competitive markets and the uncertainty of permanent or ongoing liaisons in the workplace however do not sit comfortably with such an expectation. In a review on the 'Social Virtues of Trust' (Francis Fukuyama, 1995), James Ogilvy observed that in the United States, *the balance between individualism and trust is tipping increasingly toward individualism* (p. 47). Fukuyama (1995) associates the lack of trust with economics, maintaining that *distrusting societies impose a kind of tax on all forms of economic activity, a tax that high-trust societies do not have to pay'*, (p. 47).

From a social psychological perspective, humans are less likely to behave rationally in a time of dilemma or crisis. From research on social dilemmas, it is evident that rather than egocentric behaviour, individuals are prone towards co-operative behaviour due to the group identity effect (Brewer & Kramer, 1986). Even when there is no anticipated future gain or reward, co-operation still exists through social identity, (Dawes & Thaler 1988; Dawes et al., 1990). This is not surprising based on the tenets of social identity theory (Tajfel & Turner, 1979) as people define themselves based on their group memberships and are reinforced towards higher self esteem depending upon their in-group evaluations. The underlying assumptions are that, rather than individual and personal gain, group memberships are valued for both social and psychological reward. Reinforcing these assumptions in working groups can enhance teamwork. Zand (1972) reported a saliency of group effect; when groups where briefed to expect trust from each other, they exhibited more trusting behaviours. In view of the fact that a degree of implicit trust exists in all interaction (Barber, 1983), perhaps it is significant that over the last ten years the importance of trust in social economic, political, and organisational relations has increasingly been recognised (Bianco, 1994; Sitkin & Roth, 1993). Radical changes in organisational structure over the last decade have altered people's attitude towards employment. Constraints on job longevity and distributed work patterns have caused concern in the work place, where employees and employers alike cannot expect the same loyalty and certainty about the future. Although these shifts have perhaps caused some demise of trust in the existence of long term exchange relationships, the realisation that rationality increases transaction costs, limits risk taking and provokes people into engaging in self-protective behaviour is eventually being recognised. Therefore perhaps it is time to redress the balance and find new mechanisms and strategies by which to foster trust in the workplace. This points towards the need to train people within-context in the workplace towards a greater expectation of trust through creating greater awareness and enhancement of group identity and co-operation.

With greater fluctuation in economic markets, companies have necessarily had to find new ways of increasing productivity whilst reducing costs and labour with fewer resources, (Lewicki & Bunker, 1996). They have had to become more flexible and responsive to rapid changes and higher competition in industrial markets. Organisations are constantly striving towards achieving increased quality production and greater success, not only through down-sizing, centralising or restructuring their companies, but by learning how to promote and nurture more co-operative working in forming new alliances and networks within and across organisational boundaries. There is little evidence of research in this area in applied settings, although in 1995

Miles & Snow developed their 'Human Investment Philosophy' into the construction industry. By adopting such a philosophy it was considered that organisations could put more effort into promoting programmes of new cultures and team building and provide guidance and training for workers. The researchers maintained that gradually, organisations would strive towards becoming more 'people focused'. This would promote seeking to improve the interpersonal dynamics, including competence and trust building at the individual team and organisational level. However to date there is no research evidence from commercial or industrial settings that the author could find to substantiate this philosophy. In a review on how 'new organisations' are managed, Limerick and Cunnington (1993) identified trust as being the most crucial competency necessary for quality management of networks. They point out that trust *'helps to reduce transaction costs, reduces uncertainty about the future'* and '*eliminates conflict*', all of which help towards *'minimising the need for bureaucratic structures that specify the behaviour of participants who do not trust each other.'* (p. 95-96, 1993). There certainly seems to be an inverse relationship between rules and trust as confirmed by Fukuyama (1995). The more people depend on rules to regulate their interactions the less they trust each other and vice versa. Furthermore, this lack of trust in organisations translates into the need for greater hierarchical and vertical integration and so the downward spiral goes on. Trust however does not develop automatically. In order to break this spiral strategies that are carefully structured and managed need to be found to help trust develop. These could then be incorporated into organisations training programmes so that ultimately they form part of the organisational culture.

As in personal relationships or within and between teams or in new technology, trust is seen as a developmental process that grows or diminishes according to how it is fostered reinforced and maintained. How this is realised in terms of actual processes and behaviours within and between teams is considered to be contextually driven and might be different across different industrial domains.

1.2 Research Domain

Trust is a particularly important ingredient in Human Supervisory Control (HSC) domains where interdependent shift teams are continuously controlling remote pieces of plant over a twenty-four hour period. Environments such as energy distribution plants, where team members are often physically separated and yet are totally reliant on each other and their technology, are both volatile and complex. Commonly in control rooms, control engineers have to process vast amounts of information as well as carry out many other tasks simultaneously. Having to deal with changing and novel interfaces, autonomous work groups and practices are affecting the locus of control for the operator and their workload. Progress in technology has led to dramatic changes in the nature of working practices and behaviours in process control (Kragt, 1994), and as HSC has evolved over the last century the role of the operator has moved from overt physical effort to covert mental manipulations (Hollnagel, 1993). The whole concept of the control engineer's task has also undergone drastic changes from being reactive to proactive (Zwaga & Hoonhourt, 1994). Control engineers are now able to extract and have access to more high level information through multi-user System Control and Data Acquisition (SCADA) systems, which means they have fingertip control of whole operating plants through a series of windows. This has led to a reduction in personnel and increased remoteness in some control rooms. Although greater computer power has allowed increased information availability, creating less physical load, this has led to more mental workload, (Wilson & Rajan, 1995). As technology develops even further, it is envisaged that virtual control rooms may exist, (Stanton & Ashleigh, 2000). Currently engineers are often distributed and yet have to supervise the remote physical components of the plant as one team through computer interfaces. Face to face communication is becoming rarer as technological advancement increases but as Hettenhaus (1992) argued that when dealing with teams, it is essential that any new technology or strategy adopted is supportive of the whole socio-technical system and not just parts of it.

Advancement in one area however could well cause deterioration in others; a state of psychological remoteness that can be caused by physical separation, (Wellens, 1993). Wellens found that physical proximity influences communication strategies, as separating teams by physical distance causes decay of group situational awareness, which can subsequently cause breakdown in team decision making. Wellens, (1993) proposed that communication media was therefore a crucial element in creating the necessary linking bridge that allowed physically separated teams to develop a sense of group situational awareness that would ultimately enhance their collaborative decision making and remove this feeling of remoteness. Wellens considered this was dependent upon the amount of richness or bandwidth associated with specific technologies and how they compared with face to face communication. In other words the *type* of information and the *way* it was presented to remote team members was more important in enhancing between team communication and team performance than the information capacity. Wellens also maintained that distributed decision making might be easier if more abstract representations of actions and information were presented. There is certainly research evidence to support the fact that interface design based on higher levels of functioning has positively influenced human behaviour in supervisory control. Abstract interfaces have enhanced fault detection (Praetorius & Duncan, 1991, Wood, Wise & Hanes, 1981), increased attentional resource capacity, (Greaney & MacRae, 1996) and enabled a more holistic goal-orientated approach towards planning and optimising control tasks, (Stanton & Ashleigh, 2001, Vicente et. al, 1995). It is therefore considered that presentation of information and type of display may also have some bearing on the way that control engineers perceive trust in their technology, as well as in each other, both of which are essential if they are to *maintain* control of the plant. Trust in each other is also essential so that the whole socio-technical system becomes one synchronous entity. Bhattacharya, Devinney & Pillutla, (1998) maintain that it would be trivial to expect trust to exist in an environment of certainty. HSC environments are full of uncertainty and risk; a good reason for examining the concept of trust and how it exists within and between teams and in technology in such domains. As Thompson (1967) observed, under conditions of uncertainty and complexity requiring mutual adjustments, sustained co-ordinated action is only possible where mutual confidence and trust exists. The fact that this assumption has not yet been researched within an applied HSC domain, specifically in the energy distribution industry, is the underlying rational for this thesis.

1.3 What is Trust?

The definition of trust according to the Oxford English dictionary is when one has *a 'firm belief in the reliability or truth or strength of a person or thing.'* When one trusts, one has a '*confident expectation*' in others behaviour or words, that they are reliable and true. To take something on trust is '*to accept or give credit to without investigation or evidence*'. Deutsch (1962), defines trust as the confidence when making a choice that it will lead to a beneficial rather than a harmful outcome. He emphasises that trust is built from a mutual co-operation between individuals; where their goals are *promotively interdependent*; (i.e. positively correlated). In order to receive trust there is an element of risk attached, a willingness to put oneself at risk with another person, Scanzoni, (1979). Similarly, Currall (1990), in his interpretation emphasises the dependency on others and defines trust *as one individual's reliance on another person under conditions of dependence and risk*, (p.41, 1990). Hart, (1988) sees trust as a degree of one's belief, depending on how much sensory evidence is available to us. He notes that to believe is to have faith, trust and confidence in someone or something, *'it is a feeling that a person or thing will not fail in performance'*, (p. 187, 1988). Faith denotes an unquestioning acceptance of something or someone without tangible evidence - as in faith in God. *'Faith is the substance of things hoped for, the evidence of things not yet seen'*, (Hebrews 11.vs1). Trust, is a feeling of expectation based on inconclusive evidence whereas confidence is more of a convicted feeling based on sound evidence or logical deduction. Hart therefore sees the definition of trust as lying halfway in the continuum of words connoting 'belief', (Hart, 1988).

It seems that trust incorporates all these definitions mentioned above although it is accepted that there is no one single or universally accepted definition of trust, (Kee & Knox, 1970; Shapiro, 1987; Sitkin & Roth, 1993). Shapiro for example comments that the attention research has given to trust has resulted in *'a confusing pot pourri of definitions applied to a host of units and levels of analysis'* (p.624, 1987). Hosmer, (1995) confirms that *'there appears to be widespread agreement on the importance of trust in human conduct, but unfortunately there also appears to be equally widespread lack of agreement on a suitable definition of the construct.'* (p. 380,1995). Indeed many researchers have not even attempted to define it, (Bateson, 1988; Erickson, 1978; Williams, 1988).

Trust, as well as being hard to define universally, is multi-functional. As already mentioned, trust can become the solution to the insoluble problem, it can steer people from self-interest to that of others. It can serve as a backdrop to a co-operative and successful team and it can provide a framework through which people can chose to negotiate their relationships, (Misztal, 1996). In relation to HSC domains it may be used in order to maintain team synergy and control a remote and volatile piece of plant. It may serve as the 'glue' that a team looks for to keep it together when they are physically separated from each other. The phenomenon of trust is therefore so complex and its function so ubiquitous that, rather than trying to explicate trust through definition, it is thought more important to consider how our perception of trust can be made more explicit, tangible and measurable within different contexts. In order to develop trust and enhance co-operative working generally one needs to ask what observable strategies can be engendered into company and/or team culture to create a greater trust awareness? Trust may incorporate a confident expectation in someone or something, but this can only develop from observable behaviour that matches ones expectation. Furthermore this expectation emanates from being in a goal orientated state; if the current state is perceived to not match the desired goal then an error signal predicts that a behaviour has to change in order to match that goal. This forms the basis of Perceptual Control Theory (PCT); a framework in modelling human behaviours developed by Powers (1973). This theory, in relation to trust, will be discussed in more detail later in this review; however only when the current state matches the goal state can one be totally confident and believe in that person or system; i.e. achieve trust. With regard to HSC domains therefore, rather than posing the question *what* is trust, perhaps it is more appropriate to ask what perception of trust do HSC engineers have and what behavioural strategies are necessary to achieve the goal of trusting a system or team member and when?

The constructs of trust, (however one defines the word), will apply only if those constructs are perceived as appropriate to the environment in which people want to achieve trust and with what or whom. Contextual appropriateness is an important issue and something that should not be ignored, particularly when considering engineering control behaviour (Hollnagel, 1993). Attributes of trust or ways of explicating trust are likely to change depending upon where you are and what your goal is. From an ecological perspective (Gibson 1986), trust could be considered a value-rich ecological process which is only achieved by encompassing the actor within its environment. In Gibson's terms the environment provides both behavioural and perceptual *affordances*. This is Gibson's own word that means the state of the world that makes the human tend to or naturally do or perceive something, Gibson (1986). Therefore the affordance of a chair in one domain may be to sit on, whereas in another it may be to stand on and in another to use as a shield, or even a weapon. What is perceived as an *appropriate affordance* in one domain therefore may differ drastically from that of another, depending on the actor's perceptual goal and expectation embedded within its context. If this is applied to the concept of trust for example, one may expect to find trust explicated in terms of caring and benevolence when talking about trust between superiors and subordinates, (Gaines 1980). Whereas perceiving trust in a doctor/patient relationship needs competency on the part of the doctor and a sense of moral obligation (Barber, 1983). Benevolence and caring although preferred are not necessary in order for correct diagnosis and treatment of the illness to take place. If the goal is achieved and the doctor's behaviour matches the expectation of the patient in this context, then a trusting relationship is likely to be formed. It is considered appropriate therefore to conduct research within the context of control rooms to evaluate how and when control engineers' experience trust with their team colleagues and technological systems within HSC domains; what strategies they perceive as affording trust within this context.

1.4 Types of Trust

This author has identified four key integrated areas of trust within the context of HSC domains as; interpersonal, team, virtual and technological trust. In order to avoid ambiguity of terms, interpersonal describes trust between two people, team trust refers to trust between members of one team (intra) or between two teams (inter). Virtual trust refers to trust that exists when teams of people are working remotely, with little or no physical interaction. Technological trust is the trust that control engineers have in the systems that they use. By identifying characteristics of trust that co-exist within each individual area, commonalties and differences may be found across areas as well as some interrelating elements. These four different derived areas of trust are discussed independently in the next section and Table 1.1 categorises all the trust elements mentioned throughout this literature review across all four areas. Based on the concept of trust as a collective attribute, (Cummings & Bromiley, 1996; Lewis & Weigert, 1985), which will be discussed later in this review, the table is also divided into three fundamental dimensions of emotive, cognitive and behavioural.

	Emotive	Cognitive	Behavioural
Interpersonal	faith/belief	shared attributes	willingness to take risks in *anticipation*
	shared values and attributes	information	acting from threat of punishment/or towards mutual rewards
	anticipation of future interaction	knowledge	predictability
	mood/emotions		dependability
	motivation		reliability
	confidence		consistency
		expectancy	honesty
			reciprocity
			shared experiences
Teams	cohesiveness/ team spirit	mutual definition of common goal	communication processes
	self esteem	team knowledge	co-operation
	confidence	broad role definition	co-ordination
	relinquishing self interest	collaborative decision making	seeking and giving help/feedback
	communal relationships	information	free exchange of information
	interdependence	norms/rules	high involvement
	commitment	group-identity	negotiating honestly
	collectivism		consistency
Virtual Teams	social categorisation	sharing same mental space	proactive action - need to respond
	relinquish self - interest	composure/control of conflict	mixture of social and task orientated exchange
	enthusiasm	common goal	intuitive leadership
	interdependence	procedures/rules	predictability
		cognitive skills	reliability
			feedback
			task focused
Technology	faith/belief	perceived usefulness	taking risk in using system for manual function
		functional fidelity	meaningful feedback from system
	confidence	expectancy	technical competency of system
			reliability
			ease of use
			consistency of control and display

Table 1.1 Matrix of trust categories across three dimensions

1.4.1 Interpersonal Trust

Within the field of social psychology there has been extensive research carried out on the dimensions of relationships, (Duck & Perlman, 1985; Valley et al, 1995). Greenhalgh & Chapman (1994), found that trust was the central factor in over eighteen empirically identified dimensions. Others have specifically researched the role of trust in personal dyadic relationships, (Boon & Holmes, 1991; Rempel et. al, 1985). Rempel's model of trust was based on the notion of people understanding their partners in terms of 'acts', 'dispositions' and 'motives' that predict positive responses', (p.98, 1985). Their hierarchical stage model measured three elements of trust; predictability of behaviour, dependability and faith. They found that trust in relationships was established mainly from faith in partners wanting to share the same things (e.g. intrinsic motivation), hence trust developed from a mutually satisfying interaction, which then generates its own rewards. Boon & Holmes, (1991), defined the three stages of trust in relationships as moving from idealisation through evaluative to the accommodative stage. Mayer et al's (1995) theory of trust emanates from the perceived attributes of the trustee and trustor in terms of *ability* (competence), *benevolence*, (care for the other party above oneself) and *integrity*, (principles they are guided by) which create dependability and reliability.

Barber (1983) takes a broader view of trust, basing his definition on degrees of expectation in relationships, noting that *'all social interaction is an endless process of acting upon expectations which are part cognitive, part emotional and part moral'* (p.9, 1983). At the basic level he refers to it as an 'expectation of persistence', an inherent trust we have in the laws of nature. The second type of expectation is that of *technical competence* in the way people carry out their roles. This is based on those with shared knowledge and expertise, that their performance will match our expectations (i.e. doctors, lawyers, etc.) Thirdly trust is referred to as *fiduciary responsibility*, an expectation that people will fulfil their moral obligation to help others who depend on them. This is a form of trust based on the distribution of power - a mechanism that is used to control - that is greater than just the level of competence. Trust from this perspective then is something that develops over time - a product of situational characteristics and socialisation. Conversely other researchers maintain that trust is an individual personality trait (Rotter, 1980), an underlying stable characteristic (Stack, 1978), that we have an inherent predisposition towards trust (Mayer et al 1995). These studies reveal that those who are more likely to trust are equally more trustworthy and are therefore less likely to lie, cheat or steal, hence they are more well-adjusted, happy and generally more likeable people. Trust therefore can be experienced and sustained from people's internalised value system, and from sharing values, attitudes and emotions, trusting relationships are created (Jones & George, 1998).

From the many fields of research, it is evident that the concept of trust is multidimensional as well as being a dynamic phenomenon. Trust is not static, but can oscillate upwards or downwards and is contingent upon many other factors. Whatever elements are used to describe interpersonal trust, they all seem to encompass some emotional, cognitive, and moral issues, which in turn dictate behaviours. All of these factors are based on evidence that is accumulated over time, where people are expectant of each other depending on how much evidence they have or at what stage of the relationship they are at. Trust can also be viewed in terms of an interpersonal debt system, (Burt, 1992). We may invest into a relationship and by using cues, we evaluate the degree of trust we can expect back. However we do not *know* that the debt will be recognised until the trusted party reciprocates when we are in need. Therefore, in an attempt to reduce our costs in time and energy when trying to identify trustworthy contacts, we are more likely to choose those with whom we share similar social attributes, as they are more likely to reciprocate.

In summarising the literature, the most significant elements of trust at work in interpersonal relationships appear to incorporate three elements;
a propensity to trust in others based on similar values or shared attributes; a willingness to take a risk in the anticipation of some future interaction; faith or a degree of belief that others will be motivated towards mutually beneficial rewards. These factors could be described as the antecedents of trust. Once a degree of trust exists between two people it can be maintained through the ability or competence in meeting each other's expectations and the confidence they have in each other, based on acts and accumulated knowledge. Predictability, dependability and reliability are the elements that are created by trusting or being trustworthy.

1.4.2 Trust in Teams

Trust becomes a more complicated concept when considering it from a team perspective as a team generally consists of multiple, interdependent actors. It is precisely *because* of this interdependency, complexity and uncertainty that exists in any team interaction, however, that necessitates some element of trust being present in order for effective functioning, (Jones & George, 1998). Formal agreements and structural controls are a poor substitute for trust in teams, who should be both flexible and responsive to environmental change and fluctuations in social processes, although as Porter (1997), points out, such substitutes are often difficult to discard. Luhmann (1980), argues that trust is necessary to reduce complexity in social systems. He advocates that trust is preferable to distrust as it saves time and energy. Therefore, even though rarely made explicit, from the many interdependent factors inherent in successful team working, one of the most important components *has* to be trust. Research devoted to teamwork within the human factors domain, refer to determinants such as cohesiveness, (e.g. Martens & Peterson, 1971; Mayo, 1993), co-operation (Ilgen et al 1995), co-ordination, (Stout et al. 1990) and effective communication processes, (Lassiter et. al., 1990). These are named as being some of the most important in achieving team effectiveness. Deutsch (1957) saw trust as a pre-requisite to the existence of any stable co-operative system. As high performing and effective teams should work as co-operative systems, it is therefore assumed that trust is a critical ingredient. Deutsch (1962), also advocated the elements of *'communication and co-operation as the two most important antecedents of trust'*, (p.158, 162). It is possible therefore, that by attempting to encourage such behaviours, members would achieve a better mutual understanding and thus the element of trust within and between teams would be made more explicit.

Limited work has been undertaken in endeavouring to understand this phenomenon in teamworking. Recent growth in autonomy and self managed teams and networked organisations however, is convincing researchers to recognise that trust is an important concept that warrants closer examination, (Cummings & Bromiley 1996; Jarvenpaa & Leidner, 1998). Within collaborative decision making, research has shown that it is these unique team level constructs such as trust, co-operation, co-ordination and communication patterns that have a significant effect on team decision making both directly and indirectly, (Ilgen et. al, 1995). These authors claim that trust might interact with mean team ability and that when both are high, teams are successful. When trust is low however, irrespective of ability level, the team is more likely to be less successful in achieving their task. Trust certainly affects team decision making at the team level, which can also be enhanced or debilitated by the power and/or status of individual members. Similarly, Rosen (1989) argued that members who are often resistant towards participating in team decisions maybe because of a lack of trust. This is manifested in people feeling intimidated or exploited by higher status group members (e.g. managers, technicians, etc.), who impede their motivation.

Evidence exists therefore that trust is a critical team construct and necessary for an effective functioning team. Because teams consist of multiple interdependent actors and the fact that complexity and uncertainty often exists within and between teams, trust saves time energy and drawing on other resources. Without trust, teams are more likely to fail despite competency levels. Trust also allows reticent team members to become more participative and therefore motivated. Trust reduces the need for structural and bureaucratic controls and has a positive effect on team decision making. From the literature it seems that the prerequisites of trust in teams are consistent communication and co-operation between team members, a willingness to risk action, based on a shared common goal and a willingness to openly share information both horizontally and vertically across team members.

1.4.3 Virtual Trust

What of those groups who do not have the advantage of sharing the same time and/or space? - a concept that is becoming more common across organisations. Such teams are often referred to as *virtual* (eg Lipnack & Stampts, 1997) where people are physically distanced from each other, although working on the same team. Emerging technologies are consequently becoming more pervasive in organisations allowing geographically separated teams to work as though they are (virtually) collocated, (Mark, Grudin, & Poltrock, 1999). With this massive growth in distributed teams it seems that technology has forced people to quickly develop a mutual trust with regard to the sensory data upon which social bonding is formed, (Cerulo, 1997). In her discussion on how new technologies are forcing people to re-adjust to the concepts of social interaction, Cerulo found that personal, informal and even intimate exchanges between strangers were exhibited before information on the set topic was offered. Therefore, rather than physically being located in space, relationships were built upon sharing the same shared goal or task location.

Where an absence of direct social cues exist, people tend to seek out specific others in anticipation of long term relationships; those they can personally identify with through their mutual experiences, (Walther & Burgoon, 1992). In their study using groups of students with no history, working face to face or via computer, Walther & Burgoon assessed relational communication development whilst people were collaboratively working over a period of five weeks. They found that when only using computer-mediated communication (CMC), people still developed in relational dimensions. In particular, results from the dimension of receptivity and trust - defined as the amount of openness, rapport and desire to be trusted - showed that trust develops. Over time both groups increased their level of trust to a final convergence; albeit initial exchanges in the face to face condition were higher.

With regard to virtual teamwork, some authors point out that teams may become dysfunctional in terms of role ambiguity or overload, social loafing and absenteeism or have a general low individual commitment, (O'Hara-Devereaux & Johansen, 1994). Handy (1995), argued that trust needs *'touch'* and questions whether a totally virtual team can achieve team effectiveness and/or task performance without frequent face to face interaction. Technological environments may also impair a group's functional performance, thereby inhibiting the development of trust, (McGrath, 1991). The implication is that in circumstances where ad-hoc teams are brought together to complete a specific project or task, time and added diversity impedes the development of trust through gathered information and social interaction. Investigating the global dimension of virtual teams however (where team members are located in different countries), research has found that even without social cues, trust, warmth and attentiveness can be developed over a virtual network, (Jarvenpaa & Leidner, 1998). Meyerson et. al, (1996) claim that in this situation it is a *'swift trust'* that is imported from expectations of trust from past experiences. Rather than based on interpersonal dimensions, swift-trust emanates from forms of stereotyping - categorising others through information processing and action. In an attempt to identify different forms of trusting relationships in virtual teamworking, Nadhakumar & Baskerville (2001), found that Video Teleconferencing Personal Computers (VTPC) helped to enhance trusting relationships between virtual members of a large organisation. Although initially the VTPC was installed in order to improve communication across the workforce, the desktop multimedia facility was seen *as 'helping users to overcome the* *barriers for collaboration and knowledge sharing'* (p.3, 2001). Consequently the facility became an integrated part of the company's technological infrastructure. Two separate virtual team evaluations found that the VTPC helped to develop online sharing relationships; extending authority relationships and task-based temporary relationships. Consequently a form of '*abstract trust*' was reported to exist between team members. This trust was not based on personal relationships or reciprocal sharing and disclosures, as the team life span was finite and they had no past history of working together. Rather, the trust that developed was based on organisational social order, routines and a body of reflexive knowledge that existed within the company culture. Participant team members however still proactively sought to personalise these trusting relationships through actively seeking face to face interaction whenever possible. It was noted that without such social personalised interaction the emotional or affective element of trust did not exist. Team members also perceived some modes of the VTPC as unreliable, which made them feel isolated, made them less positive in their attitude and often created a fear or anxiety that they were 'missing out' on what was going on between other team members.

In any virtual environment, where there is no opportunity for face to face interaction, other cues have to be sought in order to be able interpret others intentions. In order to produce mutually effective behaviour, people need their expectations to be met and it is in meeting these needs that trust will develop. Jarvenpaa & Leidner, (1998) found that *action* or *intended action* was a significant factor that promoted mutual trust between virtual team members in a self-fulfilling fashion. The more immediate response to a virtual communication, the more trust developed amongst the team. Even when members could not act immediately or had a problem with carrying out their particular task, communicating the reasons *why* they could not fulfil their obligations to the other team members was seen as a positive act. This substantiates the views of Hawisher & Morgan, (1993) who maintain that in the absence of face to face communication, more emphasis rests on an intense *need to respond.* Other factors that enabled trust to be established within virtual global teams were classified into communication behaviours and actions, Jarvenpaa & Leidner, (1998). In facilitating trust the higher trust teams were seen to be exchanging socially orientated comments and enthusiastic responses early in their negotiations. This was followed by people taking the initiative, and coping with technical uncertainties, by establishing norms and rules for the team to adhere to. Groups who maintained high trust throughout the project were those who were consistent and predictable in their communications and who always gave timely feedback to each other. They acted according to procedures they had set and quickly became task focused. They also enjoyed positive natural leadership from whoever had the most ability on the task in hand. These high trust teams portrayed a composed response to crises; they were not flustered by turbulence and despite conflicts, worked towards the common goal of the group rather than their own self-interest. Other earlier research into dispersed teams however has demonstrated that more commitment and attraction existed between virtual team members than those who were face to face, (Alavi, Wheeler & Valacich, 1995). Discrepancies exist from the literature therefore as to what *type* of trust develops between virtual team members and whether a *temporary*, *abstract* or *swift* trust formed between teams on a project through CMC is enough to sustain an emotional bond and lasting trusting relationship across the team per se. It is again considered that external influences, such as type of team, task and the contextual environment may have some bearing on this question.

In summarising the literature, it appears that in a situation devoid of social cues as in virtual teamworking, trust develops by anticipation (expectation) of long term relationships, where personal identification comes through sharing mutual experiences and social identification through shared goals. Trust is also built by categorising others through information processing and action; it is nurtured by consistent and predictable communication with timely feedback as well as feed-forward, together with an intense need to respond – an action or intended action. Trust in these situations can only be achieved by relinquishing self-interest in the pursuit of the common goal, however in some cases there is evidence that only a *'temporary'* trust exists if there is no chance of any face to face or social interaction, (Handy, 1995; Nandhakumar & Baskerville, 2001). As Handy (1995) points out, in order to enjoy the efficiencies and other benefits of the virtual organisation, society needs to rediscover how to run organisations, based on trust rather than control. *'Virtuality requires trust to make it work; technology on its own is not enough.'* (p. 44, 1995).

1.4.4 Trust in Technology

The increasing intrusion of automation into our everyday lives means that we now have to quickly adapt and be willing to put our trust in new technology for almost everything we do. Accessing money, train or cinema tickets is now an everyday occurrence via machines. The escalation of telephone banking and automated domestic utilities has almost completely removed the human element out of customer service functioning.

Observations from research in the energy distribution industry (Stanton & Ashleigh 2000), found that when evaluating people's perception of various systems within the control room, engineers were initially reluctant to use them. For example when administrative tasks were initially automated, people still clung to their notepad and pencils commenting *'when we write it down ourselves at least we know where to find it again,'* (Grid Operations Controller). The implication being that in this age of smart machines, humans are still reluctant to put their trust in them, preferring to rely on their own skill knowledge and experience. It appears that people are not initially willing to put themselves at risk until they have gained experience from using the system and had positive meaningful feedback from it. In other words optimum trust can only be achieved through greater congruency between human and technological goals. In relation to this in a study researching user acceptance of information technology, Davis, (1993) found that perceived usefulness of a system, (i.e. does it perform the task), was fifty percent more influential than the ease of use of the system in determining how much the system was *actually* used. This emphasises the importance of designing new systems with the appropriate functional capabilities as, if the automated function achieves the task more accurately and in half the time, then people are more likely to use it, hence learn to trust it. When controlling complex systems in the domain of HSC, which is often highly volatile and unpredictable, it is necessary for operators to develop trust in automation in order to reduce cognitive workload, (Bainbridge, 1983; Reason, 1990; Wickens, 1992, Norman, 1990).

Controlling any dynamic system (e.g. energy transportation), demands greater interdependency both within and between teams as the task is continuous over time. It is therefore important to develop a fuller understanding of the key elements of trust between shift workers and their technology. Essentially, as teams have become more distributed over organisational and geographical boundaries technology is being more heavily relied upon as the main vehicle of interaction and control and trust is seen as a vital component of this socio-technical system.

Sheridan (1988), interested in the degree of trust within the human-machine relationship, suggested that we should be concerned about technological expansion. With technology now encompassing every domain of life Sheridan muses that although technology has allowed us to convert almost anything to be remotely controlled on a whim, this ultimately means that we will be expected to *'abandon all responsibility to the computer'*, (p.160, 1988). It is therefore important when designing future systems that consideration is given to how operators will adjust to the different functions of automation. The degree of trust people have in their interaction with machines may be significant in the number of accidents involving automation (Wiener & Curry, 1980).

There is limited research on trust within the area of Human Supervisory Control (HSC). However, Muir (1994) in her pioneering work into trust in automation points out that trust is similar to mental workload or tacit knowledge; '*intervening*' variables that only reside in the human mind; '*they mediate the humans' observable responses to environmental stimuli*', (p. 1909, 1994). Muir also found the concept of trust both difficult to define and measure and based her experimental work on an integrated model of Barber's (1983) *fiduciary expectancy* and Rempel's (1985) developmental process of *predictability*, *dependability* and *faith* to investigate trust in automation. She found that operator's perception of trust did not change with experience but from the competence of the machine. Generally operators used the system they trusted and rejected those they didn't, reverting to manual operations when they felt the technology unreliable. If an automated part failed, their trust was reduced in another function using that same component, although this did not generalise to other independent parts of the system.

In a later study Muir & Moray, (1996), varied the properties of control and display response in the simulated plant system. Results showed that trust varied as a consequence of the amount of error introduced and was highest when control was exact and displays accurate, (i.e. when both human and technological goals met). Even though control and display modes were separate, people's trust in the control properties was affected by what was displayed. This has implications in the design of interfaces, as lack of functional fidelity can not only reduce trust but may also incur possible error in control action and decision making. Contrary to (Muir's, 1994) previous findings, this later research indicated that trust or distrust did generalise from one mode to another and develops over time from experience. When in constant error mode, participants learned to compensate and made adjustments; hence trust grew over time confirming that to develop trust in automation people *do* need experience, (Muir, 1994). Using differing amounts of magnitude and variability of error, Muir & Moray, (1996) found operators' trust diminished quickly at first but only gradually from thereon as the error increased. This indicates that machine behaviour must be both consistent and in line with operator's expectations in order to foster trust. People only use automation to the extent that they trust it, if not they quickly revert to manually doing the task. This implies that consistency and reliability in control and display information affects the degree of perceived trust and whether it develops or deteriorates.

Results from Muir & Moray's stage development of trust in automation were directly the reverse from Remple's (1985) original interpersonal model, however it must be pointed out that these subjective measures only tested a small novice sample. Although the authors explain that the human-machine development of trust may significantly differ from dyadic romantic relationships, it is possible that the participants of the study could have misinterpreted the semantics. In other words if each factor was defined and explained in context to the specific task domain, maybe results would be different. Additionally, as pointed out by Muir & Moray (1996), if trust evolves through experience, it is considered that by testing a larger sample of engineers in a real-world setting, experience may affect results. Therefore differences in the way the elements of trust are defined, interpreted and used in different domains may potentially make a difference to the way trust is conceptualised. Alternatively it may be as suggested earlier, that trust develops from an initial faith or belief that the system will perform as expected in meeting the goal, but only after observable evidence that it conforms to expectancy can people learn to trust it. Given this explanation, Muir & Moray's, (1996) findings would be consistent with this view as faith was highest in the first training session, expressing a belief based on no evidence, (Hart, 1988). Dependability was highest in the last training session, indicating that over time people can learn to trust the system. Finally, predictability scored most in the actual experiment, implying that through consistent and reliable machine behaviour people would come to expect the system to perform its responsibility, as they become more dependent on it.

1.5 Theories of Trust

When considering the different theoretical approaches of exploring trust, it may be possible to extract some commonalties and differences between them. From an extensive review of the literature however, it seems that most researchers have used the underpinnings of interpersonal trust and adapted them to professional or group/ organisational relationships, implying trust as developing through incremental stages. Lewicki & Bunker's (1996) theoretical model identifies three stages of trust apparent in professional relationships based on the taxonomy of Shapiro et al, (1992). The authors identified these as c*alculus-based, knowledge based and identification based.* They claim c*alculus based* trust is more typical when people had little or no knowledge of each other. They argue that initially people are vulnerable and often uncertain about self-disclosure therefore they are more likely to trust in others, based on the threat of sanction or punishment in violating that trust. This initial form of trust is a weighing up process where people are considering the costs and benefits to themselves, the organisation and the working relationship. In considering teams, this early stage of trust acknowledges the existence of fragility and uncertainty, perhaps similar to the early formation of teams when in their forming or storming stages, (Tuckman, 1965). Where gender, roles, status, and/or location already diversify multiple actors, however, rather than being motivated by threat of sanction, it is considered that teams may be more likely to be motivated by the reward of achieving their mutual goal. The second stage of trust according to Lewicki & Bunker is *knowledge based*, where behaviour is more predictable because of the information gained about the trustee; therefore there is more of mutuality between them. Thirdly trust develops into i*dentification based* by which time there should be a complete empathy within the relationship; a full understanding of each other's needs, wants and intentions. As in group identification, group based trust should develop as the team identifies with its goals. Group saliency therefore increases greater frequency of co-operation hence promoting trust, (Kramer & Brewer, 1986; Kramer, 1993).

Using a Symbolic Interactionist model (Mead 1934, cited in Jones & George, 1998), trust has been explained as an iterative process (Jones & George, 1998). From this point of view trust evolves through mutual definition of a situation and can be viewed as an interdependent spiral (Butler, 1983; Zand, 1972) moving upwards towards unconditional trust or downwards towards mistrust, according to the experience of interacting values, attitudes, moods and emotions with others (Jones & George, 1998). The authors differentiate between conditional and unconditional trust by describing what effects either kind could have on teamwork or co-operative behaviour in organisations. Conditional trust exists where attitudes are favourable to support future interaction and can enable co-workers to meet a common aim or objective. Unconditional trust however can *'convert a group into a team'* (p. 539, 1998). This type of trust exists where people are willing to invest whole-heartedly into the common good of the team, making personal sacrifices and continually promoting co-operative acts. Through shared values, attitudes and positive moods and emotions, team members are motivated towards stimulating others to act similarly thereby reinforcing the positive affects. Jones and George suggest that unconditional trust can lead to other social processes that can enhance the development of synergy within teams including elements such as broader role definitions, communal relationships and high confidence in others. Help seeking behaviour and a free exchange of knowledge and information, together with subjugation of personal needs and ego for the greater common good also helps promote unconditional trust. One has to question however how to encourage people to invest whole-heartedly into a shared common goal. Many organisational teams may perceive that they share a common team objective but still act from an individualistic perspective.

Empirical evidence to substantiate the claims of Jones & George, (1998) is not available to date. This author postulates that if the perception of trust were made more explicit in relation to achieving a common goal within the working context, then behavioural strategies could be developed as tangible measurements of trust in order to enhance team trust. It is through the variation in actions that perceived unconditional trust could eventually be fostered and sustained, rather than vice versa. It has been suggested that trust can only evolve through experience (Lewicki & Bunker, 1996; Remple et al.1985; Shapiro et. al, 1992) and although one may inherently have an expectation towards a willingness to trust, there is risk involved until the behaviour matches that expectation. In considering the cause and effect of trust however, it may be helpful to think of it as an ongoing reciprocal process, where one affects the other depending on the perceptual goal of the person or persons and the context they are situated in.

1.5.1 Perceptual Control Theory

An appropriate view to approach the concept of trust is from the actors' point of view within the context of what they are trying to achieve (e.g. their goal orientation). The theory of Perceptual Control is a framework for modelling behaviour that may be useful in explaining this. Perceptual Control Theory (PCT), originated from the engineering concepts of classical control theory; its core tenet being that *'all behaviours result from the control of perceptions'*, (Powers 1973). Instead of thinking about behaviour as emanating from environmental stimulation, PCT sees it as being purposive and human beings as control systems striving to achieve different goals. As control systems our behaviour controls the consequences of our action. We perceive from behaviour (*input*) how our current state (*perceptual signal)* differs from our desired goal state *(reference signal)*. The amount of feedback, in terms of magnitude

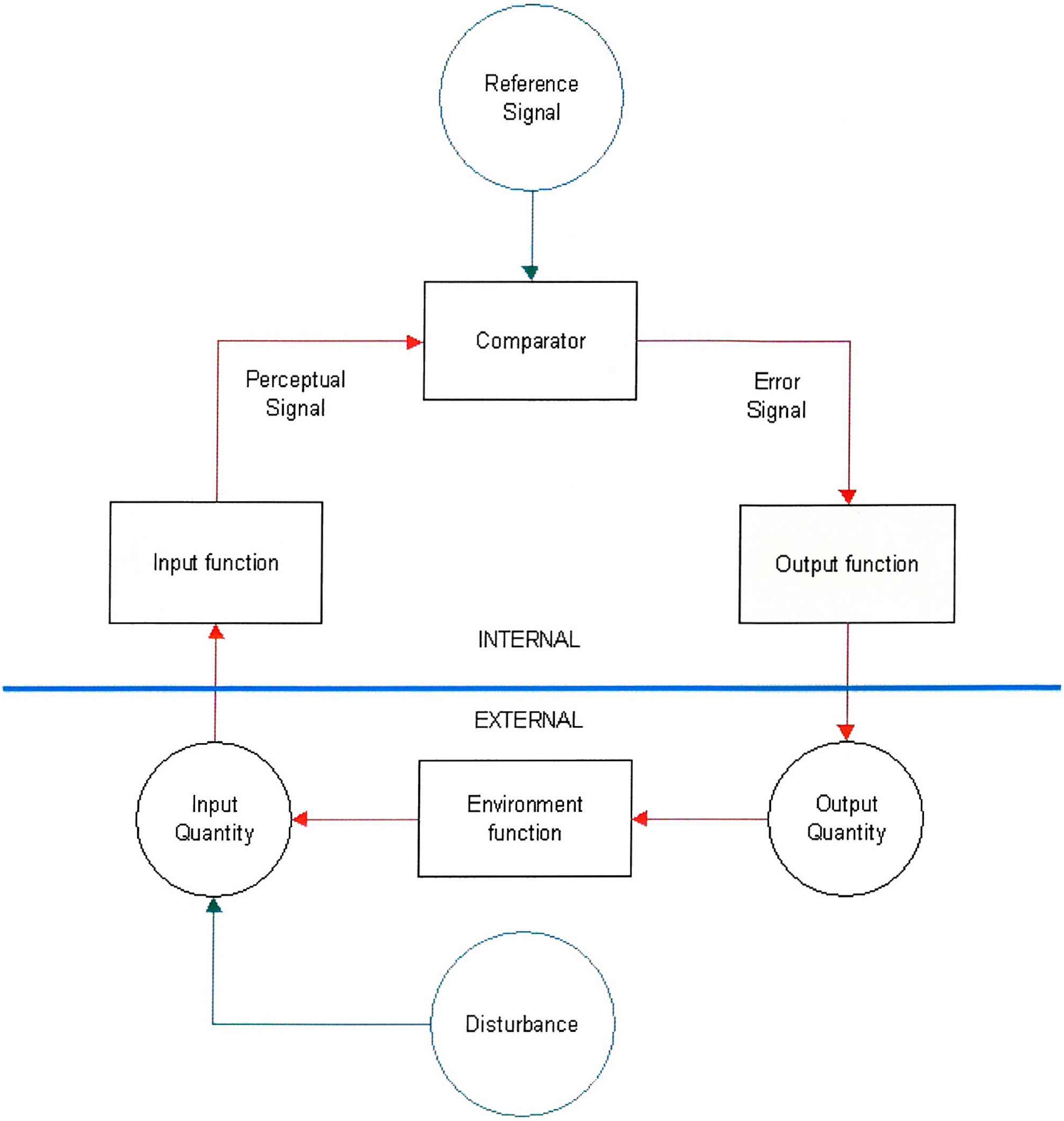

Figure 1.1 Basic PCT control system (Powers, 1973).[1]

[1] Reproduced with permission of the author; copyright Powers, (1973).

of error signal perceived, enables us to act to convert the error into a physical effect on the environment, thus changing the current state towards meeting the goal. The whole concept of PCT therefore is that humans interact with the world via a feedback loop. The basic model of PCT is shown in Figure 1.1 and can be related to an HSC environment.

The blue bar across the diagram separates the active control system from the environment. Red lines display the closed causal loop of control. The circles in the environment show where the physical variables may be measured as an output, input and disturbing quantity. The green lines indicate the effects of independent variables; the reference signal and the disturbances. The input function converts a sensed variable in the environment to a signal representing it inside the system; the output function converts the error signal into a physical effect on the environment.

When controlling an energy distribution system for example, control operators have a reference point or goal of trying to *keep a steady state in balancing input or generation with demand.* There may be a variety of fluctuating variables in the environment as well external disturbances, which distracts them from achieving this goal. There is variability within the task itself, for example, that can affect perception of control such as fluctuation in demand, loss of flow, change of input, storage availability, etc. Another influence may be how control and display information is presented via the SCADA system. There are external environmental disturbances (unplanned disturbances) that could include noise, the physical working environment, emergencies, unplanned loss of personnel, etc. Other internal environmental influences may include team structure, dynamics and/or location of teams or whether engineers are working together or remotely separated from each other. The longevity of team members' working relationships, absenteeism, health, personality differences etc., all these factors are influencing engineers' perception of controlling their goal. Their behaviour therefore continuously seeks to minimise the perceived errors in maintaining or reaching their common goal of balancing the system, interacting with the technology, immediate team members and/or other personnel.

Although relating this model to trust in teams and technology is slightly more complicated, it is hypothesised that this framework may be adapted to model how trust could be measured and monitored within engineering domains. Shift team members within process control tasks inherently share one common goal and therefore trust in each other and their technology is a high priority in achieving this objective interdependently. When a team member perceives from his/her *comparator feedback* signal that there is a discrepancy between goal expectation of the system or team member and the current state, then some action needs to be taken in order to change the outcome. With regard to team trust however, other factors that must be considered are role and status of team members and/or company politics and culture. This author argues that with multiple actors working together there are two courses of action that can be taken. If the perceived control of team members emanates from self-interest rather than from a team perspective then negative action is likely to follow. This could lead to a blame culture, breakdown in the team environment and reduced performance. Consequently egocentric behaviours feed back into the perceptual input in a negative way in terms of a reduced perceived trust less feel good factor or team spirit and cohesiveness, hence less perceived control. The perception of error away from the goal increases, creating mistrust and the cycle continues. Alternatively where team members share the same objective and are open, willing to risk, and can openly share a collective perception of control, they will more likely use positive behavioural strategies. These positive responsive actions will decrease the perception of error, enhance the team perception and so reinforce the willingness to risk a second time round. With the perception of moving nearer to the goal, team trust increases and with it team performance. These concepts are presented graphically using the PCT framework in Figure 1.2.

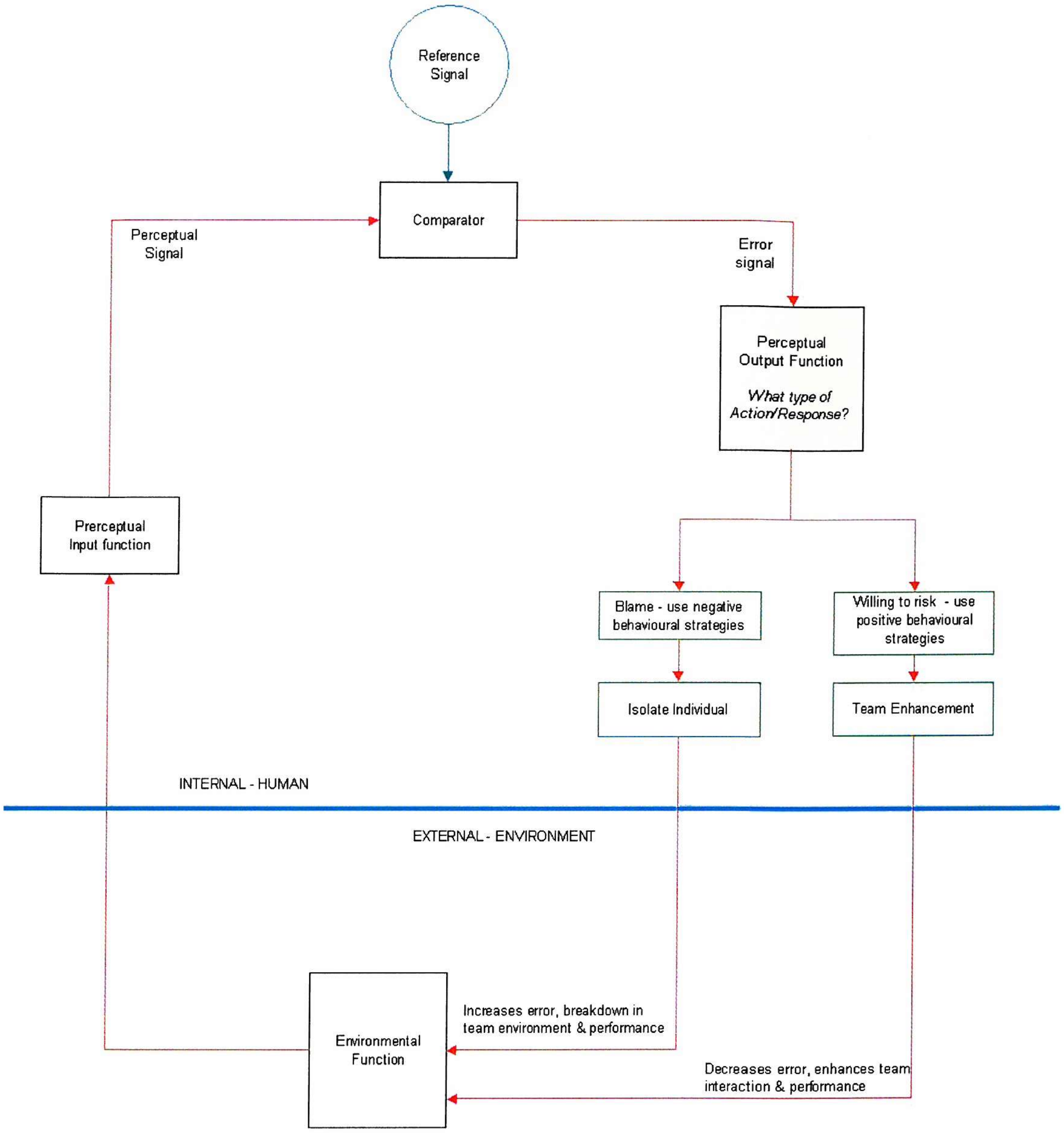

Figure 1.2 Hypothetical example of developing team trust using PCT model.

1.6 Learning to Trust

In evolutionary terms we have had to *learn* to develop trust through taking risks in order to survive as a species (Kipnis 1996). Kipnis argues that from a phylogenetic perspective trust may be an unnatural emotion, as we have to trust people who do not share the same genetic pool. Whether through survival of the fittest, socialisation or an inherent personality trait, learning to trust is vital when working in teams, as each person is reliant on another. Rentsch et. al, (1994) posit that teamwork improves with experience. Core teamwork knowledge involving enhanced communication strategies, interdependence, co-operation and other relational dimensions, also are likely to be found in teamworking experts, (Salas, et. al, 1998). Similar to trust, teamwork knowledge has been identified as developing in stages (Anderson, 1982; 1987). He argues that from declarative knowledge involving learning rules of how to perform in a team, through developing an understanding of relationships by compilation of facts to applying the rules, members eventually gain procedural knowledge from practising those skills, which then become automatic. As highly experienced teams are more effective in their overall performance (Dyer, 1984), it is plausible to assume that as trust is a relational dimension of teamwork, higher levels of trust will exist in expert teams. Differences in the levels of trust both intra and inter team should therefore be apparent, dependent upon how long they have been in a team, how well they know other members and what teamwork knowledge they have gained. If one applies the correct rules and norms and acts in accordance with them (e.g. for the common good of the team rather than through self-interest), this promotes an increase in knowledge of members. It is argued that by continually applying appropriate behaviours one learns to develop better teamwork knowledge and thereby enhance trust It is interesting to note that as mentioned earlier, Jones & George (1998), argue that through shared goals, unconditional trust develops *exposing* other behaviours (explained by the authors as social processes). Conversely, from a PCT perspective, it could be argued that from sharing the same goal members seek to meet those by acting to minimise the disturbances (errors) in the environment. This may be from the physical (external) environment or from the factors that make up the team or organisational (internal) environment. Therefore, within a PCT framework, modelling trust between teams of people and technology may look slightly different from the original. Time however is still a dependent factor, dependent upon how long it takes for the teams to *mutually* achieve their shared goal. As external and internal variables fluctuate and disturbing influences shift them from their goal, team members have to change their behaviour to reduce these disturbances, in their endeavour to meet the goal. Referring back to Figure 1.2, learning to trust may equate to openly monitoring the number of cycles of team action needed to reduce the perceived error to meet the accepted level of control or optimum trust.

1.7 Evaluating Trust

The literature is replete with different perspectives for examining trust between interpersonal and professional dyadic partnerships, together with some evidence of trust in organisations (Cook & Wall, 1980; Cummings & Bromiley, 1996; Zand, 1972). It is also apparent that research on trust between dispersed teams is also gaining momentum, (e.g. Jarvenpaa & Leidner, 1998; Meyerson et. al, 1996; Nandhakumar, J. & Baskerville, R. 2001). There is an absence of empirical evidence into team trust, particularly within applied settings. It is also evident that, with the exception of the research by Muir, (1994), Muir & Moray, (1996) and Moray et. al, (1995), there is little evidence from the investigation into trust in technology, particularly within HSC domains; albeit the very nature of the environment assumes trust to be a vital component.

To date, research methods within the area of trust have come from different sources. Muir (1994) used elements from interpersonal trust theories to measure trust in technology. Other trust measures have been a small part of a wider taxonomy of social and relational interaction factors, (Burgoon & Hale, 1987; Dunphy & Bryant, 1996; Jarvenpaa & Leidner,1998), where trust has simply been incorporated as a team factor. Other methods have included modelling trust in a mathematical mode in order to rationalise it (Bhattacharya et. al, 1998). Research has been accused however of being too precise with definitions of trust, whilst ignoring the social context or situation that is being investigated (Bhattacharya et. al, 1998).

Context is considered to be a crucial element of teamwork in organisations, especially where there is greater unpredictability and complexity. One of the primary aims of this thesis therefore is to examine the concept of trust as a unique element of team interaction in a context-specific domain. Although there is little evidence of research into trust in organisations (Cook & Wall, 1980; Zand, 1972), Cummings & Bromiley (1996) developed an instrument for measuring trust, maintaining that it provided a *'reliable and valid method of measuring trust in between units in organisations or between organisations,'* (p. 319, 1996). They based their trust inventory on the premise that organisations share a common belief system in trying to reduce transaction costs and complexity by aiming to promote collectivism. Certainly increased organisational restructuring (Belasco 1989), and greater emphasis on different team structures has made trust the necessary foundation from which a team can build success, (Zenger et. al, 1994). Diversity of membership in terms of race, culture, age, gender etc., is another important reason for trust to be fostered within and between teams, (Mayer et. al, 1995). In fact Rotter (1967) deemed trust *critical* for an organisation to survive. Achieving this mutual aim however, depends on the shared norms and values, particularly a willingness to forsake self-interest for that of the team (Porter, 1997). Due to the interdependent nature of teams, there exists an inherent amount of vulnerability and risk; an environment ripe for trust to evolve or dissolve. Cummings & Bromiley (1996) maintained that a certain amount of implicit trust between members may be assumed as each one is dependent upon another and used this rationale to develop their Organisational Trust Inventory, (OTI). Using the definition of trust as a belief system in a shared common goal, group action should be based on:-

a) good-faith efforts to behave in accordance with implicit and explicit commitments

b) honesty in negotiations preceding those commitments

c) not taking advantage of another person even when opportunity presents itself.

This implies that members of the team/organisation are behaviourally reliable and fulfil their commitments. This model assumes that people are true in their statements, that their behaviour is consistent with knowledge of the teams needs and desires and that people will operate within the norms of the group and not take advantage of others for self- interest.

As has been suggested, trust may develop along a continuum, (Lewicki & Bunker, 1996; Shapiro et. al, 1992) it may also be experienced as an emotive belief, thought of as knowledge about something or someone but also reinforced by intended behaviour according to the views of Creeds, Fabrigar, & Petty, (1994). Based on this assumption, Cummings & Bromiley, (1996) included these three dimensions of an *affective state*, (emotive trust) *cognition* and *intended behaviour*, to develop a matrix against the three elements of trust as a belief system. This conceptualisation emanates from the sociological perspective of Lewis & Weigert, (1985) who saw trust as a collective attribute. The cognitive process is that of discriminating between people and/or groups and organisations by classifying them into trustworthy, not trusted and unknown categories. The emotive factor evolves from the emotional bond amongst those who participate in the relationship and is underwritten by social action. Cummings & Bromiley (1996) also maintained that because trust can reduce transactional costs, organisational effectiveness can only ultimately be achieved through inter or intra-group action that is based on this endeavour. In other words people will behave in a continuous effort to fulfil their commitments, be honest in exchange and negotiation and behave towards the shared common goal, against limited opportunism. The OTI questionnaire was therefore developed in accordance with their definitional matrix of trust that reflected these three elements of shared belief across the three dimensions of an affective state, cognition and intended behaviour, as seen in Figure 1.3.

	Component of Belief system		
	Affective State	Cognition	Intended Behaviour
Keeps Commitments			
Negotiates Honestly			
Avoids taking excessive advantage			

Figure 1.3 The Cummings & Bromiley (1996) trust matrix.[2]

This author could find no further supporting evidence to substantiate the validity of the OTI since its development in 1996, however it was considered that it may prove useful in gaining a base line measure of trust within an HSC context, to examine whether this matrix generalises to different domains.

1.8 Problem Statement

Although trust is considered a vital element in teamwork where engineers are totally interdependent in their goal of continuously controlling a remote process (i.e. energy distribution), no known empirical evidence exists to date on trust in such domains. Specifically, there is currently no known working model of trust indicators that can be applied to engineering work domains and used to monitor or develop trust. As far as the author is aware, none of the above mentioned methods of evaluating trust have been developed and/or tested in applied HSC environments. It is therefore considered important and timely that research is carried out, with a view to understanding how

---

[2] Reproduced with permission of the authors, copyright (Cummings & Bromiley, 1996).

control engineers perceive trust and the level of trust that exists within and between shift teams and technology in control rooms. The need to trust technology is becoming more vital as human operators become more remote from each other and consequently more reliant on their systems. This is a problem that needs serious consideration, as in order to trust technology interface designs, control displays and generally the *way* that information is presented has to facilitate user needs (Davis 1993), and match human expectation, (Muir & Moray, 1996; Norman, 1990).

1.9 Method

The high construct validity and reliability of the Organisational Trust Inventory, (OTI), (Cummings & Bromiley 1996), legitimises this questionnaire to be used as an initial base line measurement of trust. This will be investigated in control rooms to examine whether the OTI generalises to HSC domains. Although this data may prove useful in gaining an idea of how trust is perceived within HSC environments, it is considered that differences may exist due to changing aspects of the environment and the perception that engineers have in terms of their goals and expectations. Using a grounded approach such as the Repertory Grid (Kelly, 1955) method is therefore considered an appropriate way of producing meaningful information. Unlike questionnaires, Repertory Grid methodology has no designer bias, but enables standardised scoreability. This minimises interviewer interpretation as participants have to score applicability of description themselves, (Stewart & Stewart, 1981). From their extensive research of business applications these authors also found that Repertory Grid procedure was a useful tool in designing questionnaires as it often highlights important areas that other techniques miss. When considering such a complex concept as trust, it is thought necessary to investigate in depth what control engineers actually perceive trust to be about and not prescribe what issues the author or other researchers consider important. By undertaking a study of engineers within their own contextual domain, it is anticipated that the grid data might reveal important areas of concern for inclusion in a questionnaire for future studies that might otherwise be ignored.

In order to measure the important issues of interface design and team separation, a simulated control room scenario is considered an appropriate context, where a controlled task will enable performance measures as well as perceived trust to be calculated.

1.10 Summary of Review

All the elements of trust from past research and discussed in this review are categorised into a matrix, as shown in Table 1.1. This highlights the main factors drawn from the literature found within interpersonal relationships, teams, virtual teams and technological interactions. In line with the Cummings & Bromiley (1996) model, the elements have been divided across emotional, cognitive and behavioural states to provide an overview of how trust *might* be construed from a variety of ways across different domains. In many respects the same constructs are used over the four different factors, only differing in nomenclature. This implies that whatever names one gives to these constructs, in order to foster and maintain trust there needs to be some level of belief in the other person or persons based on either a shared value system, or in respect of teams, a mutually common goal. How *this* is achieved would be the subject of another thesis, however within the environment of energy distribution, it is taken as a given that control operators do share a commonality in their task of *'safely and securely controlling the plant or system to the highest efficiency'*. It is however important to examine the *way* that trust is perceived throughout such tasks between teams and technology before considering how best to nurture and develop trust in these working domains. It is considered that the behavioural strategies teams use in order to reduce the changing disturbances that influence their perception of control need to be defined and observed when considering trust in teams, especially within context of HSC tasks and environments. In controlling a remote plant or system, although the overall shared and expected goal is the same, because there are so many layers of commands and sub-tasks between team members and their systems, there could be a wider physical and psychological gap (Wellens, 1993), to bridge between expectation and achievement. Potentially therefore there is more error to control, which may be due to diversity in membership, the team's structure and distribution or the fact that between multiple actors emotional and cognitive elements are more difficult to interpret. In PCT terms, control engineers may not even discriminate between such factors within their sensory perceptual input of controlling a system. The error effects however, may be exacerbated by remote systems and/or teams, oscillating secondary tasks, lack of face to face communication, as well changing interfaces and increased automation. All these variables serve to increase the gap between the desired and achieved goals, a situation that can only be corrected by increased feedback (responsive action), (Farrell, 2000). Furthermore, the perception of control may fluctuate more rapidly within a task force who have multiple roles, undertake different activities simultaneously and who have to be vigilant even under difficult conditions around the clock. Particularly within and between shift teams who, by their very nature may not conform to the way others perceive trust.

Within HSC environments, the emphasis generally tends to be upon a continuous work process. It is considered that such a domain could be described as an interdependent cycle of procedures, routines and behaviours that are continuously maintained by a team of operators throughout a twenty-four hour period. In terms of developing and fostering trust therefore, it is considered that a model of trust should match their expectations and work processes of achieving their shared goal. Similar to Zand's (1972) model of the *Interdependent Trust Spiral*, developing trust within or across HSC teams is an ongoing cycle of continuously disclosing accurate, relevant and complete information, in an effort to reduce the error in meeting expectations and achieving the common goal. As members become more involved in sharing their perception of control via positive feedback strategies, they will accept the influence of others and become more interdependent. This interdependency is reinforced through a higher level of trust; enabling greater risks to be taken. Conversely, if their perception of control comes from an individualist perspective and they employ negative strategies (e.g. placing blame on other members), they could move further away from the target, the error will increase in their perception and trust will diminish, (see Figure 1.2).

By adopting such a perspective of trust as an interdependent system within a PCT framework, it is considered that a better understanding may be gained of how trust can be measured and monitored within and between teams and in technology in HSC domains. There are potentially appropriate elements of trust relative to engineers and contextual factors are likely to be different in control rooms; these will be incorporated and developed into a PCT framework in the final working model of trust.

Theoretically, as discussed previously, a team involves diversity and interdependency aiming for a mutual and common goal, so inherently some degree of trust should already exist, (Cummings & Bromiley, 1996; Porter, 1997). Cummings & Bromiley (1996) also maintained that trust as a belief system incorporated behavioural, emotive and cognitive factors. The belief of a shared objective assumes that team members will be motivated or willing to take risk in the pursuit of that goal and/or from the saliency of group identity. From controlling their perception as a team goal, positive strategies will reinforce that perception as error is reduced and they meet their target. Within the perceptual input box they will perceive enhanced cognitive elements of collaborative decision making and skill interdependency, which will enhance team knowledge (Anderson, 1982; 1987). Furthermore these factors may reinforce the affective state of members, providing a *feeling* of collectivism and confidence in each other, thereby their perception will signal enhanced interdependency. Zand (1972), claims that the trust spiral is ongoing and can be enhanced or diminished by changes at any point in the cycle. Although this author would not argue with Zand, it is postulated that by conceptualising and explaining trust within-context and in relation to the perception of team control, trust awareness will increase and so precipitate the appropriate behavioural strategies that need to be displayed within and between teams. It is also acknowledged that there may be antecedents of trust that are formed through sharing a common goal and therefore expectancies of other team members that promote the initial willingness to take risk in order to achieve their goal. However, rather than values, attitudes emotions and moods that drive the team *into acting*, (Jones & George, 1998), it is considered that it will be through the endeavour of goal performance that will drive the behavioural strategies to be either positive or negative and thereby enhance or debilitate trust.

It is possible that the PCT model can also be applied to technology as it is through the feedback system of the machine that affects the engineer's perception of control and how far they are away from their target goal. Farrell (2000), researched optimum system feedback information using different modalities for military air-crew. He examined which 'best' configuration of a system interface would achieve lowest workload and highest trust when pilots were entering the 'ingress' process of a military combat mission. The PCT framework applies as in attempting to achieve the goal, if pilots have to integrate and emit less information and action, they minimise perceptual error, reduce mental workload, therefore they are likely to have more trust in the system. Perceptual error is a function of time (i.e. the longer it takes for feedback from the system confirming input from the pilot, the higher the perceptual error. Farrell (2000), posits that one direct voice input (DVI) command from the pilot to start the 'ingress' process followed by visual output (VO) confirming the action from the system, was the best configuration for optimising trust in the system. DVI minimises settling time therefore decreases workload, hence increases trust in the system. Perception of control was considered higher when system feedback could be processed in parallel rather than serial mode. The more positive the perception of control, the nearer one will be towards meeting the goal, therefore the more one is likely to trust the technology. A more common example is a VCR where the operator depresses one key to rewind a tape and the machine gives continuous feedback of its status via a number counter. The user has a near continuous perception of the procedure, therefore greater perception of it achieving the goal, rather than if the system feedback was via a yes/no state.

As has been considered throughout this review, trust involves a complex taxonomy of various elements, some of which may be more or less relevant in an HSC context. What elements *afford*, (Gibson 1986), one domain or situation may not be relevant in another. It is therefore necessary to examine these various elements that together may culminate into an optimum reference point for trust within and between teams and in technology.

1.11 Aims

The aims of this thesis are to

1. Investigate the issue of context in relation to trust by using the Cummings & Bromiley (1996) model in applied HSC domains and attempting to identify factors of trust in relation to team interaction.
2. Identify the dimension and level of trust that currently exists within and between known working shift teams in HSC control rooms, some of whom are working remotely from their colleagues within the same team. A grounded theoretical approach will be used for this investigation.
3. To explore the concept of trust in technology and teams by using a simulated control room task, in order to test whether location and/or type of interface is a confounding variable in fostering trust, especially where the only interaction is from system feedback.
4. Develop a framework of strategies for the perception of trust that are contextual to HSC domains.
5. Develop a working model of trust that can be used as an applied tool to measure and monitor trust in HSC and possibly other commercial engineering domains.

2 Chapter Two: Organisational Trust Inventory

2.1 Introduction

Cummings & Bromiley (1996) tested their trust matrix (see Figure 1.3) on a sample of three hundred students and employees of an MBA programme at Minnesota University. Results from the Organisational Trust Inventory (OTI) showed that from a total of 81 items the model achieved an acceptable Comparative of Fit Index, (Bentler & Bonnet, 1980, cited in Tabachnick & Fidell, 1996) with highly significant item to factor correlations of .6 or over. Three factors confirming the latent variables of affect, cognition and intent to behave were highly correlated (.93, .80 and .93) respectively and composite reliability of these three factors was high ranging from .94 to .96. As the overall fit of their model was so strong the authors shortened the OTI to a more manageable size. A twelve item short form OTI remained which excluded the intent to behave questions and only using the cognitive and affect items the results achieved an item to factor correlation of .70 or over. A repeated estimation of the fit of the model achieved a higher correlation (Bentler's comparative fit index was .98). Composite reliability for all three factors and across the three dimensions of *affective*, *cognitive* and *intent to behave* was high with no correlation below 0.77, with Cohen's kappa of .83 (Cohen, 1960, cited in Cummings & Bromiley, 1996). Cummings and Bromiley found that the explanatory power of the short OTI was almost identical to the longer version and claimed it to be '*a valid and reliable instrument in measuring trust between teams in organisations or between organisations*', (p.319, 1996).

As mentioned in chapter one, (see section 1.10), there is an inherent need for trust to exist within and between shift teams in HSC domains who, by their very nature may not conform to the way others perceive it. From interviewing management personnel from two energy distribution control companies, they were unanimous in their opinion that trust is a vital ingredient within and between HSC teams. Managers were both keen to discover how they could investigate the level of trust both within and between teams within the energy industry, and what methods of monitoring and developing trust could be developed and implemented in order to help them promote trust in teams in the future. Of particular interest was that one company had recently re-structured and reduced the size of their control teams. The other company worked in teams where members of the same team were physically remote from each other. The OTI was considered to be an appropriate instrument for taking an initial base line of trust within and between shift teams in this setting and to investigate the three dimensions and whether the collective attribute theory applied. It is considered that the whole ethos of trust may therefore be very different in such applied settings. Unlike students studying MBA courses, HSC domains are very volatile where performance is linked to reward and profit and where feedback on performance is often only via a computer interface. They are particularly goal orientated having to carry out a series of hierarchical tasks in order to achieve their target. Some differences are therefore expected in the way control engineers perceived trust.

The rationale for using the OTI as a baseline measurement of trust in HSC teams was that it appeared to achieve high scores in construct validity and had been developed to measure intra-inter organisational trust; albeit in a different applied setting. It was considered that this would give confirmatory support and evidence of validity to the Cummings & Bromiley model and was therefore an appropriate starting point towards measuring team trust. It was also believed that due to the basic tenet that control room engineers share a basic belief system in a common goal, that the same dimensions; *keeping commitments*, *negotiating honestly* and *not taking advantage of others* might be confirmed within and between shift teams in a control room setting. The same 12 items were used from the original short form Organisational Trust Inventory (OTI) and set out in the same order, (see Appendix 1). Six behavioural questions were also taken from the long version of the OTI with highest item to factor correlations, (over .6) and included in the current questionnaire. These items were intended to measure how the perception of trust was manifested in the team's own behaviour within control room teams.

2.2 Method

2.2.1 Participants

At the request of the management of each company and at the request of the author, participant teams volunteered who were going to be on shift duty during the time of the study. Prior to the study taking place each team was given a presentation on the importance of trust within Human Supervisory Control (HSC) domains at the monthly team meeting. Each team had a briefing on how to complete the questionnaire before collecting the data. The study had full support of the management from both companies and results have since been presented back to the teams.

A sample of 121 participant engineers volunteered to complete the OTI in respect of experiencing trust within a control room shift team. Two participating companies were sampled (63 from company 'A' and 58 from company 'B'). A total of eight teams were sampled across each company and each team was made up of four major roles. 52.1% were engineers, 22.3% senior engineers, 7.4% managers and 18.2% technical support engineers. The majority of participants had been working in the industry for over ten years (84%) and only 4% of the sample had been in the industry less than 3 years.

2.2.2 Scoring questionnaires

Half of the statements in the questionnaire were worded negatively (Nos. 4,5,6,9,10,12,13,15,16) as a consistency test of response. These items were therefore reverse scored in order for the analysis to be correct.

2.2.3 Analysis

Although the sample size consisted of a ratio of 6.1 participant to item response rate and was in line with the Cummings & Bromiley responses, a ratio of 4-1, the literature conflicts on this matter. Some authors recommend that the ratio of participant to item can be as little as 2.1 (Barrett & Kline, 1981b) for confirmatory analysis, whilst others maintain that samples need to be ten times the number of parameters. Although accurate estimates have been obtained with smaller samples (Boomsma, 1987), from the current data it was considered that this sample size was not large enough to carry out confirmatory analysis. It has been recommended that for maximum-likelihood estimates to be accurate, it is necessary to have very large samples (e.g. over 500, Nunally, 1978). The current study gained 121 responses to 18 items. An exploratory factor analysis was therefore considered an appropriate alternative to examine the factors emerging from this data.

2.2.4 Results

Analysis was carried out using SPSS where an initial correlation matrix provided some clustering among certain variables, although no coefficients were above .75. Items (1,9,10,12, 15 & 16) showed little or no correlation with other items. From the factor analysis commonalty table, these items showed a lower correlation and were therefore eliminated from any further analysis. A standard exploratory Factor Analysis was re-run, bearing in mind the Cummings & Bromiley a-priori target matrix identifying the three dimensions of; *keeping commitment to others*, *negotiating honestly*, *avoids taking unnecessary advantage of others.*

A varimax rotation produced 5 principal components (eigenvalues over 1), accounting for 77% of the variance (77.07). Results are presented in Table 2.1.

Table 2.1 Factor loadings for factor analysis of trust items.

	Factors				
Item No.	1	2	3	4	5
4	.72				
5	.88				
6	.79				
2		.82			
11		.85			
3		.60			
7			.88		
8			.86		
17				.91	
18				.88	
13					.83
14					.81

No discrimination between emotive and cognitive trust was found across the factors, however items 4, 5 & 6 all correlated onto the Cummings & Bromiley dimension measuring *avoids taking advantage of others*. The second factor could be described as *keeping commitments*. Items 2 & 11 were highly correlated, however in the original

Cummings & Bromiley model these items were predicted to measure two different dimensions. Item two confirmed dimension one; *keeping commitments* and item eleven confirmed dimension two; *negotiating honestly*. From the present data set both items loaded on to the same factor and again there was no discrimination between the two latent factors of emotion or cognition. Additionally item 3 loaded on to this factor albeit at a lower coefficient and was originally intended to measure *keeping commitments*, this convinced the author to keep this factor as intended (*keeping commitments*), (see appendix1). Items 7 & 8 uniquely loaded on to factor three and were both intended to measure an emotive feeling of trust in the original OTI. Although these items were highly correlated, the questions were measuring different dimensions from the original OTI. Cummings & Bromiley (1996), intended item 7 to measure the dimension of *negotiating honestly* and item 8 to measure *keeping commitments*. In this study however there was no discrimination between these two items. Items 7 (*I feel that members negotiate honestly within this team)* and Item 8 (*I feel that members in this team keep to their word*) appeared to be identifying a general *honesty* construct. As no other items loaded on to this factor and inter-correlation was high, it was considered reliable. These three factors identified from this data appear to be similar to the dimensions predicted in the Cummings & Bromiley model, although the same items did not load on to their factors exactly. Furthermore, even though their questions were worded in order to tease out differences between emotive and cognitive perception, (e.g. *I feel, I think*), no distinctions were found in the present study with the exception of items 7 & 8, both of which were measuring the emotive element. Factor four was identified by high correlations of behavioural items (17 & 18). Although these two items were intended to measure the behavioural impact of *avoids taking advantage of others* (dimension 3 of the original Cummings & Bromiley model), these items seemed to be measuring *openness* of team members in terms of *working with others and sharing information*. As seen in Table 2.1, inter-correlation of these two items was high producing a unique factor, with no other items loading on to it. It was considered that these correlations were particularly high because they were directed at the respondent themselves rather than to *others in their team*. Finally, factor five was as predicted in the original model and was identified as *behavioural monitoring of compliance*. This factor was also considered to be unique with high independent correlations

2.2.5 Summary of Factor Analysis

In summary, results of the factor analysis show that a dominant factor of trust was perceived in terms of;

Not taking advantage of others.

Four other factors confirmed were;-

Keeping Commitments

Honesty in negotiating

Openness (i.e. in working and sharing information)

Not monitoring compliance.

Although no discrimination between cognitive and emotional feeling was confirmed, behavioural items were highly correlated and loaded onto two independent factors. Further analysis to investigate differences between teams and in particular between roles and independent teams within company 'A' & 'B' was carried out using standardised scores from summation of the item scores that loaded on to each factor.

This was to ensure that scores were not simply domain specific but could relate to any industrial population.

Z scores were calculated from summing the item scores of each factor for each participant and transforming them to a standardised residual. In order to test for differences, 4 (roles) by 2 (company) repeated measures Multivariate Analysis Of Variance (MANOVA) was conducted with the five trust scores as dependent variables. Results are shown in Table 2.2.

Table 2.2 Multivariate analysis of variance for trust, role, and company.

Source	df	F
	between-subjects	
Role	3	.567
Company	1	2.095
Role x Co.	3	3.303*
S within-group error	113	(1.39)
	within-subjects	
Trust	4	.905
Trust x Role	12	2.876**
Trust x Co.	4	.379
Trust x Role x Company	12	.961
Trust x S within-group error	113	(1.035)

Note:- Values enclosed in parentheses represent mean square errors.
S = subjects n = 121
*$p<.05$, **$p<.01$

A significant interaction effect was present between role and company and between trust and roles. This means that differences exist in one or more roles between the two companies and there are differences in one or more of the trust factors in some team roles according to which company they came from. No main effect of role or company on any of the trust scores was found and no three-way interaction. From examining the line graphs of each factor by team role for company 'A' and B' respectively in Figure 2.1 and Figure 2.2, it can be seen that there are similarities in the variance of scores across the two companies for factor five, (not monitoring compliance). There is also indication that there are differences in trust scores between engineering roles as there is more variance in scores for this role in company 'A' than for company 'B'.

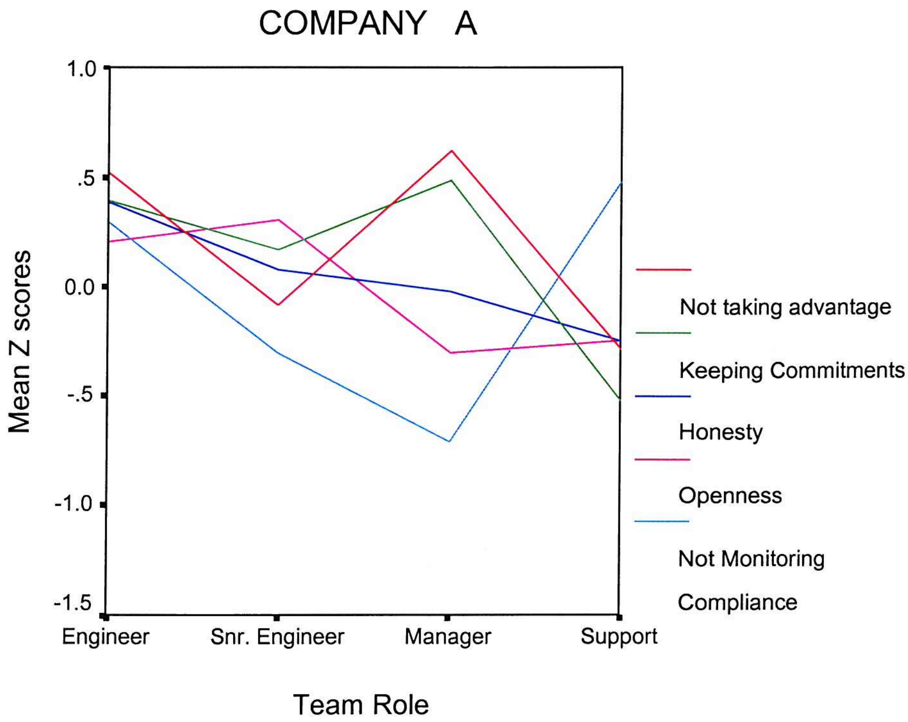

Figure 2.1 Line graph showing mean z scores for five factors across team roles for company 'A'.

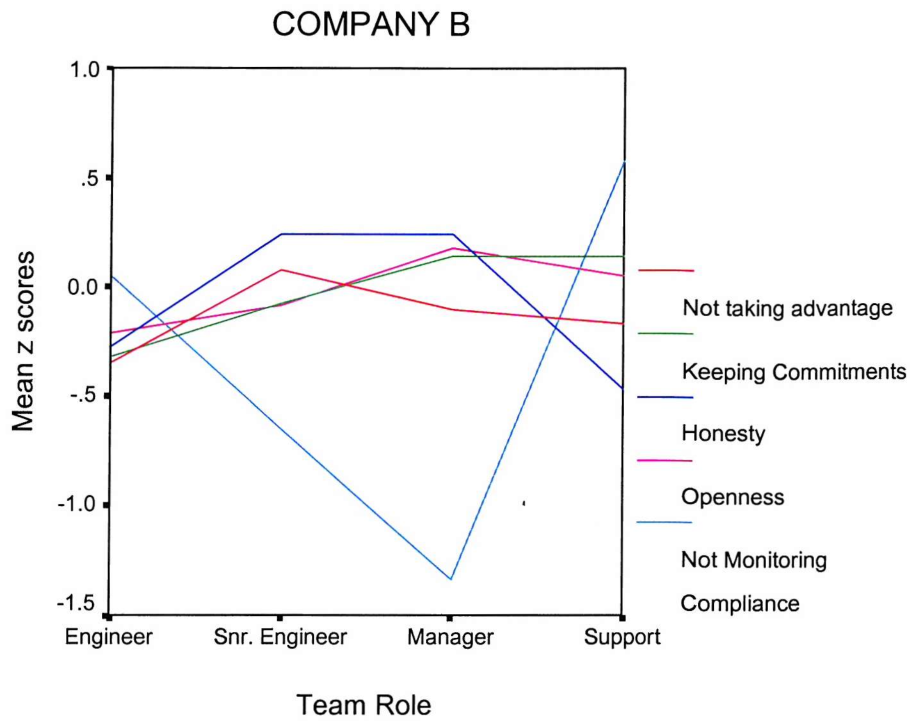

Figure 2.2 Line graph showing mean z scores for five factors across team roles for company 'B'.

In order to test whether differences were significant, a further series of MANOVAS were carried out, taking each role independently against the five dependent trust factors (DV) and the independent variable of company, (IV). Repeated measures MANOVA results for between role and company are shown in Table 2.3.

Table 2.3 Multivariate analysis of variance for role, company and trust.

Role Source	df	F Engineer	Sr. Eng	Manager	Support
		between-subjects			
Company	1	15.183***	413	.702	1.370
S within-group Error	61	(1.750)	(1.269)	(.553)	(.707)
		within-subjects			

Trust	4	.320	1.838	4.615**	2.955*
Trust x Role		1.212	.530	1.123	.641
Trust x S within-Group error	61	(.925)	(1.530)	(.553)	(.918)

Note:- Values enclosed in parentheses represent mean square errors.
S = subjects n = 121
*p<.05, **p<.01, ***p<.001

Table 2.3 shows a significant main effect (p <0.001) of company within the Engineering role, indicating company 'A' engineers scores were generally higher but with more variance than company 'B'. Figure 2.3 shows the mean standardised scores of each trust factor within the engineering role and highlights the differences in scores for this team role across the two companies.

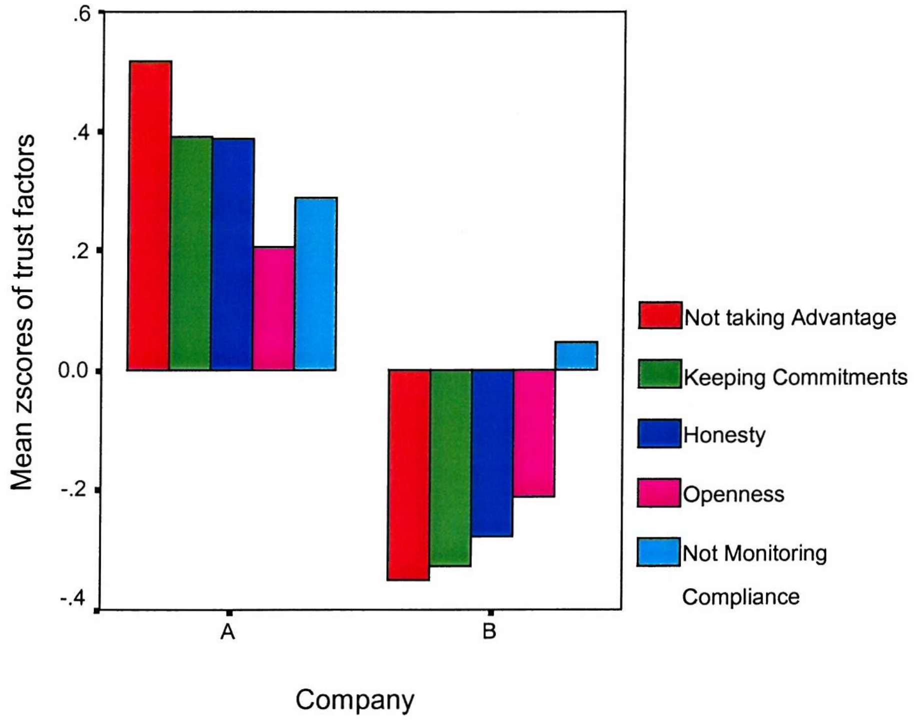

Figure 2.3 Bar chart showing means factor score for Engineers role by company

No between company differences were found for any of the remaining roles. A main within-subject trust effect was found for managers and support roles, respectively.

This means that across both companies, differences existed within the trust factor scores for both managerial roles and support engineers. Examination of the standardised mean factor scores for factor five, (*not monitoring compliance*), see Table 2.4, suggested this was where the differences lay.

Table 2.4 Mean z scores and standard deviations of factor 5 for managers and support roles.

Role	Company	M	(SD)
Manager	A	- .7155	(1.09)
Manager	B	-1.3334	(.702)
Support	A	.47307	(1.07)
Support	B	.57282	(.723)

Managers scored generally much lower in this factor than the others factors and support engineers scored generally higher. A Oneway Analysis Of Variance (ANOVA) for factor five by role and company confirmed a significant role effect F = 9.087, (3, 113); $p<0.001$, but no company effect F = 1.702 (1, 113); ns. This indicates that in terms of a behavioural measurement of trust, support engineers are less likely to monitor other team member's compliance whereas managers are more likely to.

As no main company effect was found, but differences between some roles across trust factors were evident, the two companies' scores were aggregated and a further MANOVA analysis carried out to measure trust scores across roles. Results are shown in Table 2.5.

Table 2.5 Multivariate analysis of variance for trust and role for company 'A' & 'B'.

Source	df	F
	between-subjects	
Role	3	.464
S within-group error	117	(1.580)
	within-subjects	
Trust	4	.859
Trust x Role	12	2.960**
Trust x S within-group error	117	(1.042)

Note:- Values enclosed in parentheses represent mean square errors.
S = subjects n = 121
*p<.05, **p<.01, ***p<.001

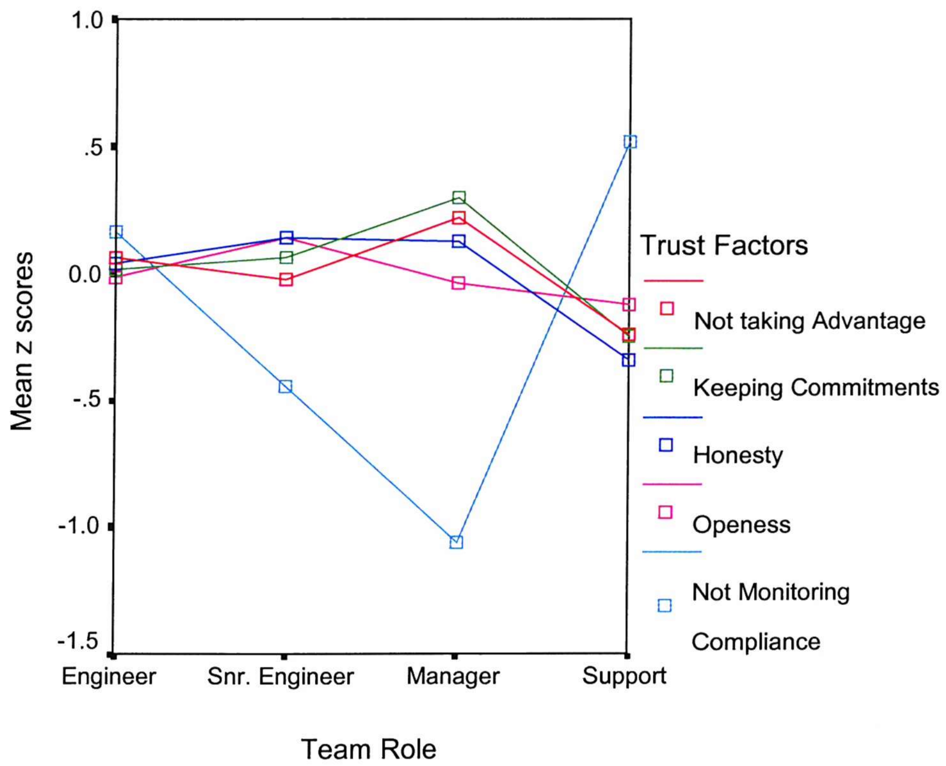

Figure 2.4 Line graph showing mean z scores of factors for company 'A' & 'B' across team roles.

No main effect of role or trust was found but there was an interaction between the two. This means that for one or more roles significant differences in trust scores exist. The aggregated estimated means of the five trust factors were plotted against each of the roles. The line graph in Figure 2.4 shows that trust scores are similar across the roles and within one standard deviation from the mean. Trust factor 5, however, shows differences across roles. An ANOVA was conducted on each trust factor to test for differences between factors. Results confirmed that there were significant differences in factor 5 only (*not monitoring compliance*) across roles, $F = 9.184$ (3), $p<0.001$. Bonferroni post hoc tests confirmed significant differences between the following team roles, shown in Table 2.6.

Table 2.6 Bonferroni post-hoc tests.

Engineer vs Snr. Engineer	$p<0.05$
Engineer vs Manager	$p<0.01$
Snr. Engineer vs Support	$p<0.01$
Manager vs Support	$p<0.00$

These differences can be seen more clearly in Figure 2.5 and confirm that the higher status people hold the more they are inclined to monitor other team members compliance.

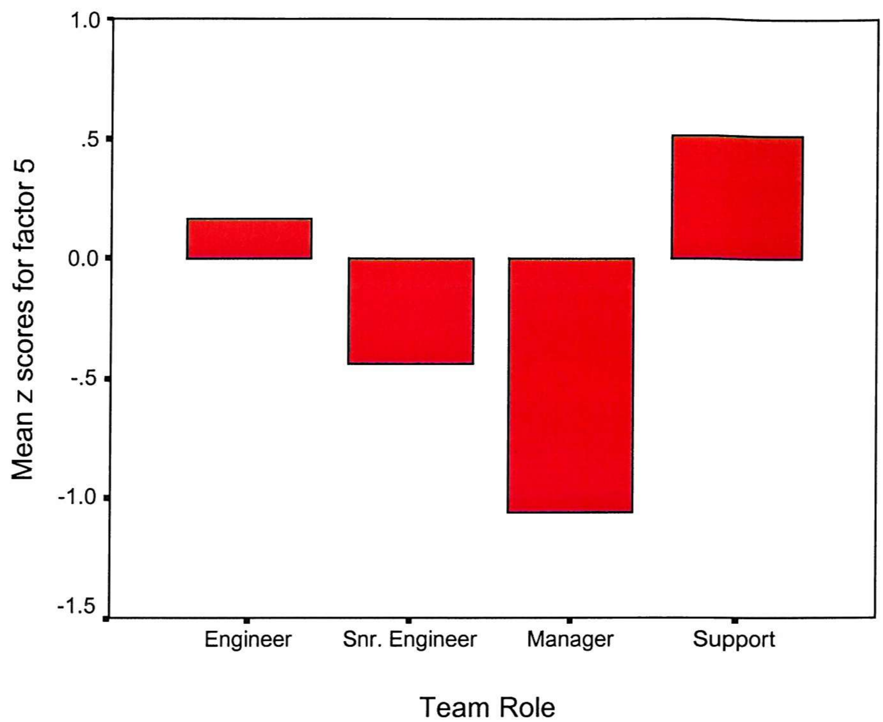

Figure 2.5 Bar chart showing aggregated mean z scores for factor 5 by team role.

It was considered appropriate to test for team differences with regard to trust within each company as one particular team may be influencing the overall results of company results. Small n sizes and uneven distribution provoked non-parametric tests to be used. A Kruskal-Wallis test showed that differences between team scores in company 'A' existed only in the first three factors of *not taking advantage*, *keeping commitments* and *honesty*. Results are shown in Table 2.7.

Table 2.7 Results of Kruskal-Wallis test for between team differences in company 'A'.

Factor	Chi-square	df
Not taking advantage	20.883**	7
Keeping Commitments	19.200**	7
Honesty	25.855**	7

$^{**}p<.01$.

Examining the mean rank scores for these three factors indicated that the engineering shift-control teams 'A-F' were very similar in distribution with the exception being team 'C' whose scores were considerably lower. Support and managerial teams also appeared to show much lower scores across these three factors. A Mann-Whitney test was used to confirm if there were any significant team differences, results of which are given in Table 2.8.

Table 2.8 Results of Mann-Whitney test.

Factors	Team Names	Mean Rank	Z Score
Not Taking Advantage			
	E[b]	11.07	
	Manager[c]	5.31	2.50**
	D[b]	11.2	
	Manager	5.15	2.61**
	D	15.36	
	Support[d]	8.82	2.28*
	B[b]	9.64	
	C[a]	3.92	2.68**
	B	16.00	
	Support	8.50	2.62**
	B	11.93	
	Manager	4.56	3.20***
	F[b]	11.00	
	Manager	5.38	2.44*
Keeping Commitments			
	F	16.50	
	Support	8.25	2.91**
	D	14.93	
	Support	9.04	2.07*
	A[b]	16.00	
	Support	8.50	2.64**
	A	10.93	
	Manager	5.44	2.41*
	F	11.36	
	Manager	5.06	2.76**
Honesty			
	A	9.14	
	C	4.50	2.35*
	A	15.29	
	Support	8.86	2.49*
	A	11.79	
	Manager	4.69	3.14**

Table 2.8 Results of Mann-Whitney test (cont.).

Factors	Team Names	Mean Rank	Z Score
	C	4.50	
	D	9.1	2.35*
	C	10.17	
	Manager	5.50	2.20*
	D	15.29	
	Support	8.86	2.49*
	D	11.79	
	Manager	4.69	3.14**
	E	11.71	
	Manager	4.75	3.01**
	F	11.57	
	Manager	4.88	3.08**
	Support	13.79	
	Manager	7.50	2.32*

Note N = (a-d) a=6, b=7, c= 8, d=14
*p<.05, **p<.01, ***p<.001

Results for company 'B' were much more evenly distributed across the teams, apart from factor five, where the support and managers teams were very widely distributed with standardised mean z scores varying by two standard deviations. A Kruskal-Wallis test was run for the five factors against team role and results confirmed that no significant differences across factors existed except scores for factor five, (*not monitoring compliance*), which reached significance at the 10% level; Chi-square=12.575, df = 6; p=0.050 (=<0.10). Mann-Whitney tests confirmed where there were differences and particularly that the support teams scores were significantly higher and managers' scores in this factor were particularly low, as seen in Table 2.9.

Table 2.9 Results of Mann-Whitney test

Factors	Team Names	Mean Rank	Z Score
Not monitoring	B[a]	10.41	
Compliance	Manager	4.30	2.41*
	C[b]	7.96	
	Support[c]	14.31	2.38*
	C	10.71	
	Manager[d]	4.90	2.18*
	E[e]	9.22	
	Manager	4.20	2.10*
	Support	9.38	
	Manager	3.20	2.81**

Note:- n's = (a-e) a=11, b=12, c=8, d=5, e=9
*p<.05, **p<.01, ***p<.001

2.2.6 Summary of Results

Five independent factors of trust were found, although no discrimination between cognitive and emotive dimensions were confirmed. Behavioural items however were highly correlated and measured two distinct behavioural factors, of *Openness* (sharing information and work) and *Not monitoring compliance* (not checking up on others). No main company effect was found although an interaction between-subject effect was evident across companies within the engineering role. Within-subject effects were found for factor five across managerial and support engineer roles. Between team differences were evident in factors 1, 2 & 3 within company 'A' where team 'C' trust scores were significantly lower than the other five engineering teams. The support and management teams also scored significantly less in these three factors than the other teams. Within company 'B', team scores were more evenly distributed where only a slight difference was found between scores in factor five, generally indicating managers scores significantly lower and support teams scores significantly higher than other factors.

2.3 Discussion

Results presented from this study show a definite five factor matrix and it is considered that differences between trust factors may exist due to team structure and/or role in HSC domains. Although the OTI was used to generate a baseline of trust measures across an applied control-room situation, dimensions of trust found did not exactly match those of the original Cummings & Bromiley (1996) model. Differences between component of belief as in cognitive or emotive elements were also not confirmed and in fact from examining the item to factor loadings, it is possible that engineers interpreted the questions very differently from MBA students. Cultural issues were highlighted such as differences in use of language and interpretation. Contextual variation in goal orientation also needs to be taken into consideration when administering questionnaires across different samples. The American students used to develop the Cummings & Bromiley instrument seemed to answer the questions in a different way from that of English energy distribution engineers. For example items 7 & 8 gave very different results across the two domains. Item 8 in the original model (*I feel that members in this team keep to their word*), reliably measured *keeping commitments* according to the Cummings & Bromiley model, however in the current sample this item was interpreted as *negotiating honestly* (e.g. telling the truth). Keeping their word to American students in a business programme may be thought of as commitment, as in something they would see through to the end, whereas engineers perceived it as being honest.

The common denominator between the two samples was that both worked in teams, were part of a larger organisation and both shared in the aim of achieving a common goal. The MBA students were working on producing a joint project, whereas the control engineers had to maintain continuous balance of an energy distribution system. From examining the differences in factors and the fact that no discrimination between cognitive and affective dimensions were highlighted in this study, indicates that it is difficult for even highly validated instruments to be transferred from one domain to another. It is considered that further data from a variety of applied organisational contexts need to be evaluated in order to establish calculated norms for the Cummings & Bromiley (1996) model for these factors in other domains.

Another notion is that within different contexts (e.g. an engineering cohort), trust is not perceived as a collective attribute as Lewis & Weigert, (1985) explain. The lack of distinction between cognitive and emotive trust dimensions in this study however, does not necessarily mean that there is a lack of understanding or emotional bond between engineers, simply that it is perceived differently. From an engineering perspective engineers in a control room are goal orientated towards controlling a remote piece of plant therefore the trust elements important to them are going to coincide with that common goal. The fact that these engineers (within company) were from established teams, having known each other for many years, also has relevance; emotional bonding, team spirit, shared knowledge and understanding would have been established over the years. In their perception of control specific factors of trust were considered important in helping them to maintain *their* target performance; factors that 'afforded' (Gibson, 1986) what they were trying to achieve. For instance *not monitoring compliance* was seen as an important element that affected their perception of trust between team roles. Specifically, managers and senior engineers were more inclined to check up on team members than engineers and support staff. Within any organisational structure, it may seem obvious that the higher up the hierarchy one becomes, the more likelihood there is of monitoring subordinate's compliance. However, this does not help to develop interdependent trusting teams who are supposed to be working together towards one common goal across roles. It may in fact have the opposite effect in creating a feeling of resentment and dissent amongst team members in a lesser role. This then affects the team environment and a perception of distrust towards the management may set in. In fact other researchers have considered that the more people monitor compliance of others the less they trust other team members, (Porter 1975).

In PCT terms, the error or psychological gaps in the case of perception of trust increases away from the target goal, which then has to be bridged. This could be rectified by a change in the behaviour such as confronting a problem and deciding on a best practice solution for all the team. Alternatively in a remote team, it could mean changing the *way* people communicate through technology. In terms of achieving team rather than individual goals as in developing team trust, all members involved have to work towards reducing that percentage of error. This may mean that senior engineers may have to lessen their monitoring behaviour whilst support engineers may have to slightly increase theirs in order to reach the optimum level of trust needed to keep the team balanced and working effectively. In essence, if the error is allowed to become too great, then it may be difficult to ever get back on target.

The significant differences within the engineering role across the two companies may be accounted for by differences in organisational structure. Although both companies shared a similar hierarchical structure, *team* structures were very different. Inter-team differences were also obvious specifically within company 'A', which may be explained by their team structures. Although intra-team trust was perceived to be high, there were significant differences in three of the factors (*not taking advantage, keeping commitments and honesty*) between the engineering teams, management and support roles. This may have been because support engineers and managers were physically separated, working in a completely different environment. This may have created an 'us and them' situation and would not have helped in creating a positive group identity with the rest of the shift team. Team 'C' within this company particularly seemed to have low perception in the first three trust factors. Although there are no known reasons for this, it is considered that if one team is not constantly aiming towards the common goal and have a lower perception of trust, this will have an ultimate affect on between (inter) team trust. Team structure in company 'A' was particularly hierarchical with one superior to three subordinate engineers. The layout of the control room also mirrored this structure which may have incurred increased monitoring behaviour from supervisors just by inference. Earlier research on team structure maintained that it should be optimised between hierarchical and heterarchical, depending upon the organisation, intra task and inter-task complexity and demand, (Stammers & Hallam, 1985). From a series of case studies, these authors confirmed that horizontally organised teams generally performed better than vertical ones, especially under high work load and task complexity, although this was not the case in this study in terms of score, there was less variance between the team roles.

Team configuration in control rooms has also been found to affect human supervisory control behaviour, (Stanton & Ashleigh, 2000). It is argued that the same factors may have an effect on the way that trust is manifested within and between control teams.

Generally control teams are smaller in company 'A', (three engineers and one senior engineer per shift). These small shift teams work in the same location, whilst support and management staff although visible, are located nearby in an adjacent room. Company 'B' however adopts a different approach. The shift teams are much larger, having a more heterarchical (flatter) structure, incorporating management and support engineers within the same control room. Company 'B' runs a single unit control centre that consists of one large control room. For security reasons a smaller control room is located in another geographical area. Engineers who drive the system (e.g. National and General Dispatch Engineers) are therefore physically separated from the rest of their colleagues, even though they are members of the same shift team. This means they share less social and face to face interaction, only maintaining control and communication through technology. Stanton & Ashleigh, (2000) found that flatter structured teams promote more effective teamwork, as they adopt pro-active planning behaviour as opposed to reactive system driven behaviour. Even though teams are optimally structured however, physically distancing within-team members may have had a detrimental effect on the element of trust as well as reducing performance. It has already been established that quality of communication affects levels of situational awareness (Salas et. al, 1995) and that being physically separate or working 'virtually' leads to decay in situational awareness and breakdown in collaborative decision making, (Wellens, 1993). This may well be a factor that affected levels of trust in the engineering role, as in company 'B'. Wellens argues that separating team members causes psychological distancing; the further away from the physical representation (i.e. from face to face) so the interaction bandwidth narrows or the richness deteriorates, causing a *psychological remoteness*. This may account for the lower perception of trust within the engineers' role that worked in company 'B' in the present study. They were cut off physically from other team members, although were supposed to be sharing the same situational awareness and making collaborative decisions in working towards one common goal. The type, amount and bandwidth of information via the technology may not have been adequate for these goals to be achieved and the perception of control was reduced. The variable of location is therefore one that needs addressing in a future study.

The most dominant factor of trust from this sample was the perception of *not taking advantage* of other team members, an element that is possibly more important and relevant within a control room environment as there is more risk attached to process control tasks. It is also acknowledged that this factor may incorporate all the others. For example if team members perceive themselves as being *committed* to each other, are *honest* in *openly sharing information* and *not continually checking up on each other*, this must equate to *not taking advantage* of each other. Due to the high risk factor that exist in control rooms, there is potentially more that can go wrong that may affect the perception of control in terms of the team meeting their target goal. For instance, there are more external as well as internal environmental distractions that may be influential. Because teams are either working in very close proximity or totally remote and all rely on technology to perform their job, the element of *not taking advantage* of others enables people to take greater risks and so develop a more secure trust and greater interdependency. Porter et al., 1975 confirm that '*trust enables people to take risks and that where there is trust there is the feeling that others will not take advantage*' (p.497, 1975). In terms of a shared goal, engineers aim towards minimising error in their target goal of constantly supplying energy safely and efficiently 24 hours per day. Any deliberate errant behaviour towards another team member or selfish individualistic goal orientation, could jeopardise the team in achieving their goal, whilst causing serious disturbing influences elsewhere throughout the company. Potentially such mistakes could cost the organisation thousands of pounds, or more seriously cut off customer supply and/or cause an accident. Interdependency is crucial in these domains, a factor only developed by *not taking advantage* of other team members and working towards team synergy and collectivism, rather than self-interests. This was one factor therefore that engineers perceived as important and something they were constantly being made aware of.

2.4 Conclusions

From the results of this study, it is evident that teams in control rooms emphasise and are concerned with slightly different factors from University MBA students in their perception of trust. From this study it is apparent that context is a significant factor, together with how the controlling variable (i.e. goal) is defined. The nature of the task and team structure and/or dynamics also had an influence on how engineers perceived levels of trust, although more stable in heterarchical structured teams, intra-team remoteness reduced trust. Within hierarchical teams, there was less integration across roles, which resulted in more competitiveness between team members in terms of increased *monitoring of compliance* and more perceived *taking advantage of others*, particularly by superior roles (e.g. managers). It is therefore considered that a more grounded methodology would be an appropriate next step in this research to examine specific elements of trust that are relevant to HSC domains. Further research could consider a repeat study in another applied HSC domain in order to test the reliability of these factors. and develop norms for these working domains.

3 Chapter Three: A Grounded Approach[3]

3.1 Introduction

From results of the OTI as described in Chapter two, it was considered that HSC operators may perceive trust very differently within engineering domains. It is therefore anticipated that by using a grounded approach and undertaking a more in-depth contextual study in this domain, more context rich data will assist in developing an appropriate framework for such environments, resulting in a practical model of trust.

This study aims to ascertain the *importance* of trust in HSC domains. It also aims to measure existing *levels* of trust within teams, between existing teams and in current technological systems used in applied control rooms. Initially it was decided to keep the three dimensions of trust in mind from the Cummings & Bromiley (1996) model whilst collecting this data. It was considered that engineers may put more importance on a feeling of trust than observable active responses of trust, or that they would stress more cognitive elements. In accordance with the literature and the contextual domain of this study it was hypothesised that:-

a. Due to different personal expectations, different constructs would be found important within teams between teams and within technology.

---

[3] This chapter appears as a peer reviewed journal paper in *Cognition Technology and Work*, Vol. 3 (2) 2001.

b. Differences would be found between the three dimensions of trust across groups (i.e. intra-team, inter-team & technology).
c. The level of trust scored would be higher within teams than between teams.
d. In accordance with Muir (1994) trust in technology would be less when machine performance did not meet expectations.

3.2 Method

Repertory Grid methodology is a technique based on the work of Kelly (1955) and from his research, the emergence of the Personal Construct Psychology (PCP). Kelly introduced PCP to explain how people conceptualise their own worlds or environments. PCP is based on the axiom that we are all essentially scientists who actively generate and test our own hypothesis in relation to reality. People constantly construe a network of constructs about something or someone in order to maintain or strengthen the predictive power of their own hypothesis in relation to the actual state of the world. It is almost like a self-analysis technique that Kelly found invaluable in his work of psychotherapy. He wanted to be able to measure clinical problems of his patients and then use these measurements in his therapeutic approach to be able to re-measure after the therapy.

This of course is a problem in any domain. How can one gain an insight into a single employee or team of people with a particular problem in one context and then make predictions with any degree of accuracy about those same problems in a different context? The other problem with lots of measurements is that they suffer from observer bias. Results of research are biased by the experts in whatever perspective or domain of psychology they believe in. Observer bias is a serious obstacle in trying to understand someone else's point of view. Repertory Grid technique overcomes this but also allows a standardised scoreability, enabling repeatability and reliability of results, (Stewart & Stewart 1981). This technique was therefore used to elicit important constructs of trust to engineers working in energy distribution control rooms. It was anticipated that a contextual bottom-up approach would allow specific domain relevant elements of trust to be incorporated into a final model of trust.

3.2.1 Participants

Sixteen male control engineers were interviewed from two energy distribution organisations, (2 X 8). The two cohorts held similar roles within interdependent shift-teams, whose task was to continuously control an energy distribution system. The age range of participants was 30 years (24-54 years), mean and standard deviation ($\underline{M}$ = 39, $\underline{SD}$ = 9.1), respectively. All participants were either trained as chemical or electrical engineers and had a minimum of 3 years experience working as a control room engineer, ($\underline{M}$ = 10.93, $\underline{SD}$ = 7.4).

3.2.2 Procedure

Each participant volunteered to give their opinions on the concept of trust in HSC domains. They were asked to think about the concept of trust in their specific workplace. The Repertory Grid method also allows the whole process to be made bespoke to the domain and three groups of different elements were developed from the control engineers themselves and used to indicate intra-group, inter-group and technology. These were developed based on the nature of the work in the control rooms and were therefore context specific to their working environment. Elements have to be nouns or names and so engineers devised elements according to their own understanding of their teams and environment. For example an intra-team element was represented by (*another member of my shift team*), whilst a (*member of the support team*) represented an inter-team element. An example of a technological element was the (*System Control And Data Acquisition),* (SCADA) system. Triads of elements were taken from each group (e.g. intra-team, inter-team & technology) in turn and participants were asked what important construct or characteristic made two of these elements similar but different from the third. There were seven elements in each group, and all the elements used on the grid can be seen in Appendix 2. Interviews lasted from 1-2 hours for each engineer, depending on how quickly they elicited constructs. This produced a positive/negative continuum for each construct see Appendix 2.

A laddering technique, (Kelly 1955), helped to clarify understanding for the researcher and validate the meaning of the constructs that had been given by the control engineers. For example if engineers gave a construct of 'honesty', the researcher would ask 'how' and 'why' they perceived one person more honest than the other, in what way were the two different. (see Appendix 3 for an example of laddering technique). Participants were also asked to clarify what the word meant to them in the context of their work domain. At no time did the researcher know the name of the 'person elements' as engineers were told to think about the people and the reasons for their answer before eliciting that particular construct. In this way the whole conception of trust in relation to other intra-team members, inter-team members and their technological systems were totally their own view of what trust meant to them. The researcher was not allowed to prompt or give any examples of what a construct could be. Simply because an engineer gave the construct of 'honesty' did not automatically presume the opposite end of the continuum to be 'dishonesty'. The researcher had to ask the participant to freely offer an opinion. Participants were then asked to score each element using their own elicited constructs along a (1-5) Likert scale, indicating the amount of trust perceived from each element. For example if they had given the construct of 'honesty' – 'not open' as important, they then had to assign a score to each group of elements along the continuum of honesty – not open, where 5 = very honest, and 1 = not at all open.

3.2.3 Analysis of Data

Content analysis was performed on a total of sixty different constructs elicited from the sixteen participants. Three main dimensions of emotional, cognitive and behavioural were defined by the constructs elicited and in line with the Cummings & Bromiley (1996) model, as it was considered that there may be some dimensional differences across the group elements. Using three separate judges the constructs were reduced to thirteen core constructs by checking the definitions of each word several times in the Oxford English Dictionary and scrutinising interview notes from each participant. Each elicited construct with the same definition was categorised into a core construct, (e.g. constructs such as: open, honest, truthful, principled were categorised under the core construct of *Honesty*). An example of the categorisation is given in Appendix 4. An independent expert in Repertory Grid procedure and the main researcher independently categorised each construct into a core construct and then into one of the three dimensions of emotive, cognitive or behavioural trust. This exercise was repeated eight times and in order to test inter-reliability, nearest scores were taken and a Spearman rank correlation was carried out, $r_s = 0.891$ $n = 13$; $p<0.01$.

By calculating the frequency count of core constructs or their subordinates within each group (e.g. intra/inter-team and technology), a hierarchy of trust constructs in terms of importance was developed for the three groups. Mean participant scores for each core construct across all elements were calculated. This gave an overall participant score for every element and an overall mean group score for each core construct. In order to compare any differences between groups, non-parametric Freidman ANOVA tests were carried out on the thirteen core constructs. A paired Wilcoxon test was then carried out to identify where group differences lay.

3.3 Results

Results of the frequency count for the degree of importance of constructs were calculated as a percentage within each group. This was achieved by taking the frequency of times each construct was mentioned and comparing it with the number of times all thirteen core constructs were mentioned within each group. Table 3.1 shows the most important core constructs of trust found *within* each group; this is presented in a top-down hierarchy.

Table 3.1 Hierarchy of perceived importance of constructs within group shown in percentages.

Intra-team	**%**	**Inter-team**	**%**	**Technology**	**%**
Honesty	20	*Quality of Interaction*	16	*Quality of Interaction*	21
Understanding	16	*Understanding*	12	*Reliability-*	13
Respect-	13	*Teamwork*	12	*Performance*	11
Confidence	9	*Honesty*	10	*Understanding*	10
Quality of interaction	9	*Confidence*	10	*Communication*	10
Proactively	6	*Communication*	8	*Expectancy*	10
Reliability	6	*Reliability*	8	*Confidence*	10
Communication	6	*Ability*	6	*Proactively*	7
Teamwork	4	*Commitment*	4	*Ability-*	4
Commitment	4	*Respect*	4	*Respect*	2
Ability	3	*Expectancy*	4	*Honesty*	2
Performance	3	*Performance*	4		
Expectancy	1	*Proactively*	2		
Total	100		100		100

As hypothesised, (hypothesis a), differences were found in importance of constructs across the three groups (intra-team, inter-team & technology), although some commonality in constructs existed across the three groups. Respondents perceived *quality of interaction*, *understanding* and *confidence* to be an important core construct across the groups, albeit at different levels of importance in the hierarchy. *Quality of interaction* was felt to be the most important in respect of trusting technology. *Understanding* was the next common construct across the three groups; this was perceived to be more important within teams, followed by between teams and technology. *Honesty* was perceived as the most important construct within teams, whereas it was third down the hierarchy between teams. Constructs were more evenly distributed for the inter-team group with *honesty* and *confidence* sharing the same importance, however *honesty* was not applicable to technology. *Confidence* was perceived to be generally at the same level of importance across the three groups.

From identifying the importance of trust factors across the three groups, participants then scored each element in each group to give a mean level of trust for each of the thirteen core constructs within each element category (intra-team, inter-team and technology). From the following bar charts, it is apparent that although *quality of interaction* was considered the most important construct of trust in technology, when control engineers were asked to score this construct against the technological elements, trust was low, ($\underline{M} = 2.4$, $\underline{SD} = 1.52$). This supports hypothesis d), as the results imply that actual scored level of *quality of interaction* did not meet expectations. *Understanding* was another common construct in importance across the three groups and showed highest score within the intra-team group, followed by the technology group. Although this construct was thought of as more important *between* (inter) teams than in technology, scores did not reflect this. These results suggest some group differences across the three dimensions, generally supporting hypothesis b). Figure 3.1 to Figure 3.3 show that scores for constructs across the three dimensions were generally higher within teams, which supports hypothesis c). The results of the Freidman test statistics on the thirteen core constructs confirm these differences and are reported in the following three sections.

3.3.1 Emotive Constructs

From the Freidman test statistic $\chi^2(2, \underline{n}=13) = 8.680$, $\underline{p}<0.05$ results confirm that there was a significant difference across groups for the construct of *confidence*. A Wilcoxon signed paired test revealed that more confidence was felt within teams than between teams ($p<0.05$) and within teams than in technology, ($p<0.01$). The construct of *Respect* scored differently across groups, $\chi^2(2, \underline{n}=11) = 11.636$, $\underline{p}<0.01$. A post-hoc

Wilcoxon test confirmed that intra-team *respect* was significantly higher than inter-team ($p<0.05$) and the technology group, ($p<0.01$) and scores of inter-team respect were significantly higher than technology, ($p<0.05$). There were no significant differences in *commitment*, $\chi^2(2, \underline{n} = 4) = 5.733$, ns, although scores were higher in intra and inter-team than in the technology group. The construct of *teamwork* showed differences $\chi^2(2,\underline{n} = 8) = 8.857$, $\underline{p}<0.05$ between groups. Significantly higher *teamwork* was scored within teams (intra-team) than between (inter-team) ($p<0.05$), and technology ($p<0.05$) respectively.

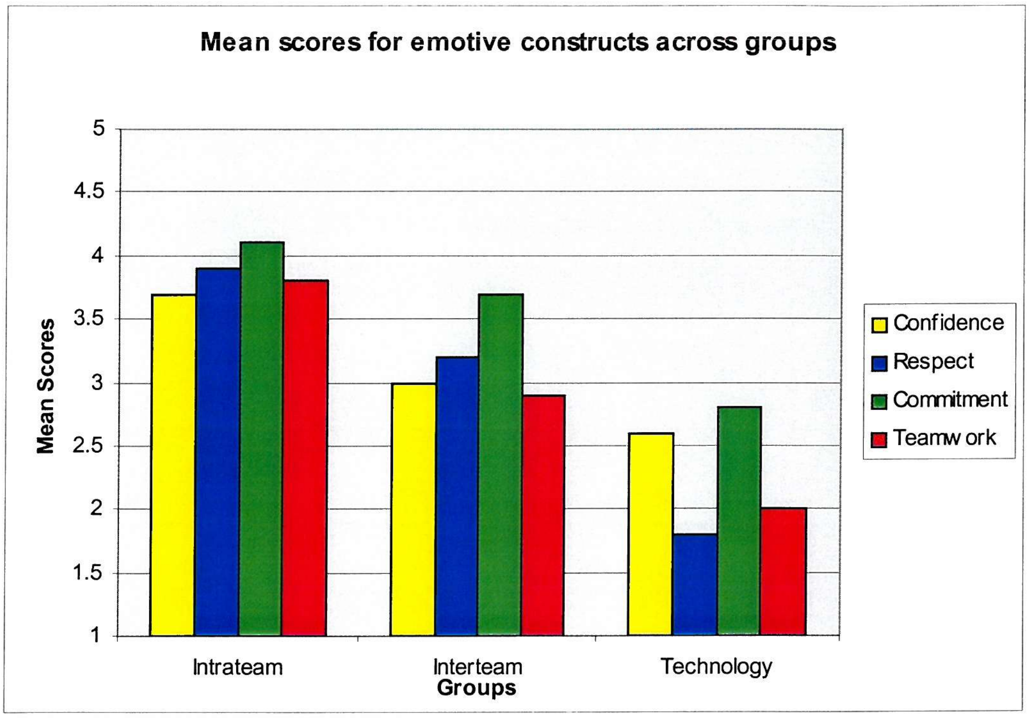

Figure 3.1 Bar chart showing mean scores for emotive constructs across groups.

3.3.2 Cognitive Constructs

The Freidman test showed no significant differences for the construct of *understanding* between groups, $\chi^2(2, \underline{n} = 10) = 4.667$, ns. From the means however, see Figure 3.2, the construct *understanding* scored respectably higher in the intra-team group than in the inter-team group; although it was considered more important between (inter) teams. Results show that respondents perceived *understanding* as being fairly good of immediate team members, ($\underline{M}$ =3.8, $\underline{SD}$ = 0.52), but between teams (e.g. with members of the planning support team or managers), engineers scored less ($\underline{M}$=2.8, $\underline{SD}$ = 0.83). Test results for the construct *ability* showed significant differences, $\chi^2(2, \underline{n} = 7) = 10.640$. $\underline{p}<0.01$. Differences were for intra-team and inter team ($p<0.05$) and intra-team and technology, ($p<0.05$). Results showed significant differences in *expectancy* $\chi^2(2, \underline{n} = 9) = 6.063$, $\underline{p}<0.05$. Specifically there was a higher *expectancy* in the intra-team group than the inter-team group ($p<0.05$). Results also showed that generally engineers have a greater *expectancy* of their technology than they do of colleagues in other teams, although this was not significant.

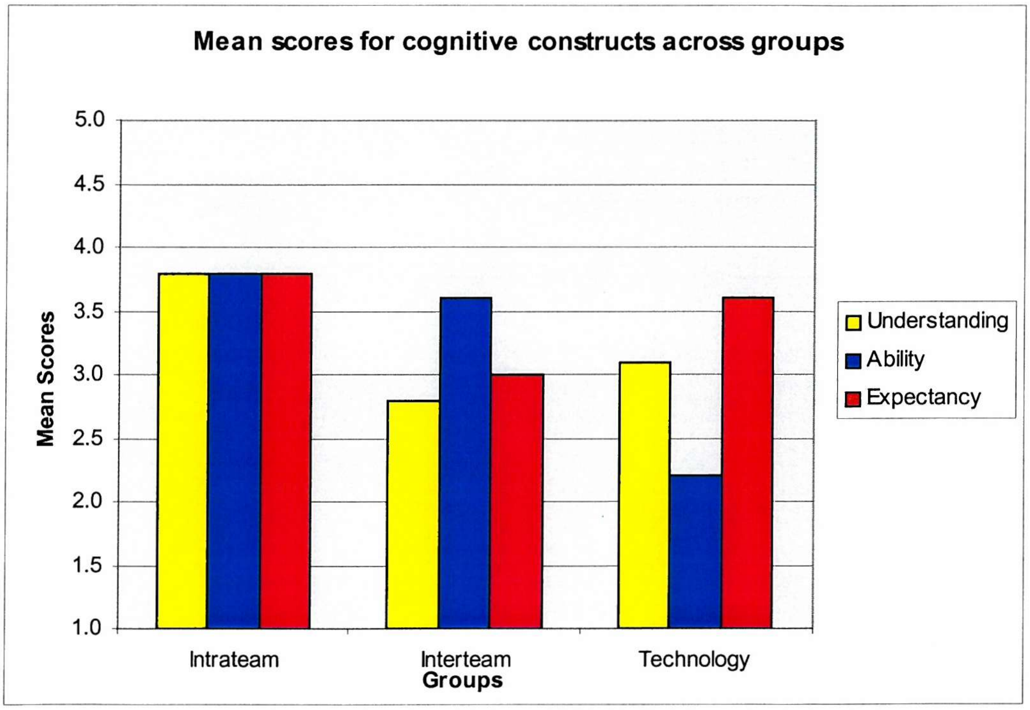

Figure 3.2 Bar chart showing mean scores for cognitive constructs across groups.

3.3.3 Behavioural Constructs

The construct of *honesty* was significant $\chi^2(2, \underline{n} = 15) = 22.533$, $\underline{p}<0.01$and post hoc tests revealed intra-team *honesty* significantly higher than the amount scored between teams ($p<0.00$), or from technology ($p<0.00$). There were significant differences for the construct *reliability* $\chi^2(2, \underline{n} = 12) = 8.522$, $\underline{p}<0.05$. Intra-team scores were significantly higher from inter-team ($p<0.01$) and from technology, ($p<0.05$), although this construct was thought most important for the inter-team group. The construct *proactivity* $\chi^2(2, \underline{n} = 8) = 6.750$, $\underline{p}<0.05$ was again significantly higher within teams than technology, ($p<0.05$) but the inter-team, intra-team difference, although higher was just short of significance level. In the construct of *performance*, results showed no significant differences $\chi^2(2, \underline{n} = 9) = 5.515$, ns. Differences in the construct *communication* were found $\chi^2(2, \underline{n} = 9) = 6.889$, $\underline{p}<0.05$ and post hoc tests confirmed this was significantly higher within teams ($p=<0.05$) and from technology ($p<0.05$), than from between team members. The construct of *quality of interaction* was a highly important variable from the engineers' perception, specifically within technology. Results conveyed that *quality of interaction* was significantly different $\chi^2(2, \underline{n} = 15) = 13.525$, $\underline{p} <0.00$, with intra-team scoring significantly higher than both inter-team ($p<0.00$) and technology ($p<0.00$).

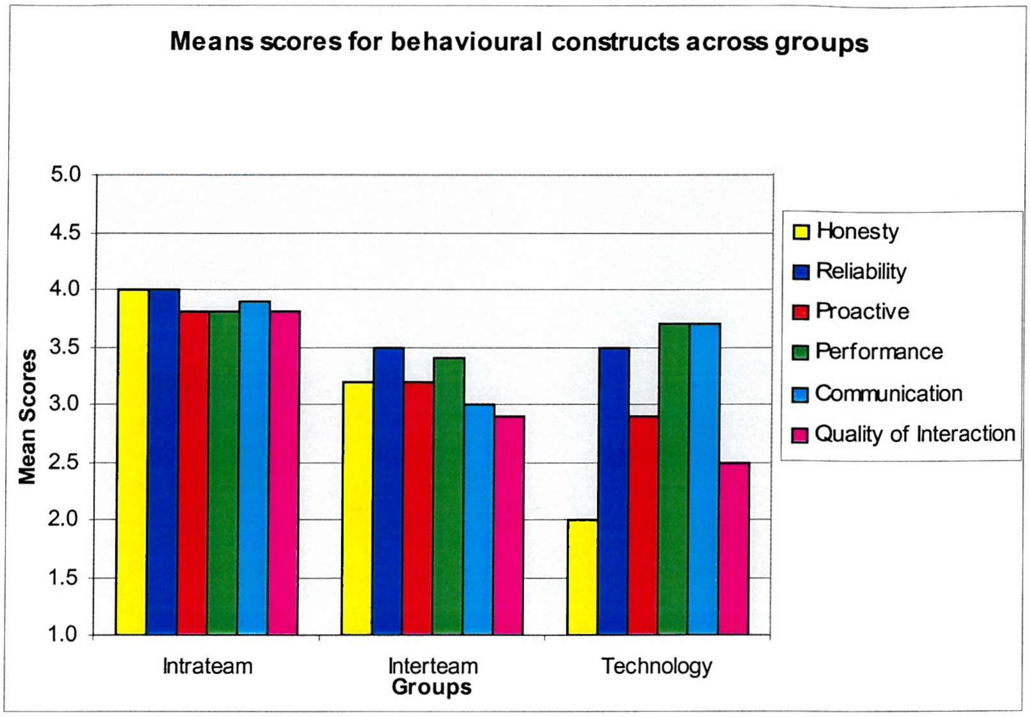

Figure 3.3 Bar chart showing mean scores for behavioural constructs across groups.

3.4 Discussion

The discussion is divided into three sections coinciding with the three dimensions of emotive, cognitive and behavioural trust, to reflect the results.

3.4.1 Emotive Constructs

The results show that feelings (emotive constructs) of trust in terms of *confidence, respect, commitment* and *teamwork* were considerably higher within (intra) teams than between (inter) teams, which from a social psychological perspective, (Turner, 1982) is what one would expect as an in-group identity is formed over time. Engineers working together within the same team are more likely to have developed higher trust through a sense of belonging, when they reach this identification stage of trust (Lewicki & Bunker, 1996).

There is a possibility however that group-think symptoms may develop when cohesiveness is high (Janis, 1983), especially in such volatile and complex environments. The balance between finding the optimum level of trust and developing an illusion of infallibility in control rooms needs to be addressed. This is important in the endeavour of remaining goal orientated as well as having a well-balanced interdependent team. It could be argued that in a control room particularly, very high intra-team trust could lead to intense group identity with added competitive problems of 'us and them' agendas between teams. This assumption is based on the tenet that according to Moorhead, Ference, & Neck, (1991), group-think refers to *'a mode of thinking that people engage in when they are deeply involved in a cohesive in-group, when the members; striving for unanimity override their motivation to realistically appraise alternative courses of action.'* (p. 539, 1991). There have been many incidents where major disasters could have been avoided had symptoms of group-think been caught in time (e.g. *Challenger Space shuttle*, (1986). This was a typical example of where group-harmony and belief in the group's own inherent morality was preserved against all costs – even people's lives. In the post-mortem 'Challenger' debate it was found that the NASA manager ignored the engineers' warning of a possible catastrophe with the O-ring arguing that the risk was just like every other one encountered in the business. He took the attitude of 'everything is going to work out all right because we are a special group', (cited in Griffin, 1997). Janis, (1983) points out that this attitude is a typical example of the illusion of invulnerability that group-think teams produce. Janis maintained that there are three primary antecedent conditions that contribute to group-think - highly cohesive teams, separation from outside opinions and/or influences and leader preference or style. All these conditions could certainly simultaneously exist in an energy distribution control room, a situation that could no doubt lead to disastrous consequences. One way of avoiding this is for inter-teams as well as intra-teams to share the same mental model and for team members and leaders alike adequately determining and agreeing on clear objectives. Potential risk of in-group decisions and mutual collaboration of alternative solutions to problems must also be determined. Optimum team trust and cohesiveness therefore, as well as inter-team interdependency is necessary, all of which point to sharing the same perception of control within and between control teams.

A higher sense of emotive trust is also expected between proximal teams, as they have more opportunity for social interaction, exchanging non-verbal cues and sharing group norms and can therefore develop greater synergy and interdependence. Within the sample however, some intra-team members were working in separate control rooms and yet in-group emotive trust still scored significantly higher than between group members (even though they were physically separated). These results tend to oppose the view of previous researchers (Handy, 1995; O'Hara-Devereaux & Johansen, 1994), who have argued that lack of physical proximity can make teams dysfunctional in terms of role ambiguity or overload, social loafing, absenteeism or in feeling a general low individual commitment. McGrath, (1991) also maintains that technological environments may impair a team's functional performance, thereby inhibiting the development of trust. It could be argued however, that in this study although team members were working virtually, they maintained a high perception of control and were more task focussed, possibly because they had been working together for a number of years.

Although *confidence* was considered important across all three groups, there appeared to be a lower feeling of confidence from scores in the inter-team and technology groups. This warrants some concern as all engineers had at least three years experience of the systems and the majority had even longer established relationships with colleagues in other teams. These emotive dimensions of trust however may have been affected by the perception of others' behaviour between group members. The *teamwork* construct rated highly between (inter) groups when asked how *important* it was, but was significantly lower when scored. This may indicate a lower level of trust with regard to sharing the same inter-team goals, another reason for the need to re-emphasise the common goal and to identify and monitor team strategies in how teams are achieving this. Even though systems play a major role in their everyday functioning, engineers had little *respect* for the technology, neither were they generally *committed* to it. The way in which technology *performed* or if its *quality of interaction* was low, then this may have influenced engineers' feelings of *confidence* and *respect* towards the technology as negative feedback into their perceptual input; hence create a reduced feeling of control. From Muir's initial research (1994) it was established that trust did not increase through experience but only changed with the competence of the machine. In other words when the technology was perceived to be functioning as expected and appropriately towards achieving the goal, then people were more likely to trust it. In this study lack of *confidence, respect* and *commitment* in terms of perception of trust in technology may have been due to the lower function in *quality of interaction*.

3.4.2 Cognitive Constructs

The core construct of *understanding*, which included subordinates such as (knowledge, experience and familiarity), was perceived to be one of the most important constructs across all groups. From the results it is apparent that generally engineers have a better *understanding* of the technology than of colleagues in other teams. This may be because they experienced more information sharing with their various systems than with people in other teams. Alternatively, the differences could simply be because these team members have very little or no physical face to face contact with inter-team members. With very limited social interaction, there is no opportunity to build relationships, hence perhaps a general lack of mutual *understanding* between (inter) teams is apparent here.

Conversely, a counter argument from other authors (e.g. Cerulo, 1997) has been that with the massive growth in dispersed teams, where there is an absence of physical presence, technology is forcing people to re-adjust to the concepts of social interaction. Cerulo found that even when physically remote, complete strangers could exhibit personal, informal and even intimate exchanges through computer mediated communication (CMC). She maintained that rather than physically being located in space, relationships were built upon sharing the same goal or task. Similarly, Walther & Burgoon (1992) found that reciprocity and trust could develop over time even when groups of students with no prior history worked together on a collaborative project using only CMC. This indicates that trust can develop without social cues and/or familiarity, even when people are remotely working as long as they do share some commonality. In Walther & Burgoon's research the shared understanding was in the joint project the students had to complete within five weeks. In any control room environment, one would normally expect there to be a mutually shared objective even between teams. This expectancy comes from the whole nature of process control where the whole system runs on a continuous 24-hour basis and relies on total interdependency between members. These preliminary results therefore suggest that although people are task focussed within their individual teams, the same inter-group objective has been lost creating a lack of inter-team trust. Alternatively, it may be that inter-team relations were not perceived as trusting due to a competitive rather than co-operative ethos that still exists between teams. This condition is one that could well emanate from organisational culture and/or team structure and dynamics (see Brown, 1988).

Engineers also expressed a higher *expectancy* of the systems than from people in other teams. This maybe a learned response based on past experiences of not having their expectancies met or it maybe because they have less interaction with members of other teams than the technology. In later research Muir & Moray (1996), found that trust and/or distrust could develop in technology, as when in constant error mode, participants learned to compensate and make adjustments. Their results indicated that trust grew over time confirming that to develop trust in automation, people do need experience. The significant lower score in *ability* of the technology elements highlights the fact that system behaviour does not always meet the expectations of the engineers.

3.4.3 Behavioural Constructs

Engineers were significantly more open and *honest* within their own teams than with members of other teams. This may present cause for concern in any organisation, but particularly in an environment where interdependency with other departments including support, planning, as well as outside agents are all crucial to the success and safety of the continuous process. Participants also perceived that they had better *communication* and exchange of interaction with systems than from people in other teams. As communication is the key element of co-operative teamworking, it would seem that there are some serious issues to be addressed with regard to raising the level of trust *between* teams. *Reliability* was of importance to engineers in technology, although results suggest that the systems were perceived to be as reliable as members of other teams – not very - which is another notable issue for consideration. From Muir & Moray's (1996) research, results indicate that machine behaviour needs to be both consistent and reliable in order to foster and maintain trust in technology, but this may be dependent upon the way information is displayed and the level of control that engineers have over oscillating variables. *Performance* across all three groups was considered to be fairly stable, although results confirmed that technology scored higher in *performance* than scores from inter-team members.

The construct of *quality of interaction* was defined as the *way* in which people and systems interact. Although it incorporated many subordinate constructs (i.e. personable, informal, approachable, feedback, correct information etc.) it was rated as the *most importan*t construct within the technology and inter-team groups (e.g. the most frequently mentioned construct). Results however do not support this, as engineers viewed the *quality of interaction* between (inter) teams and from technology significantly less than from members of their own (intra) team. This may present immense problems in terms of designing new technology. If information is not meaningfully or adequately represented in terms of enabling better interaction, then engineers will be reticent in accepting it, not be proactive in using it and hence take longer to trust it. Davis (1993) argues that perceived usefulness of a system (the way in which it performs and that it does perform) is 50% more influential to users than ease of use. From the present study results show that engineers are reiterating this perception. Therefore, in order to raise the level of trust in automation, system design needs to be continuously aware of user expectations. System technology should be designed to mutually coincide with engineers' perception of control in being able to achieve their target and should be built to respond in a human centred way, (Norman, 1990).

The results of this study indicate that inter trust needs to improve, although there is room for improvement across all three groups. Definite in-group out-group differences exist, which are in most cases strongly significant. Although people perceived trust to be *important* and when questioned *expected* a high level of trust to exist with team members they worked closely with, the results from their trust scores showed a definite divide, even though there is currently some cross over in shift teams. From this it can be concluded that there is a social identity effect, where peoples perceptions and co-operative behaviour is based on their in-group membership. From research on social dilemmas, it is evident that rather than egocentric behaviour, individuals are prone towards co-operative behaviour due to the group identity effect, (Tajfel & Turner, 1979). Even when there is no anticipated future gain or reward, co-operation still exists through social identity, (Dawes & Thaler 1988; Dawes, et. al, 1990). In fact Zand (1972), reported a saliency of group effect; when groups where briefed to expect trust from each other, they exhibited more trusting behaviours. In an environment where interdependency and trust is such a crucial component of effective performance, reduced or lack of optimum trust must be considered a hindrance. Organisational economic pressures, less resources and tighter profit margins has pushed the trust issue into the forefront even more; particularly as team members are becoming more physically remote from each other. Lower trust scores in the inter-team elements confirm that in the absence of social cues and physical proximity, trust needs to be made more explicit through maintaining mutual control of the goal. From results where *quality of interaction* was low, so was *respect* and *confidence.* This implies behaviour that positively rather than negatively reinforces interdependence in maintaining control is therefore more likely to enhance emotive and cognitive dimensions. This will ultimately reduce the margin of error between perceived and actual control. Overall, although this was a relatively small sample, its contextual richness allows some valid conclusions to be made.

3.5 Conclusions

Although the control engineers interviewed emphasised the *importance* of trust in their working environment, there appeared no framework or structure in the way that trust was construed or how it could be made explicit, (this was borne out by the amount of constructs originally elicited). Indeed engineers initially had difficulty in discussing such emotive issues, but as each construct was evaluated, however, it became apparent that they did share a commonality in their language of trust. Similar constructs from those mentioned in Chapter One Table 1.1 were apparent, but specifically within this HSC context, *quality of interaction*, *understanding* and *confidence* were identified as most commonly important. From referring back to the table of elements (Table 1.1) considered relevant in developing trust, it is also evident that there needs to be a shared or mutual goal definition between teams. Whether from co-located, virtual teams or technology, this common interdependency needs to co-exist. This shared goal was taken as a given in the context of this study with control engineers. Although on the surface results indicate that engineers are goal orientated, the high in-group effects of trust, the lack of perceived trust in inter-team and technology suggests that there is a void.

Whether this is a psychological remoteness (Wellens, 1993) or physical separateness, shortfalls in *quality of Interaction, honesty, reliability and communication* could be having a detrimental effect on the wider overall team environment. This is manifested through inter-team lack of *confidence*, *respect* and *teamwork* or general reduced team synergy which consequently diminishes perception of control and causes breakdown of the whole socio-technical system, (see Hettenhaus, 1992). In order to promote trust in control room environments, it is considered that the level of awareness for a wider interdependency needs to be raised. This could be addressed by defining contextual positive behavioural strategies that could reduce the error in the perception of control and thereby enhance trust.

Results also suggest that the more isolated people become from each other (e.g. inter-teams) the less trust they perceive in each other, which emphasises the need to make these strategies more observable and measurable through contextual training. In some instances, the scores of trust in technology (e.g. *communication* and *performance*) were higher than scores for work colleagues in other teams. Teams are more likely to be high performance teams if they are high in trust, (Jarvenpaa & Leidner, 1998). This can only be achieved this through displaying consistent proactive behaviours, giving consistent and timely feedback and constantly negotiating with each other. Even when virtual team members could not act immediately or had difficulty with carrying out a particular task, communicating the reasons *why* was considered a positive act, (Jarvenpaa & Leidner, 1998). The *need to respond*, Hawisher & Morgan, (1993), is therefore more critical in the absence of face to face communication. Furthermore, in order to address the trust issue within and between control room teams and technology, it is the *quality of interaction* that needs to be enhanced. Mechanisms that will promote the perception of team rather than individual control need to be implemented into a practical model for use in HSC environments.

It is considered that the use of contextual team training in behavioural strategies relative to the teams' defined goal would increase team interdependence, the perception of a team controlled goal, which would consequently reduce perceived differences between teams and ultimately enhance trust. Finally, it is clear from this study that where and how teams are situated relative to each other and their systems may affect perception of trust both within and between teams and in technology. Contextual core constructs confirmed from this study can now be developed into a questionnaire that will reliably measure team and technological trust within the confines of a controlled engineering task.

4 Chapter four: Trust in Technology: Location and Interface

4.1 Introduction

As discussed in chapter one, the concept of trust is important when introducing new systems into Human Supervisory Control (HSC) domains, especially when teams work remotely from each other, a factor that is becoming predominant within and across organisations. Within the energy distribution industries this is especially relevant where the main aim in controlling the remote plant is to minimise error in order to effectively balance input with demand and as such this entails continually striving to minimise external and internal disturbances. These disturbances could relate to the environment or the task but perception of control and trust may also be affected by other confounding variables such as the type of system interface engineers use and the location of the team.

Research has indicated that supervisory control should be considered as 'management by awareness' (Zwaga & Hoonhout, 1994), where engineers can accurately extract the necessary information from the system. In a recent study however, Stanton & Ashleigh (2000) found that operators are still very often more system driven, (reactive) rather than proactive (able to plan ahead). The dichotomy that exists as to whether control is reactive or proactive, may depend on the system interface design, and where the engineer is located in time and space relative to the rest of his/her team. In order to develop trust, people must feel in control of the technology they are interacting with; the feedback loop should match their expectation, consequently, system design must allow for flexibility and variety of the operator, whilst taking into account the dynamic environment that the human operates in (Hollnagel, 1993). The design and function of an interface as well as team location may affect team performance and it is considered possible that these two variables may be significant when considering the concept of perceived trust in technological systems within the context of a human supervisory control task. Interdependence in goal orientation between teams, technology and the wider socio-technical system are vital if trust is to be nurtured and maintained in HSC domains. It has been established that there are elements of trust specifically relevant within engineering contexts (Ashleigh & Stanton 2001) (see chapter 3). This chapter therefore aims to investigate perceived trust in technology within a simulated control room using these elements bespoke to engineering domains, paying particular attention to location of teams and system interface design.

4.1.1 Location

Virtual organisations, virtual partnerships and remote teams are emerging as the norm of business practice in the twenty first century and it is considered that virtual corporations are here to stay, (Goldman et. al, 1995; Davidow & Malone, 1992). It is also conceived that as virtual working becomes more commonplace, those who adapt to novel technologies and use them to their full potential will be better equipped to profit themselves as well as others, (Preston, 1999). He argues that as information processing and telecommunication networks expand and people have greater access to infinite resources and information, physical proximity as a defining factor between people interaction becomes redundant. Perhaps this is more significant when multiple actors are working together in teams toward a common goal, but are physically remote. Teamworking research from academic and commercial domains both confirms (Jarvenpaa & Leidner, 1998; Walther & Burgoon, 1992) and refutes (Handy 1995; O'Hara-Devereaux & Johansen, 1994) the proximity argument. It is therefore considered appropriate to examine this conflicting evidence within an engineering context.

4.1.2 System Interface design

Generally, the merit of new technologies should not be precipitated before first examining the interaction between them and the human operator within the context of their work domain. Furthermore, as workforces become more remote from each other it is necessary to understand how changes in patterns of work and work practices are effecting the changes in perceptions of relationships between people and technology. Factors such as functional fidelity, perceived usefulness in supporting tasks, (Davis, 1993) and whether people can trust a systems competency, (Muir, 1994), should be a serious consideration. Being physically remote from the plant as well as each other promotes greater reliance on technological systems. This can cause potential cognitive overload, which create other escalating problems, (Venturino & Eggemeir, 1988). Control engineers need to feel confident that they can rely on the system they use, they need to understand that its functionality is consistent and in line with their expectations, (Ashleigh & Stanton, 2001, chapter 3), all of which will help to promote trust in technology.

The way the system is designed, the type and display of information have implications on the level of cognitive control of operators and need to be represented from a *human* perspective, (Norman, 1993). Novel technologies have the potential of either enhancing or debilitating the nature of working practices, behaviours and cognition of the human operator. Implications from Muir & Moray's (1996) work were that consistency and reliability of control and display information affected the development or deterioration of perceived trust in technology. Development of the human-machine interface is considered one of the main issues in contemporary teamworking, (Annette & Stanton, 2000), a factor that may also affect the degree of trust operators have in a system. The way humans think in a supervisory control situation is also relevant to the human-machine interaction process and Rasmussen (1986), developed his Levels Of Abstraction Hierarchy (LOAH) model to explain this, see Figure 4.1.

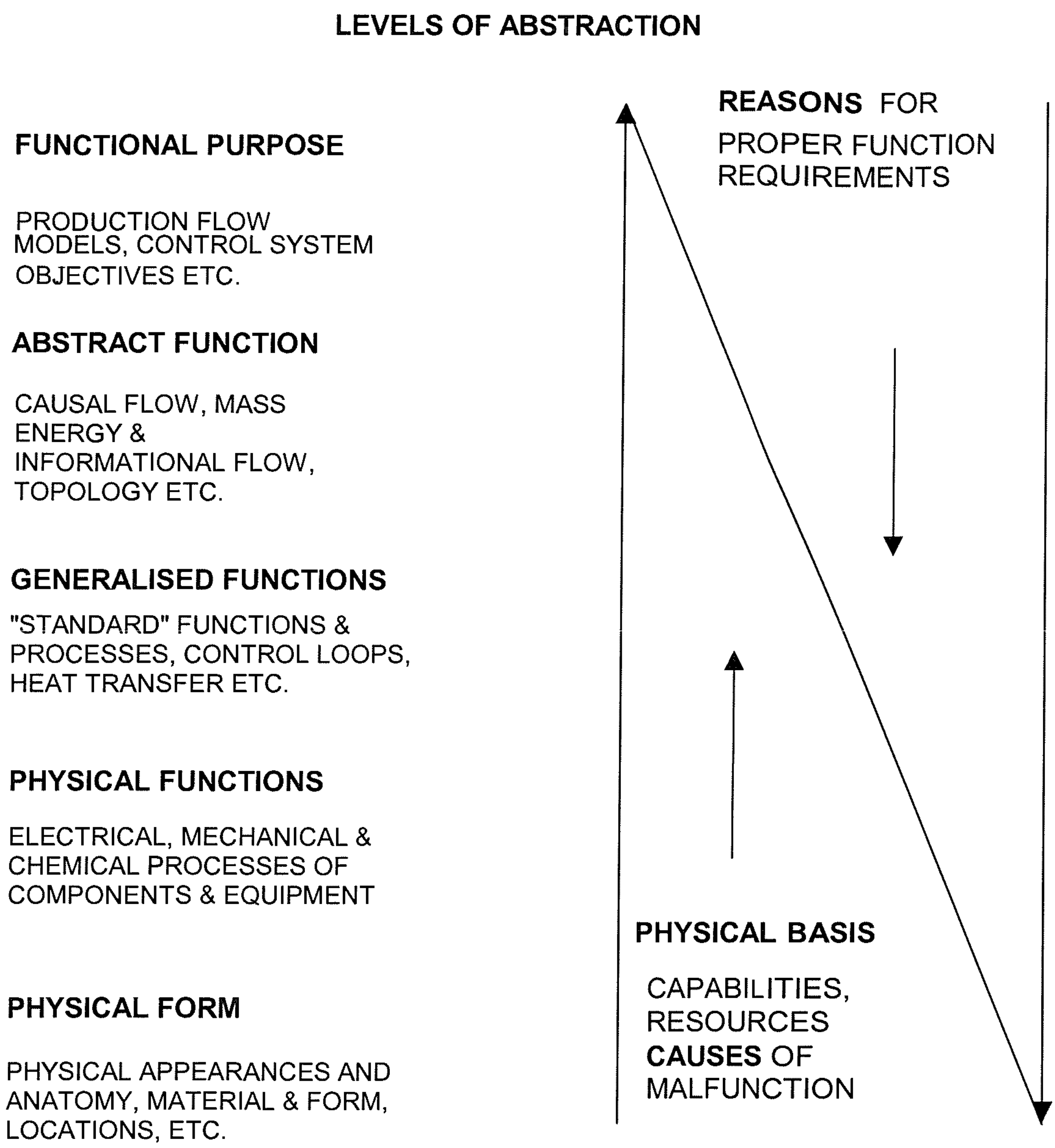

Figure 4.1 Levels of Abstraction Hierarchy.[4]

LOAH is a hierarchical model of human cognition in supervisory control that describes how the control operator moves from a concrete physical appearance of the plant's system components to a goal seeking functional and purposeful objective. As systems have become more complex and multi-layered, design technology has had to

[4] Reprinted with permission, copyright J. Rasmussen, (1986).

compromise between the physical form and functional purpose of the plant when developing interfaces. Currently most HSC domains use Supervisory Control and Data Acquisition (SCADA) systems facilitated by mimic display interfaces. This presents a two dimensional graphical representation of the plant process and equipment. Related to the LOAH model, it may be that current systems stand somewhere near the mid-point of the continuum between complete abstract functional levels and the physical form, although their functions are set between the general and physical level. Throughout the control process operators may have to shift from one cognitive level to another as the situation demands. Rasmussen, (1986) argued that the requirement to convert process objectives into physical plant manipulations added a complex cognitive load onto the operators task. He therefore suggested that using high level functional as opposed to lower level physically representative displays might substantially reduce this demand. This reduction in workload is achieved by shifting some of the cognitive process from the human into the system. If engineers have less to process it may be that their perception of control will be increased, thereby minimising error, which may help to develop trust in that system.

Past research, (e.g. Greaney & MacRae, 1993, 1996; Wood, Wise & Hanes, 1981) considers that abstract functional interfaces are preferred for fault diagnosis. This was confirmed more recently when undertaking a perceptual discrimination study on various control interface symbols, participants found that polygon symbols were the preferred choice in terms of simplicity of display and reaction time in diagnosing errors, (Roberts, Stanton, Ashleigh & Xu 2000). Jacob, Egeth & Bevan, (1976) also found the use of polygons to be a superior form of display, not only for multiples of integrated variables, but because they are processed holistically. Barnet & Wickens

(1988) confirmed that polygons were better than conventional displays in fault diagnosis. In the aim of reducing error and enabling engineers to achieve their performance target in the current study, a polygon display was used. Being visually simple and not containing layers of information to extract, this type of display was considered easier to process. In reducing cognitive load it was considered that performance would be enhanced and hence increase trust in the system. In fact recent research investigating the effect of communication technology on virtual teams, Carletta et.al, (2000), found that a fairly modest level of technology (i.e. a simple interface), supported collaborative working of virtual teams.

4.2 Aims of Study

The following study aims to investigate perceived trust in technology using two dichotomous levels of interface design and location as independent variables. In accordance with Rasmussen's (1986) LOAH model, one interface is based on a physical analogue of the real plant and the other uses a goal-orientated functional approach. Perceived trust in technology and performance measures will be taken whilst teams are working in a simulated control room scenario controlling a dynamic task based on real-world gas distribution parameters. The perception of trust in technology will be measured at time one (after training) and at time two (after the experimental task). In accordance with Rasmussen, (1986), LOAH model, it is considered that differences may be found between how respondents relate to the system in terms of trusting the system, dependent upon how much information they have to process and information representation. Based on the existing evidence discussed with regard to abstract functional symbols it was considered that trust might be higher if cognitive load was reduced. It was also considered that trust might be higher in the experimental task if participant expectations in terms of understanding were met by the technology. With regard to levels of trust in the technology and team location it is considered that differences may result from teams being remote from each other whilst controlling the system. It is therefore hypothesised that;

i) Overall trust in technology would be greater where there was less cognitive workload (i.e. using the abstract interface)

ii) Perception of trust may be different based on location.

iii) Perception of trust would be greater if expectations were met

iv) Trust in technology would increase as perception of control (performance) increases.

4.3 Method

4.3.1 Study Design

Six teams of four people were either working together in the same location (proximal), or working in separated locations (distal), and using either a virtual (physically represented), or abstract (functionally represented) interface, (2 x 2), see Table 4.1. Each team was asked to perform a simulated task of balancing a gas-network system. Dependent measures were perceived trust in the technology and group performance, details of which will be discussed later in the experimental task.

Independent Variables	Proximal-Virtual	Proximal-Abstract	Distal- Virtual	Distal-Abstract
Dependent Variables	Trust Performance	Trust Performance	Trust Performance	Trust Performance

Table 4.1 Independent and dependent variables.

4.3.2 System Design

A simulated Energy Distribution System (EDS) was developed using two dichotomous interfaces, based on Rasmussen's (1986) LOAH model. This system was originally designed for an Economic Social Research Council (ESRC), funded project, (Stanton et al 2000). The system simulated a gas network that continuously supplied energy through the system over a 24-hour period. The process of distribution had to be continuously monitored to identify unexpected fluctuations in demand and to manage certain system constraints. The EDS system is a dynamic system consisting of a National Transmission System (NTS) and four Area Distribution Systems (ADS). The NTS is a simulated networked system that constantly supplies the four ADS with predictable and controllable amounts of energy. Each ADS represents a local area networked system that supplied the end user with amounts of energy to meet demands. The topology of the system consisted of one feeder network (NTS) and four sub-networks (ADS) being fed from the main network. These sub-networks are topologically identical but have different demand levels, storage requirements and available storage. The network is shown in Figure 4.2.

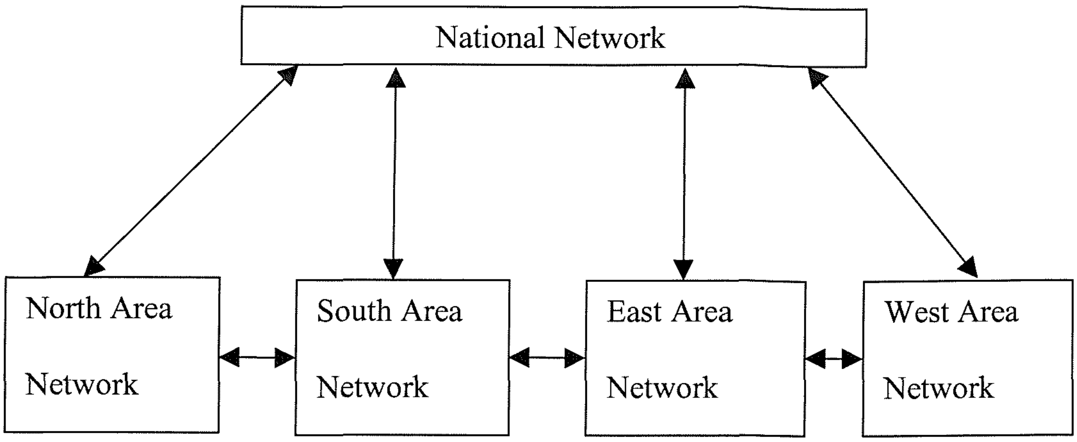

Figure 4.2 Network of the Energy Distribution System.

4.3.3 Equipment

Four networked PC's were used for the laboratory-based experiments. Each team member used a PC with either a virtual or abstract interface that represented a geographical area gas network, (e.g. North, South, East or West). Video cameras were used in each laboratory to record behavioural data of teams interacting and allow visual communication across the distal condition. Telephones were used in the distal condition to enable verbal communication among team members.

The software used to develop the two interfaces was '*World Tool Kit*'. To simulate the gas network system simulation software called *Falcon* was adapted and used to form the link from the main server computer (simulation engine) to the four networked machines. Transco BG Technology originally developed this software to simulate real process control operations for training purposes in the company. The software was then adapted for an ESRC Virtual Society Programme (see Xu et al, 1999). The simulation procedure involved three states that were continuously repeated. Behind each Graphic User Interface (GUI) the *Falcon* simulation procedure was programmed to give the necessary predicted data and output information according to real process control parameters, to each front end interface, gather instructions from the GUI's and feed back to the main server. The simulator gathered information on the number of times a holder was used, any changes of flow rate through the regulator and total cost of running the system for each team. It predicted the data necessary to operate the system, giving instructions as outputs to each front user interface. The predicted results were processed in the GUI and the instructions of the users fed back to the simulation engine. The simulated shift cycle started at Day one 0600 hours and finished at Day two 1300 hours; this was to give team members a full simulated day to control the gas system. Every four hours simulated time was equivalent to five minutes real time, which was the time parameter for the team to make a decision of any necessary changes to the system before the next time period was simulated. There was a prescribed optimal performance target for each ADS, based on real gas industry data. This was used to make the task as valid as possible to a real-life scenario and so that participant scores could be measured against these. Each area had optimum values for gas flow rate into the ADS system; holder costs (how much the holder was used) pressure costs (costs of changing the regulator) and overall main National Transmission System (gas supply) cost. At the end of each run of the experiment the Falcon system fed back to the main simulation engine each ADS performance scores for these parameters. Each area optimum parameter measure at Day two 0600 are shown in Table 4.2 and represents perfect balance of each system. The team scoring nearest to these parameters would have achieved best balance and least error.

Table 4.2 Optimal performance measures for experimental task

Optimum parameter scores	North	South	East	West
Regulator flow values over 24 hrs.	7.76	8.02	7.76	7.10
Pressure costs in £'s per 24 hrs.	744	736	4165	832
Holder costs in £'s per 24 hrs.	420	420	420	420
Bangton (NTS) costs per 24 hrs £'s	4272	4272	4272	4272

4.3.4 System Interface Displays

The first interface was based on the physical level of control in Rasmussen's (1986), Level of Abstraction Hierarchy (LOAH). This 3D physically representative graphic user interface (GUI) provided information on the overall predicted demand and supply over 24 hours, current flow rate, detailed independent profiles of flows and pressures for each consumer in the ADS and regulator and storage information. Each area network consisted of the same components. The regulator (shown as a representation of a valve with a control), the holder (shown as a representation of a gas-holder with a control panel), and the consumers (shown as Field, Leigh, Ton and Industry), so each consumer in each ADS represented either North, South East or West. The network was controlled either by changing the overall supply to the network through the regulator or by increasing or reducing local pressure by emptying or filling the holder, (local storage). The holder physically represented its state as when empty the holder physically reduced in size and expanded as it was being filled. This interface was referred to as the virtual representation (VR) and is shown in Figure 4.3.

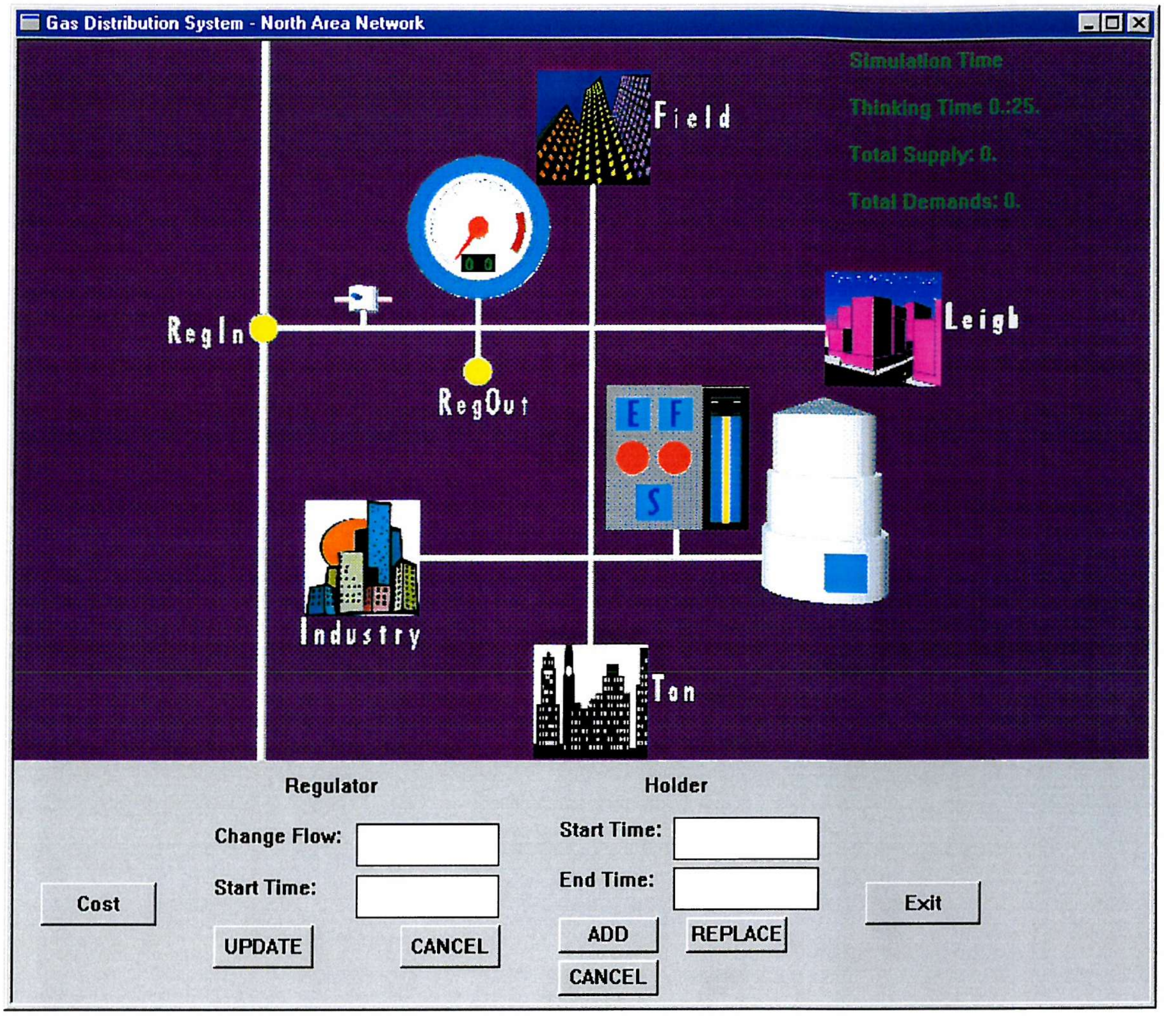

Figure 4.3 An example of the physical, virtual (VR) user interface for north area.

The second interface was designed based on the abstract functional level of control, (Rasmussen, 1986). In this interface six parameters from the gas distribution system were presented as six nodes to form the polygon. As the state of each parameter changes, so does the shape of the polygon, presenting the current state of the system, as either in balance or not. The six abstracted parameters were as follows: -

- Balance – difference between the total supply and the total demands plus a difference between the holder levels at the beginning and end of the day. This could be a positive or negative value. The optimal value is zero.

- Holder levels at End of Day (EOD) – The full holder capacity is .35MCM (Million Cubic Metres), the range of value is 0 to .35 and the optimal value is .35 MCM when at the full position.
- Minimum Pressure – The optimal value for this parameter is 10 bar, which has to be continuously monitored. Any value above this causes the system to run at a loss in terms of cost.
- Inlet flow Demand – Where there is a difference between total supply and total demand. The value can be positive or negative but the optimal value on this node is zero, when input is meeting demand.
- Pressure at EOD – This is the regulator output pressure at the end of day, which should be kept to a maximum of 38 bar as an optimal value.
- Number of hours at 38 bar – measures the number of hours that the regulator output press is 38 bar over 24 hours. The optimum value for this is 1.

In contrast to the virtual interface, the calculation for these parameters was performed by the system itself and therefore much of the cognitive load was embodied in the system that would have otherwise been required of the operator. Control functions were kept the same as the virtual interface, by sending a command through the regulator (the tap symbol) or the holder, (the volume gauge with the E, F, and S buttons on the control panel). This was to ensure that any differences found would be due to the interface itself and not method of control. When the system was in balance the polygon would keep its shape and stay green. When any parameters were out of balance - goals were not reaching optimum levels - the polygon would produce a different emergent shape in red to show a fault in control. This interface represented the abstract functional interface and was referred to as the abstract (AR) and is shown in Figure 4.4.

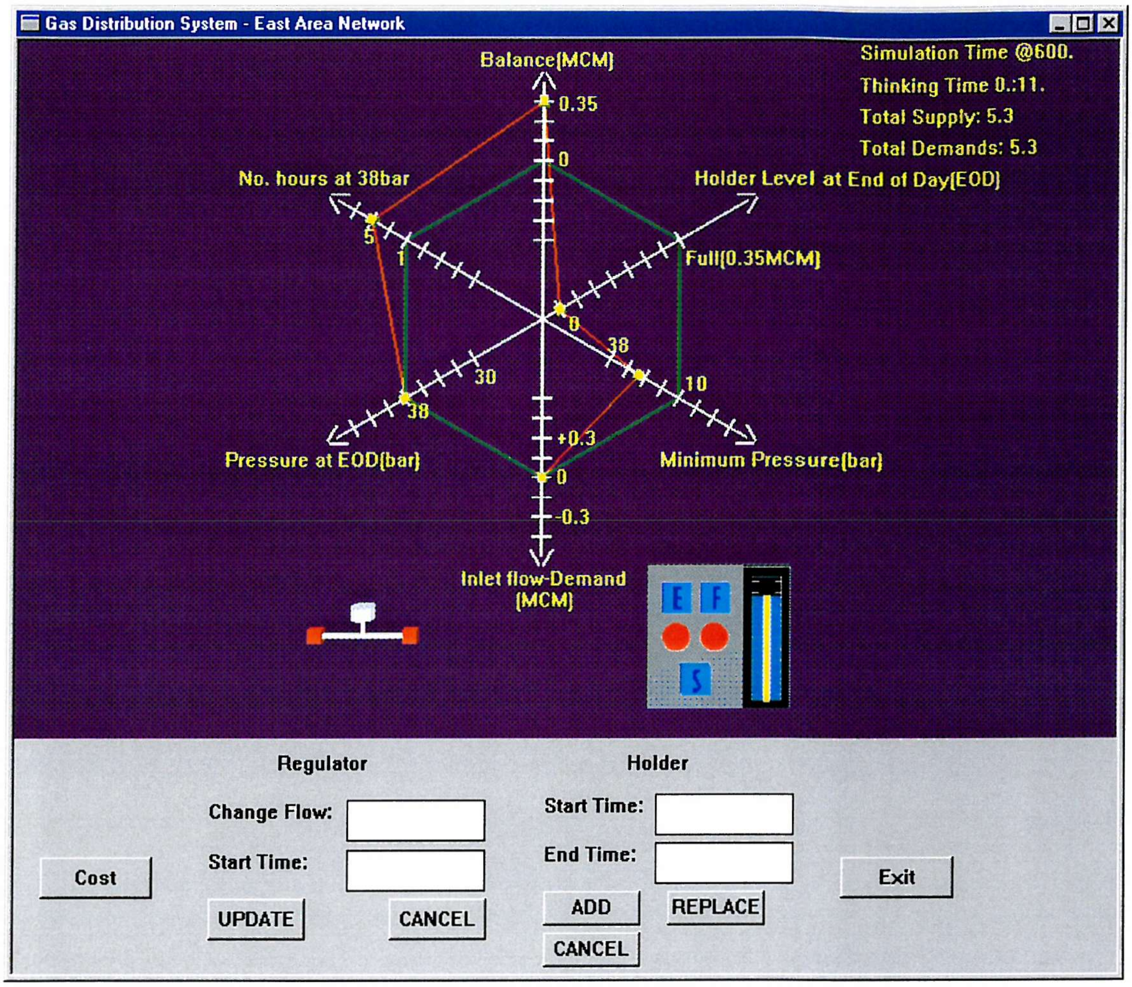

Figure 4.4 An example of the abstract functional interface for east area.

4.3.5 Participants

A total of 96 participants (6X4X2X2), were randomly selected from academic and industrial backgrounds. The criteria for selection were that participants had achieved a certain academic level in an engineering subject (3rd year and postgraduate students) and/or had some 'real-life' engineering experience. It was also stated that all participants had to have a basic understanding of the principal relationship between mass flow & energy; an indication that they had some knowledge how an energy distribution system worked. Participants were sampled by responding to advertisements posted around Southampton University Engineering departments and from a wider media pool. As the criterion was specific and quite rigorous, this made the sampling process more prolonged and difficult than anticipated. Initially the study was planned for ten groups of four participants in each condition. Although 120 potential participants were initially recruited for this study, six teams eventually had to be abandoned once the training session had been completed, as even if team members fitted the criterion, they could not always apply their knowledge to the experimental task. A total of six teams (n=24) ultimately had to be abandoned. Of the 96 participants used in the experiment, (52%) did not have actual engineering experience, although they were undertaking engineering-based degrees. The experience of 46 participants (48%) that worked in engineering ranged from 1-28 years, mean (M = 6.1, SD = 6.9) years. Participants were randomly assigned into teams and to one of a possible four conditions, (proximal-virtual, proximal abstract, distal-virtual or distal abstract). No differences in the amount of experience were found between the four different groups. Participants aged from 19 to 55 years; mean age being (M = 27.4, SD = 8.6). The sample consisted of 74 males and 22 females, however no significant differences in distribution of gender were found when the participants were randomly separated into the four group conditions. Of the sample, 73 participants were students (76%) and 23 (24%) were in employment outside of academia. Of the student population, 59% were at postgraduate level and 41% were 3rd year undergraduates.

4.3.6 Materials

Contextual elements of trust identified as important in current HSC domains (Ashleigh & Stanton, 2001), (see chapter 3), were used to develop a self-reporting questionnaire to measure perceived trust in technology. The three constructs of trust that were found to be most important to engineers in control rooms were; *quality of interaction, understanding and confidence.* These formed the basis of the items in the questionnaire and were divided into three dimensions of emotive (a feeling of trust), cognitive (a sense of cognitive understanding) and behavioural (system behaviour and feedback). Examples of the items are; (See Appendix 5).

- <u>I had faith in the system</u> – example of an emotive feeling (e.g. confidence).
- <u>The interface helped me to make sense of the task</u> – example of cognitive dimension (e.g. understanding).
- <u>The system gave me appropriate feedback when required</u> – example of behavioural dimension (e.g. quality of interaction).

Perceived trust was measured on using a Likert scale of 1 to 5 where 1= no or none at all to 5 = extremely high. It was considered that more graduation in the scale would have eliminated bias towards the mean (e.g. moderate amount), however the author did not consider that there were enough item categories to accommodate a broader scale range. Apart from the actual task performance, this was also one of four questionnaires that participants were required to complete.

4.3.7 Experimental Task

The aim of the task was to operate the gas network system ensuring all the operational demands were met (i.e. the system input-output is balanced, system pressures are kept within tolerances and team operating costs are kept as low as possible). The NTS supplied the four area networks with a constant rate of gas through a regulator. Each area represented either North, South, East or West and was run by a participant; four areas made up one conditional team.

Each team objective was linked to objective performance measures that were being monitored by the researcher, there were to:-

- Minimize the overall flow-rate variation.
- Keep all pressures above 10bar and below 38 bar.
- Operate the system as close to the 10 bar limit as possible.
- Minimize the use of the holder.
- Make sure that EOD (end of day) stock is the same as at start of day stock.

The gas input is supplied at a constant rate, however the consumers do not take gas out of the network at a constant rate. As demand can change at any time and the participants only become aware of the change after it has happened, they need to be able to respond quickly with their control actions. If demand is greater than supply then additional gas can be taken from the high-pressure pipes (line pack), the holder (i.e. gas storage facility) and/or by increasing supply through the regulator. If demand is lower than supply then surplus gas must be stored. This can either be in line pack, in the holder or by decreasing supply through the regulator. This model of the task replicates real-world gas distribution.

Each participant was encouraged to work in collaboration with other team members, as the optimal solutions to the problems set could only be achieved from a co-ordinated team effort. This was because every time an adjustment was made to the flow-rate of gas being supplied to an area, this incurred high costs. This could only be prevented by co-ordinating their flow-rate changes with other areas to minimise the overall team cost.

4.3.8 Procedure

Participants were recruited in teams of four and each team was given an initial introduction and briefing regarding the study aims. Ethical matters were then explained and all participants signed a consent form. Biographical data was collected and each team was assigned to a condition (i.e. proximal/distal abstract/virtual) and given a team identification name (e.g. North South, East or West). The procedure for answering the questionnaire was explained. The rules for the task were explained and participants were then given a set of instructions explaining what the task consisted of and how to complete it, (see Appendix 6 and Appendix 7 for example of rules for the virtual and abstract interfaces). A thirty-minute question and answer time followed for clarification of rules and the task objectives. Each participant was given a visual crib-sheet of the interface that acted as a hands-on user guide. Participants were then given a hands-on demonstration of how to control the gas network system. A training task was used to explain how to use the controls and what they must be aware of. They were also shown how to use the communication system where appropriate, when in the distal condition. Participants then undertook a training session (Approximately 1 hour 45 minutes) before performing the experimental task. This involved practising changing the regulator and holder, monitoring the costs and storage flow and completely familiarising themselves with the interface in order that they could quickly extract information. Researchers were on hand and helped individual team members where appropriate. All teams then performed the same training task, which took 20-30 minutes. This was similar to the experimental task, except no error signal in demand changes were given. The object of the training task was to ensure all participants could use the controls and understood their team objectives. Participants had to be able to understand each parameter on the interface and how to extract information from it. Criteria was set for the training task and each participant had to be able to change the regulator and control supply, empty and fill a holder, understand the costing system and be able to calculate how much gas (by more or less) was needed to meet the teams' EOD demand. Performance criteria were monitored throughout the training session and teams were not allowed to begin the experimental task until they had achieved the performance criteria. Researchers took notes on how the teams interacted with each other and whether they considered the team competent enough in using the controls to carry on with the experimental task. Some participants themselves voiced reluctance in continuing with the experimental task once they had completed the training session. These participants (n=24) were consequently eliminated from the study, (which is why participants in study totalled 96 and not 120). Participants were able to ask the researchers for help at any given time throughout the training session. Emphasis was given to the fact that at all times participants should communicate with each other and should help and support each other whilst carrying out the task, as it was only the overall *team* performance measures and costs that were important, not individual scores. After the training session before undertaking the real task, the teams were asked to complete the technology trust questionnaire via their computer. All participants were asked to work together as a team. After completing the main task, with no help from the researchers, the same participants in the same teams completed the questionnaire again in their own time via the computer.

4.4 Initial Analysis

Initially total mean trust participant scores were calculated for time one (T1) after training and time two (T2) after experimental task and scores were compared against interface and location (IV's) using Oneway Analysis Of Variance, (ANOVA). Scores of trust (from 1 = none at all to 5 = very high) relating to emotive, cognitive & behavioural items were computed giving a mean score for each participant in each category. Items 1,7,10, &11 related to a general emotive dimension in terms of *confidence*. Items 4,5,6 and 13 were computed as the cognitive dimension, relating to how the interface helped participants *understand* or make sense of the task. Items 2,3,8,9 and 12 formed the behavioural dimension, relating to the system's behaviour and feedback, or *quality of interaction* (section 3.2). As the study was interested in investigating trust in relation to teamwork and the difference in interaction with the technology dependent on location and interface, the questionnaire data was then collated in accordance with the four independent groups; (proximal-virtual, proximal-abstract, distal-virtual and distal-abstract). Oneway ANOVA's were used to examine any differences between dependent variables of trust namely; confidence, understanding and quality of interaction across conditional groups at time one (T1) and time two (T2). A repeated measure ANOVA was used to test trust differences at T1 and T2 between each conditional group. Each team was set an optimum performance target in terms of balancing the system and team costs, (see Table 4.2). Performance scores were calculated by taking the optimum target performance score for each area network and subtracting each actual participant's scores from this. This gave an overall mean measure of performance for each team according to the four conditions (i.e. proximal/distal, virtual/abstract). Scores were recalculated into least percentage error scores to make results more realistic and representative of the domain. Group cost differences were also calculated in £'s and tests of difference between groups were calculated taking three dependent variables of balance (optimum performance), percentage error and cost as dependent variables and group condition as the independent factor. Non-parametric Spearman Rank correlation tested potential associations between team trust and group performance across the four group conditions.

4.5 Results

Total mean trust scores after the training session (T1), and after experimental task (T2) for each trust category by interface and location are displayed in Table 4.3

Table 4.3 Means and standard deviations of trust (scored 1-5) for training and experimental task by interface and location.

		Training[a] (T1)		Experimental Task[a] (T2)	
Location	Interface	M	SD	M	SD
Proximal	Virtual	3.25	.71	3.23	.62
Proximal	Abstract	3.60	.36	3.50	.54
Distal	Virtual	3.20	.65	2.83	.61
Distal	Abstract	3.53	.51	3.51	.63

[a] n = 96 for each group

From Table 4.3, it can be seen that scores at T1 (after training) were higher for the abstract than for the virtual interface. Although scores were slightly lower at T2 (after the experimental task), both abstract conditions were still higher than virtual conditions. Oneway ANOVA tests of difference confirmed a main interface effect at T1 and T2, but no location effect as seen in Table 4.4. These results therefore support Hypothesis 1, but not Hypothesis 2. (see section 4.2).

Table 4.4 Analysis of variance for mean trust scores by location and interface.

Source	df	f Training	f Experimental Task
		Between-subjects	
Location	1	.247	2.257
Interface	1	8.507**	14.108***
S within-Group error	92	(.328)	(.362)

Note. Values enclosed in parentheses represent mean square errors.
*p<.05, **p<.01, ***p<.001.

The mean scores for the three trust dimensions against conditional groups for T1 and T2 are displayed in Table 4.5

Table 4.5 Means and standard deviations for three trust dimensions by groups.

Time One						
Trust Dimension	Confidence		Understanding		Quality of Interaction	
Group	M	SD	M	SD	M	SD
Proximal/Virtual	3.19	.80	3.42	.64	3.13	.81

Distal/Virtual	3.16	.68	3.19	.72	3.20	.75
Proximal/Abstract	3.64	.40	3.53	.46	3.60	.49
Distal/Abstract	3.63	.71	3.53	.57	3.57	48

Time Two

Trust Dimension	Confidence		Understanding		Quality of Interaction	
Group	M	SD	M	SD	M	SD
Proximal/Virtual	3.3	.78	3.23	.63	3.18	.68
Distal/Virtual	2.78	.74	2.87	.77	2.83	.56
Proximal/Abstract	3.35	.73	3.57	.46	3.49	.70
Distal/Abstract	3.51	.73	3.62	.67	3.40	.71

[a] n = 24 for each conditional group

As results show, mean scores are higher for abstract conditions in all three trust dimensions at both T1 and T2. Oneway ANOVA's were performed to test for conditional group differences and results found significant differences *within* the three trust dimensions both at T1 and T2. Results are displayed in Table 4.6

Table 4.6 Analysis of variance for difference of mean dimensional trust scores at T1 and T2 by groups.

		F		
Source	df	Confidence	Understanding	Quality of Interaction
		Between-Groups		
Training	3	3.716*	1.649	3.339*
S within-Group error	92	(.444)	(.369)	(.423)
Exp. Task	3	4.367**	6.986***	4.578**

S within- Group error	92	(.553)	(2.907)	(2.026)

Note. Values enclosed in parentheses represent mean square errors.
*p<.05, **p<.01, ***p<.001

Bonferroni post hoc tests were applied to take into account multiple comparisons. Within the training condition (T1), between group differences were only significant at the 10%. Within the emotive trust dimension, group differences lay between proximal-abstract and distal-virtual and within the behavioural dimension between proximal-virtual and proximal-abstract. Generally however, perceived trust differences between the four conditional groups within the training condition were not excessive, implying a fairly even perception of trust across the board after the training session. Within the experimental condition (T2) Bonferroni post hoc differences were highly significant, p<0.01. Specifically, between distal-virtual and distal-abstract groups for *confidence* in the interface. Significant differences were confirmed in *understanding* between distal-virtual and proximal-abstract groups. Differences in *quality of interaction* lay between the distal-virtual and proximal-abstract and between distal-virtual and the distal abstract groups.

These results indicate that even when working under experimental conditions being remote from other team members has little affect on perceived trust in technology when using the abstract interface. When using the VR interface however, trust scores are significantly reduced when working remotely, giving some support to hypothesis 2, (see section 4.2).

4.5.1 Results between Time One and Time Two

Differences were investigated between T1 and T2 *within* the three trust dimensions and across group conditions. Means were plotted into three line graphs for each of the trust dimensions at T1 and T2 across the four conditional groups. Scores for the emotive trust category, (Figure 4.5), show that perception of trust in terms of having confidence in the technology was slightly lower in the experiment task (T2) than in the training session (T1). This indicates that feelings of confidence had not increased over time. Within the cognitive dimension (understanding the system), mean scores were slightly higher in both abstract interface groups, giving some support to hypothesis 3. Conversely, means show a decrease between T1 and T2 for both virtual groups, especially in the distal condition, lending some support to hypothesis 2, that perception of trust may be different based on proximity, (see Table 4.6). Overall means for behavioural trust show that there was a slight decrease between training and the experimental task, apart from in the proximal-virtual condition, where a marginal increase was seen at T2. The abstract groups were again generally higher in perception of trust than the virtual groups, (see Figure 4.7).

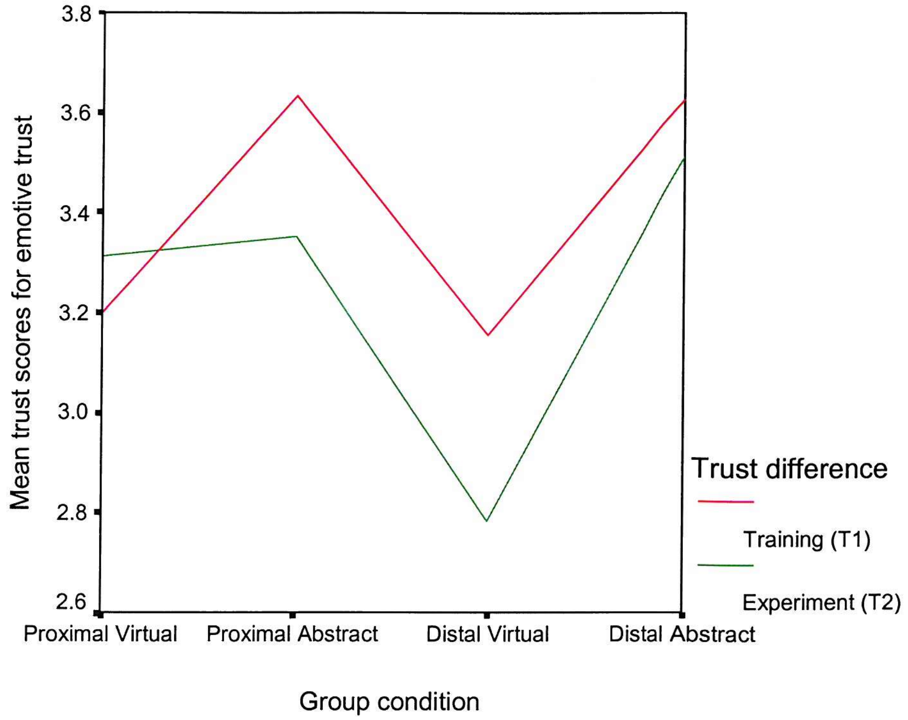

Figure 4.5 Line graph showing emotive trust for T1 and T2 by group condition.

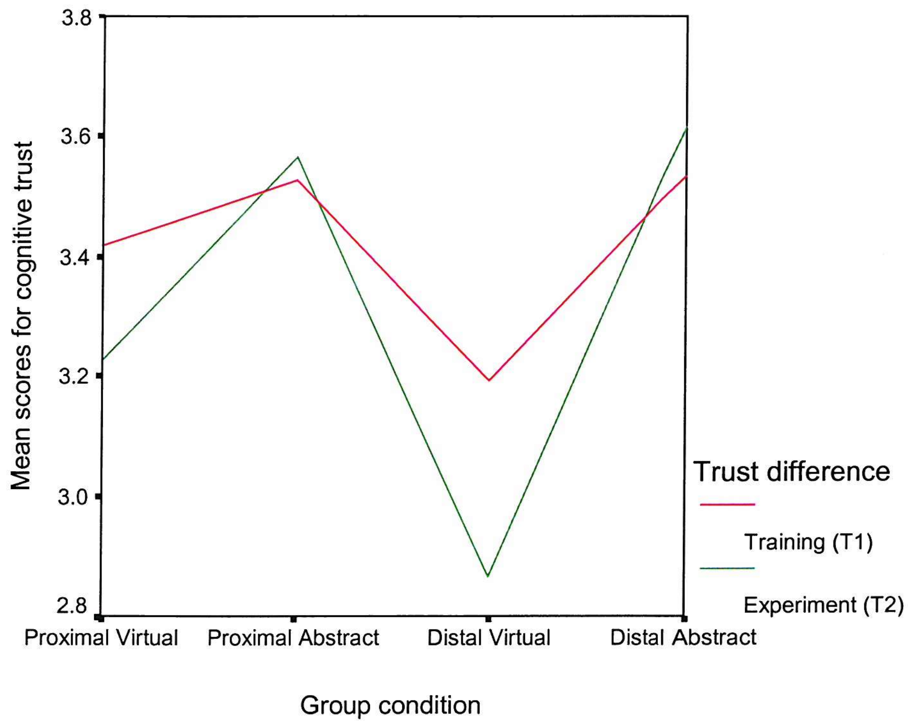

Figure 4.6 Line graph showing cognitive trust for T1 and T2 by group condition.

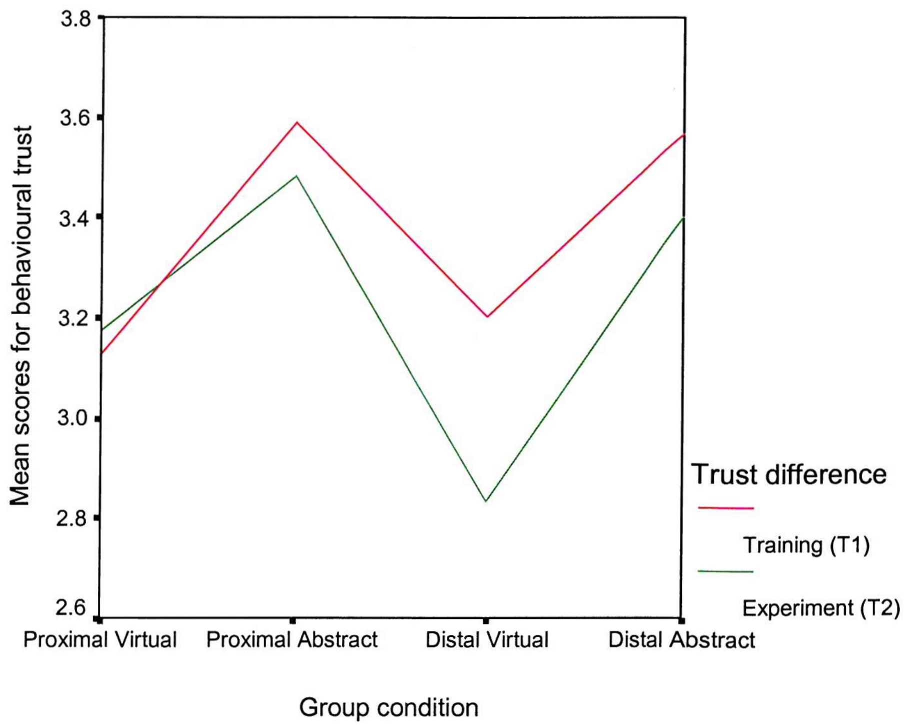

Figure 4.7 Line graph showing behavioural trust at T1 and T2 by group condition.

Repeated measures ANOVA were appropriate to measure differences between T1 and T2 in each trust dimension between the four conditional groups. Results are given in Table 4.7

Table 4.7 Analysis of variance for three trust dimensions at T1 and T2 by groups.

			F	
Source	df	Confidence	Understanding	Quality of Interaction
		Between-subjects		
Group		35.552**	5.586**	5.309**
S within-Group error	92	(.633)	(.549)	(.581)
		Within-subjects		
Trust Diff		13.546	1.149	3.685

Trust Diff x Group		31.519	1.909	1.248
Trust Diff x S				
Within-group Error	92	(.364)	(.236)	(.285)

Note. Values enclosed in parentheses represent mean square errors. S = subjects, n = 96
*p<.05, **p<.01, p<.001

Results show no main effect of within-subject trust differences or any interaction effect of trust difference and group condition, however a significant main between-subject group effect still exists across all dimensions of trust at T2. This indicates that although no significant differences exist *within* trust dimensions, or between T1 and T2, perception of trust dimensions is still affected by the conditional group people were working in at T2, (i.e. being distal or proximal and using abstract or the virtual (VR) interface). Bonferroni post-hoc tests showed group differences in favour of the abstract interface as follows;

- Confidence (emotive trust) – significant difference between proximal-abstract and distal-virtual and between distal-abstract and distal-virtual groups (p<0.05).
- Understanding (cognitive trust) – significant difference between proximal-abstract and distal-virtual and between distal-abstract and distal-virtual (p<0.05)
- Quality of Interaction (behavioural trust) – significant difference between proximal-abstract and distal-virtual and between distal-abstract and distal-virtual (p<0.05).

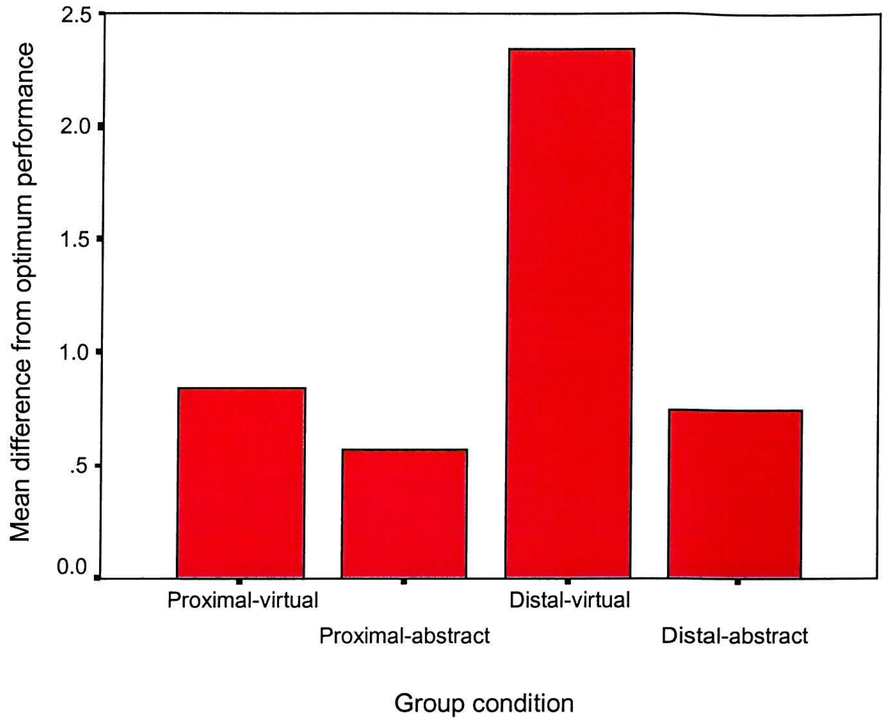

Figure 4.8 Bar chart showing mean percentage error by group condition

4.5.2 Performance Results

Abstract interface groups showed higher scores in the experimental task in terms of, optimum performance, (balancing system), and percentage error against optimum target performance and team costs. A bar chart (see Figure 4.8) gives the mean scores across group for percentage error against the optimum (zero = optimum team performance).

Scores for team costs were extreme and very unevenly distributed and indicated that even teams scoring closest to their target balance, (e.g. proximal-abstract group), overall costs were high. The distal-virtual group was the farthest away from the optimum team cost by over £32,000 over the twenty-four hours. Both abstract groups were closest to the optimum team cost with the proximal-abstract group scoring a mean difference of £12,085. A bar chart (see Figure 4.9) gives the difference of mean costs by conditional groups. Note the logarithmic scale, as cost differences were too large to show exact scores.

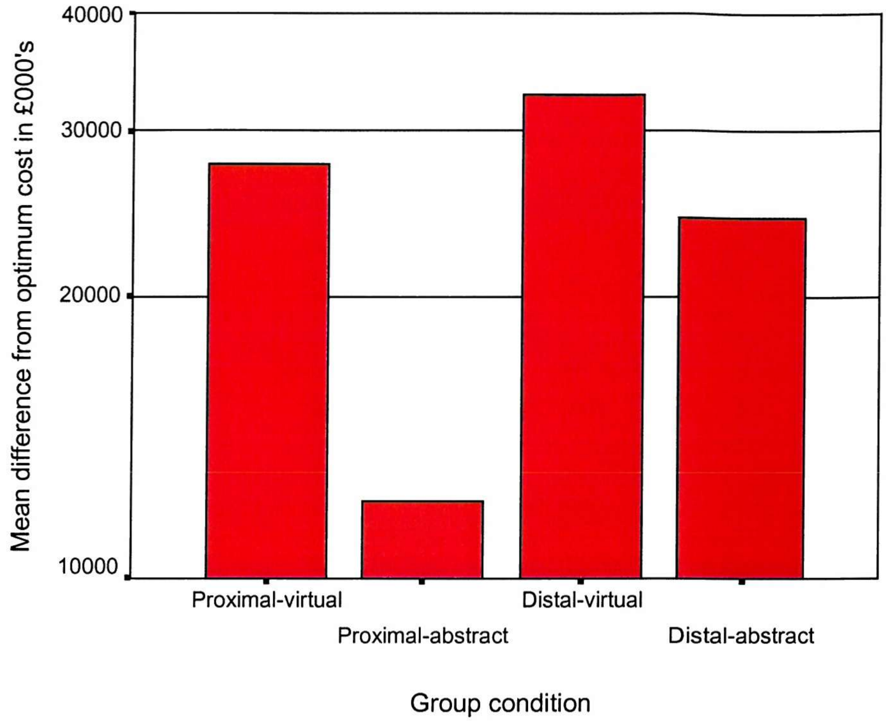

Figure 4.9 Bar chart showing mean difference in costs by group condition

A one-way ANOVA confirmed this and results are set out in Table 4.8

Table 4.8 Analysis of variance for performance measures by conditional group

		F		
Source	df	Optimum Cost	Difference from Optimum	Percentage performance error
		Between-subject		
Group	3	1.563	7.348***	7.184***
S within-Group error	92	(119)	(2.21)	(391)

Note. Values enclosed in parentheses represent mean square errors.
*p<.05, **p<0.01, ***p<0.001

Post-hoc Bonferroni significance tests confirmed inter-group differences. Within optimum performance, the proximal-virtual was significantly closer than distal-virtual group, $p<0.01$. Proximal-abstract group was significantly closer than the distal-virtual group, $p<0.00$. The distal-abstract group was significantly closer than the distal-virtual group, $p<0.01$. These results support hypothesis 4, indicating that those groups perceiving higher trust in the system (abstract conditions), also achieved actual best performance in task. Mean group trust was then plotted against group performance for least percentage error to examine any potential association between these two variables. Scatter plot graphs (see figures Figure 4.10 & Figure 4.11) confirm some association between group percentage error scores and perceived group trust in the systems in both abstract conditions, although no pattern was found in the virtual conditions.

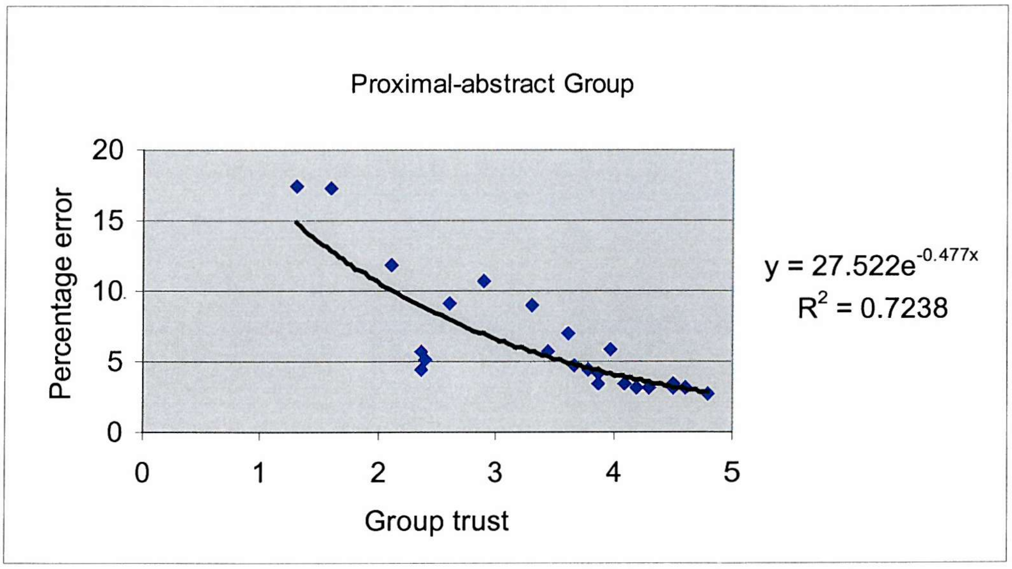

Figure 4.10 Scatter plot showing mean percentage error by group trust for proximal-abstract group.

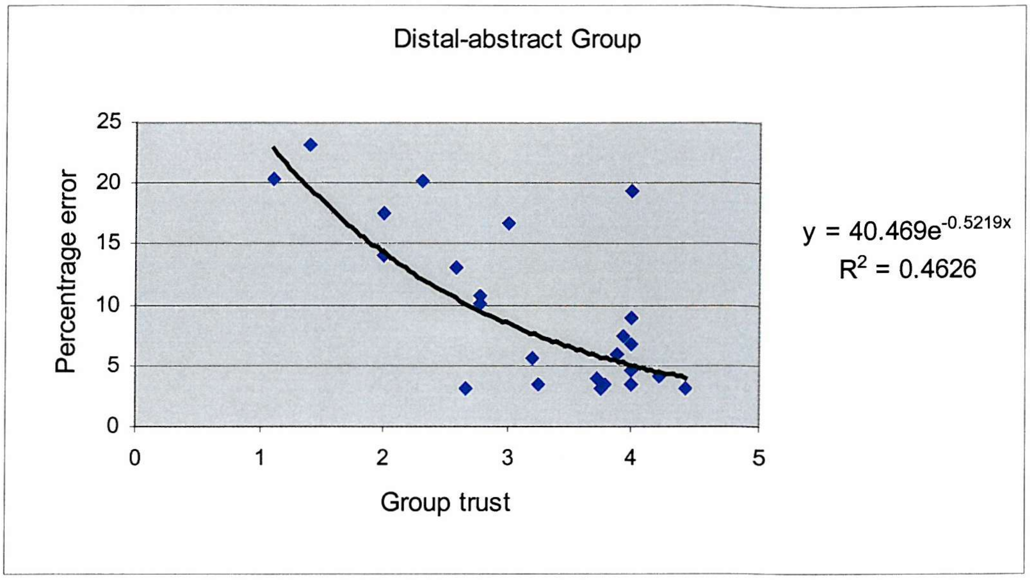

Figure 4.11 Scatter-plot showing mean percentage error by group trust for distal-abstract group.

Data was not normally distributed and extreme outlier data points were extracted in an effort to eliminate some of the variance. An exponential trend line was added to the data points. This resulted in a confirmed negative correlation of rs = -0.72 n=22 for the proximal abstract group and although a lesser coefficient, a negative association of rs = -0.46; n=24 was found between performance and trust in technology in the distal-abstract condition. These results indicate that the abstract interface effected respondents perception of trust, in that as performance scores moved further away from the optimum score, so team members perceived less trust in the technology and vice versa. This was particularly strong in the proximal-abstract group, but was still showing some correlation even when teams were working remotely from each other whilst using the abstract interface. It is also evident that perception of trust and performance are not effected when in the distal condition whilst using the abstract functional display, however both variables were significantly lower when using the virtual interface and being in the distal condition. No association was found when using the virtual-interface (VR) display.

4.5.3 Further Analysis

As previously mentioned, the technological trust questionnaire was developed from a pilot study performed with real control engineers and was based on the three most commonly important constructs of trust found in an HSC domain; *quality of interaction*, *understanding* and *confidence*, (see chapter 3). Further analysis was performed on this data in an attempt to give construct validity to the trust measures in technology. An exploratory factor analysis was performed on the experimental task data, as it was considered that this was where most differences would lie. It was considered that some distinct factors may emerge which would support the results already gained and make the trust instrument more appropriate to use in other engineering domains when investigating trust in technology.

4.5.4 Results of Factor Analysis

An initial correlation matrix provided some clustering among variables of trust. Items 9 and 13 provided very little correlation with other items and therefore were excluded from any further analysis. A further correlation matrix was performed and exploratory factor analysis run using SPSS. Results of the varimax rotated method produced three factors accounting for 66.4% (66.351) of the variance (eigenvalues over 1). Results of the component matrix are given in order of factor loadings in Table 4.9

Table 4.9 Factor loadings for factor analysis of trust variables.

Item No.	Factors 1	2	3
Item 10	.80		
Item 11	.77		
Item 1	.70		
Item 8		.83	
Item 12		.83	
Item 4			.77
Item 6			.76

Items 10, 11 and 1 all related to having confidence and faith in the technology. This first factor was seen to be a generalised trust factor as it accounted for 43% of the variance and included other items at a lower extraction level. No discrimination between the three dimensions of emotive, cognitive or behavioural trust were found, as items 2 & 3 also loaded on to this factor at a lower level, which were initially developed to measure behavioural trust. Items 10,11 and 1 had the highest item to factor loadings however and were all concerned with emotive trust. This factor was therefore considered as a trust factor, emphasising the *confidence* team members had in the technology. Items 8 and 12 correlated highly with each other and were originally selected as measuring behavioural trust or *quality of interaction.* These two items formed an independent factor with item 2 (*the system gave appropriate feedback when required*) also showing some support at a lower extraction level (.52). Factor two was therefore considered to be a valid measure of perceived trust in the technology in terms of *quality of interaction*. The third factor was made up from two items intended to measure cognitive trust. Items 4 & 6 showed high levels of extraction with item 5 (*the interface was appropriate for the task*) loading at a lower level, (.58). It was therefore considered that this factor was a valid measure of *understanding* the technology. Kaiser's (1974, cited in Tabachnick & Fidell, 1996) measure of sampling adequacy showed r= .84, confirming small partial correlations of the matrix; this indicates a good factor analysis, (Tabachnick & Fidell; p. 589, 1996).

Using factor scores for each participant from the three factors, z scores were calculated and used as the dependent variables. A Multivariate Analysis Of Variance (MANOVA) between-subject factor of interface and location for the three trust factors was conducted and results are presented in Table 4.10.

Table 4.10 Multivariate analysis of trust factors by interface and location.

		F		
Source	df	Confidence	Quality of Interaction	Understanding
		Between Subjects		
Location	1	.601	.114	5.827*
Interface	1	1.051	1.428	25.837***
Location X Interface	1	.425	.622	3.632
S within group				
Error	92	(1.007)	(.999)	(.746)

Note. Values enclosed in parentheses represent mean square errors.
*$p<.05$, **$p<.01$, ***$p<.001$

Significant main effects were found for proximal location and abstract interface. This means that respondents had significantly less understanding of the virtual interface especially when they were distal, however when they used the abstract interface they had a stronger understanding of the system irrespective of proximity. A Oneway Analysis Of Variance (ANOVA) with conditional groups as the independent variable and trust factor scores as the dependent variable was conducted to test for group differences. Results are shown in Table 4.11

Table 4.11 Analysis of variance for trust factors by conditional groups

		F		
Source	df	Confidence	Quality of Interaction	Understanding
		between-subjects		
Groups	3	1.063	.573	11.765***
S within-group error	92	(.998)	(1.014)	(.746)

Note. Values enclosed in parentheses represent mean square errors.

*p<.05, **p<.01, ***p<.001.

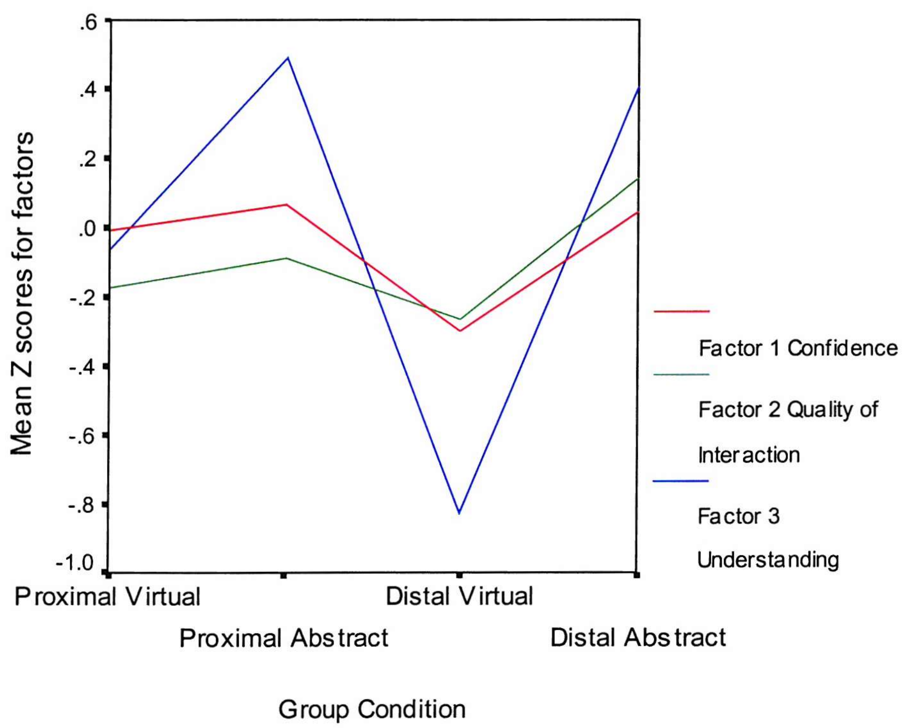

Figure 4.12 Line graph showing factor differences across groups.

Results confirm that significant differences existed between groups in trust factor three, (*understanding*). A line graph (Figure 4.12) gives a graphical summary of the differences between the three factors across conditional groups and it is noted that abstract groups in all three factors are higher. The graph shows that there is generally higher *confidence* than *quality of interaction* in the two proximal groups than the distal groups, however the variance between these two factors is minimal. The diverse variance between groups for factor three (*understanding*) was confirmed by Bonferroni post-hoc tests. Results are presented in Table 4.12.

Table 4.12 Bonferroni Post-hoc tests.

Proximal-virtual vs distal-virtual	$p<0.05$
Proximal-abstract vs distal-virtual	$p<0.001$
Distal-abstract vs distal-virtual	$p<0.001$

4.6 Summary of Results

Results found no main within-group location effects at either Time One (T1) or Time Two (T2). Significant interface effects after training T1 were found however, indicating greater trust in terms of more *confidence* (emotive), *understanding* (cognitive) and better *quality of interaction* (behavioural), of the abstract interface as opposed to the virtual interface. In the experimental task T2, significant differences were also found in favour of the abstract interface for all three categories of trust. Overall no significant differences were found within each trust category from T1 to T2, however significant differences were found *between* conditional groups from T1 to T2. Negative correlations were also found between actual team performance and level of team trust perceived in the technology for both abstract conditions. Further analysis produced a general valid measure of trust distinguished by three factors of *confidence*, *quality of interaction* and *understanding*. Differences across groups for factor three (*understanding*) were found to be significant, indicating that when participants understood how the interface worked and this matched their expectations, then team task performance increased, which in turn increased group trust in the technological system.

4.7 Discussion

In results gained after the training session (T1), trust was greater in the abstract conditions in terms of feelings of confidence (emotive trust) and performance of the system, (behavioural trust). Although no significant differences were found in the cognitive trust dimension between interfaces, this could have been because initially expectation in terms of understanding how the systems would function was the same at the training stage. Although it was a complex task with a fair amount of information to assimilate, one to one intensive training was given with individual support and Bonferroni post-hoc significance tests did not reveal any highly significant differences in trust dimensions between groups after training. Furthermore, no main location effect at T1 suggests that participants were more concerned with understanding how the systems worked, and how to achieve the task, rather than whether they were physically separated from each other. Scores were generally lower in the distal groups however, especially within *confidence quality of interaction* factors, suggesting that being physically co-located was the preferred location. This result could have been due to the fact that teams felt psychologically isolated as they were having to concentrate on a number of variables at once, (e.g. control the system and communicate to each other at the same time through technology). Researchers constantly monitored participant's performance criteria during training, therefore team members were not completely physically isolated without being able to access help. No post-hoc significant conditional group effects across trust dimensions were found at T1 although highest overall perception of trust in technology was greater in the proximal-abstract- group, apart from within the cognitive trust dimension, where the scores were the same in both abstract groups. This confirms that expectations in terms of *understanding* were similar at this stage of the study and it might therefore be assumed that a willingness to trust was present across all groups, albeit a little more in the abstract interface groups. This result indicates that generally prior to the experimental task, participants' expectation of either system was similar but presenting information in a functional way (e.g. the abstract interface) made the task easier to understand or allowed team members to make more sense of the task. This may have facilitated an initial higher overall trust of the system. Due to the nature of the task it may have been beneficial to re-run the training sessions, however, time and cost resources were limited and participants were voluntarily giving up their time.

After performance of the experimental task, T2, although results showed no significant increased trust from T1 between groups, the study found that perceived trust in technology was still greater overall across all three dimensions in the abstract interface condition. Cognitive trust was higher at T2 than T1 (although not significantly) in both abstract conditions, indicating that there was again a greater *understanding* and expectation of this interface. This may have been the result of experience, an increased perceived understanding and knowledge of the system, although other dimensions did not increase over time, indicating that it was more likely to be the type and display of information that increased cognitive trust at T2. This was confirmed by the perceived trust in performance of the system and feelings of confidence in it *within* both abstract conditions. Although not as high as at T1 after training, all results were significantly higher than the virtual group conditions. This effect may also be due to the fact that the abstract interface provided the user with information that directly related to the process goals, giving empirical support to Rasmussen's (1986) theory in an HSC domain. With regard to the differences found between conditional groups, results show that confidence (emotive trust), understanding (cognitive trust) and perceived quality of interaction (behavioural trust) in the distal-virtual group was much lower than in the distal-abstract group. Measures of trust were also higher in the distal-abstract groups than in the proximal-virtual groups for all three dimensions. This is a significant finding when considering the design of new systems especially for remote teams – it seems that abstract functional interfaces are preferable irrespective of proximity, but that physical detailed interfaces debilitate trust and performance of teams who are remote. As Norman, (1990) argues, consideration should be given to how systems comply with human natural abilities. Results here seem to indicate therefore that consideration needs to be given to where humans are located in space as well as their communication and interaction patterns.

As previously mentioned (section 1.2), when teams are separated this can lead to decay in situational awareness, which can cause a break down in collaborative decision making. Team decision making was a crucial element in this study to teams successfully performing the task. Therefore, although members in both interface conditions had access to the same methods of communication when in the distal condition, the amount and type of information presented in the virtual interface appeared to have a detrimental effect. There was certainly more information to extract as the interface presented trend plots and layered information that needed to be accessed; hence creating more workload for the operator. It may have been that this detailed physical information presented in this condition, distracted members from the task, causing a *psychological remoteness* (Wellens, 1989a), that ultimately reduced group performance and their perception of trust in the system. Wellens argues that *type* of information is more important than the amount of information capacity. In research of computer simulation studies for emergency services, Wellens & Ergener (1988) found that when controllers were given more information, teams became distracted, lost situational awareness and performance deteriorated. Conversely in a later study, Wellens, (1993) argued that distributed decision making may be made easier if more abstract representations were presented where information could be quickly accessed on a generic level. This was confirmed in this study, as a fairly strong association was found between team performance scores and team trust in the system particularly in the abstract proximal condition, however, there was also some association found between these two variables in the abstract distal group, albeit at a lower coefficient. The information presented in the abstract interface was certainly more succinct and there was less of it. These results therefore support the view of Rasmussen's LOAH model, (1986),that by facilitating holistic thinking with a more abstract functional display reduces the operator's cognitive workload. In support of Greaney & MacRae (1996), this current study substantiates that abstract interfaces tend to be superior and make the task seem easier, thereby increasing trust and performance.

Results for difference of trust between T1 and T2 did not support hypothesis 2, that trust would be greater over time with experience. Although the reduction in trust from T1 to T2 was not significant, it was enough to suggest that participants felt less confident in the technology at T2 and did not perceive functionality of the system to improve over time. An explanation for this may be that they were not confident enough in their own ability to perform the task which then transferred on to their confidence in the system, (Lee & Moray, 1994). The task was dynamic and based on a real-world process control task. Teams were expected to control for changes in system demands of their local area networks, whilst endeavouring to optimise team costs and team performance. It is also possible that self-confidence in their own ability was lower when they were left to run the task unaided, which could have consequently transferred on to their trust perception in the system; albeit self-reported unconfident respondents were eliminated from the experimental task after training. Everyone that did participate had adequately completed the training task competently and was given the option not to continue in the experiment. It is evident however that in both abstract conditions, understanding of the system (cognitive trust), seemed to increase over time; albeit not significantly. This was inevitably a symptom of the fact that the interface was an integrated display; it gave a holistic view of the whole system enabling a more contextual reference point towards teams achieving their performance targets. Rather than team members having to actively extract separate pieces of information and cognitively assemble them, the polygon presented all the data simultaneously. It was also obvious from participant comments that the perception of the whole task seemed easier when in the abstract condition. As Lee & Moray commented; '*system designers should consider how characteristics of the system affect operators' subjective feelings of trust and self-confidence*, (p. 181, 1994).

Another relevant point from the Repertory Grid study (Ashleigh & Stanton, 2001; chapter 3), was that when behavioural dimensions of trust were perceived to be low in technology, then overall trust was low. In developing important and relevant constructs of trust in technology with control-room engineers, the *quality of Interaction* (e.g. the way in which the system performed) was seen as most important. When this was lacking, it affected other perceived constructs of trust. In other words when the system did not behave in the way that was expected then perceived trust in technology dropped in terms of feelings of *confidence* and *understanding*, which in turn affected future expectancy and a willingness to use the system, (Davis 1993). This supports Zand's argument (1972) of an interdependent spiral of trust being reinforced by behaviour. In this study as his paradigm suggests, although there was a high expectancy from the team-members in the systems at T1, when the technology did not match this, particularly in the virtual (VR) interface, trust was lower. In the abstract condition however, where system functionality matched expectation and display of information was consistent, (Muir & Moray, 1996), then trust in the system was higher as was the team performance. Team performance and trust results can also be applied to the PCT framework. In a goal orientated domain with set goal parameters, (as in the abstract condition), as percentage error reduced so perceived team trust in the technology increased.

Further analysis produced a fairly stable 3 factor matrix, supporting views of engineers in applied HSC domains (Ashleigh & Stanton, 2001, chapter 3). Although cumulative percentage variance was lower than preferred (66.4%), [Kline, (1998) advocates 70 per cent or more], this result supports the view that there are definite contextual constructs of trust that apply in engineering and/or goal-orientated situations that differ from other domains. Furthermore, trusting systems may be a very different concept to trusting people in relationships. From results of this study it is suggested that in order to trust systems, people need to have a firm cognitive understanding of how the interface fits the task and whether it is appropriate in order to achieve their goal. Differences found across factor three (*understanding*), again supports the need for design of interfaces to match human expectation and understanding rather than simply being task performance focussed.

4.8 Conclusions

Results demonstrate that when information is continuous and visual feedback from the system matches the task-fit for the operator, trust in the system is better. Reduction in cognitive workload through consistency of machine behaviour and simplified display information enabled higher success in meeting the target performance and higher perception of trust in technology, both of which were independent of location. A fairly strong association existed between perceived trust and performance, particularly in the proximal-abstract group. This indicates that further work needs to be done in order to test reliability of results. Further research would require larger samples, preferably of experienced control-operators and with longer training times. More appropriately, by undertaking research in real industrial domains would enable trials of abstract interfaces to establish methodologies for encoding the cognitive load into the display system. If prospective research can reiterate the findings of this study, it may have profound implications on the designs of systems as well as the recruitment and training processes adopted in HSC domains.

5 Chapter Five: Trust in teams using a simulated control task.

5.1 Introduction

Using the same simulated control task as in the study presented in chapter four, this study measured team trust by conditional group (interface by location) both after training at time one (T1) and after the experimental task at time two (T2). Details of the experiment including participants, experimental task and procedure are all identical to those fully discussed in chapter four (sections 4.31-4.38) The taxonomy of trust used in this study was developed from an applied control room study (see chapter 3). These same constructs of trust that were elicited from interviewing engineers in an energy distribution control room were used as a guide to develop an instrument to measure trust within and between teams for this simulated control room study.

5.2 Method

5.2.1 Materials

A self-reporting questionnaire was developed based on the thirteen core constructs that resulted from the Repertory Grid study in chapter three. From this detailed interview technique it was clear that certain constructs applied to certain areas of how trust was conceptualised within an engineering domain. The three common areas of trust seen as most *important* in that applied study were *quality of Interaction, understanding* and *confidence*. Thirteen core constructs however were extracted and categorised under three dimensional headings. Emotive trust (a *feeling* of trust within the team), cognitive trust (a knowledge and *understanding* of trust within the team) and behavioural trust, (an *experience* of trust within the team in terms of response or behaviour). Although these dimensions did not to match exactly onto the Cummings

& Bromiley (1996) model, it was considered this categorisation might prove useful in developing a taxonomy of trust based on the PCT model. These three main dimensions were therefore kept and formed the basis of developing the current measures. Under the emotive dimension core constructs included; *confidence, respect, commitment and teamwork*, (a feeling of team spirit). Sixteen items made up the measure of emotive trust. Items were worded such as to imply a feeling (e.g. *I feel confident with other members of my team*). Under the cognitive dimension, constructs included *understanding, ability*, and *expectation* and were made up of twelve items. These items were worded in such a way so as to imply cognition (e.g. *I think members of my team share the same knowledge level*). The behavioural dimension included *honesty, reliability, proactivity* (e.g. taking initiative, being motivated towards the task), *performance*, *communication* and *quality of interaction*, (quality and quantity of feedback). Within the behavioural dimension, there were twenty-four items that were worded to imply action or behaviour (e.g. team members gave each other appropriate feedback). This could have been identified as a responsive communication, support or actually sharing in the task; all of which can be categorised as action. Under each construct heading, four items were developed. At least one negatively worded item was included in order to test for participant response reliability. A final category was developed made up of four items that included the word *trust.* This was designed as a separate and final measure of trust to test whether by actually including the word *trust* would make any difference to how the concept was perceived by participants.

The questionnaire was piloted on staff and students of the psychology department, University of Southampton, in order to check for any language and understanding anomalies. It was then passed to the Business Engineering Group of the University; a group of engineers and academics who research construction and engineering projects in applied domains. It was considered that such a cohort would pick up any inappropriateness of items and ensure that the items had face and content validity. It was commented that the number of items should have been standardised within each category, albeit no other anomalies were noted. The author considered that any core constructs should not be omitted at this stage, as this taxonomy had been reliably developed from a contextually appropriate study, (chapter 3). The items were randomly mixed and all construct headings were omitted so that participant responses were not biased and did not form a pattern of response. (see Appendix 8 for questionnaire development and Appendix 9 for the questionnaire that participants received).

5.2.2 Initial Analysis of Data

All items were reinstated under the construct headings and scored according to the 1-5 Likert scale, where 1 = not/none at all and 5 = extremely high. All negative items were reverse scored and total participant scores for all four areas (North , South, East and West) were amalgamated into one database and divided according to group condition (proximal- virtual, proximal-abstract, distal-virtual or distal abstract). Mean scores were calculated for each construct heading and categorised under the three trust dimensions; (emotive, cognitive and behavioural). Distribution and variance were explored taking trust constructs as dependent variables (DV) by group condition as the independent variable, (IV). Tabachnick & Fidell (1996) confirm that central limit theorem accounts for skewed distribution in grouped data and that analysis of variance statistics is robust to non-normality providing there are no outliers, (p.72, 1996). Distribution of the data was examined under each construct heading and extreme outliers (+/-three standard deviations away from the mean) extracted in order to adjust for non-normality effects. A Multivariate Analysis of Variance (MANOVA) tested between subject factors of location and interface separately for each three trust dimensions, using trust constructs as dependent variables. Oneway Analysis Of Variance (ANOVA) was then performed at T1 and T2 with one between-group variable of conditional group (proximal-virtual, proximal-abstract, distal-virtual, and distal-abstract) and trust scores for each trust category as dependent variables. Differences between trust dimensions at T1 and T2 were compared using repeated measures MANOVA, with trust scores for each category at T1 and T2 as dependent variables and group condition as the independent variable.

5.3 Results

A table of means and standard deviations are presented for each trust dimension under separate trust constructs for after training (T1) and after the experimental task (T2). The results are split into the three trust dimensions for easier understanding

5.3.1 Emotive Dimension

Table 5.1 and Table 5.2 show means and standard deviations at T1 and T2 for the emotive dimension respectively. Outliers were extracted if they fell outside the 25th or 75th percentile of distribution. Within the training condition for the emotive category case 31 was extracted from the *respect* construct, case numbers 69 and 70 were extracted from the *commitment* construct and cases 3 and 90 were extracted from the *teamwork* construct. At T2 adjustment for non-normality included discarding cases 21 and 22 as outliers in the construct of *respect*, case 19 in the construct of *commitment* and case 89 in the construct of *teamwork*.

Table 5.1 Means and standard deviations of trust by group condition for emotive constructs at T1.

	Time One							
Trust Construct	Confidence		Respect		Commitment		Teamwork	
Group Condition	M	SD	M	SD	M	SD	M	SD
Proximal-virtual	3.3	(.31)	3.3	(.39)	3.5	(.34)	3.4a	(.29)
Proximal-abstract	3.5	(.29)	3.2[a]	(.24)	3.4	(.35)	3.4	.25)
Distal-virtual	3.0	(.40)	3.1	(.48)	3.3[b]	(.33)	3.1	.30)
Distal-abstract	3.4	(.39)	3.3	(.41)	3.6	(.32)	3.4[a]	.30)

Note: - [a] n = 23 for each group [b] n = 22 for each group

Table 5.2 Means and standard deviations of trust by group condition for emotive constructs at T2.

	Time Two							
Trust Construct	Confidence		Respect		Commitment		Teamwork	
Group Condition	M	SD	M	SD	M	SD	M	SD
Proximal-virtual	3.5	(.35)	3.5[a]	(.28)	3.4[b]	(.33)	3.6	(37)
Proximal-abstract	3.6	(.25)	3.5	(.33)	3.4	(.29)	3.7	(.22)
Distal-virtual	3.3	(.29)	3.4	(.27)	3.4	(.37)	3.3	(.42)
Distal-abstract	3.6	(.33)	3.6	(.28)	3.5	(.32)	3.6[b]	(.29)

Note:- [a] n = 22, [b] n = 23

An analysis of variance for emotive trust constructs after training (T1) by location and interface showed that there was a main interface effect at TO, F = 4.05; (84), p<0.01 but no location effect, F =1.172, (84), ns. An interaction effect was also shown at T1, F= 3.270 (84); p<0.05. Table 5.3 presents results of Multivariate Analysis Of Variance (MANOVA) between-subject factors of interface and location for constructs of the emotive trust category as dependent variables.

Table 5.3 Multivariate analysis of variance for emotive constructs by interface and location at T1.

		F			
		Time One			
Source	df	Confidence	Respect	Commitment	Teamwork
		Between-subjects			
Location	1	1.249	.231	.008	3.794

Interface	1	14.757***	2.658	1.616	4.531*
Location x Interface		2.969	3.148	6.924*	10.326**
S within-group error	87	(.117)	(.130)	(.118)	(.008)

Note:- (values enclosed in parentheses represent mean square errors)
*p<.05, **p<.01, ***p<.001

Results indicate that within the emotive trust dimension more *confidence* was experienced within teams when participants were in the abstract condition and that *teamwork* (e.g. team spirit) was felt significantly less in the virtual condition. Although no location main effect was found, within this trust dimension, an interaction effect showed that perception of *commitment* was higher in the virtual condition when teams were proximal, but when in the abstract condition, teams seemed more committed when separated (distal). A similar interaction effect was noted within the *teamwork* construct. Results of oneway ANOVA within trust dimensions between the four conditional groups (proximal-virtual, proximal-abstract, distal-virtual, distal abstract for T1 are presented in Table 5.4.

Table 5.4 Analysis of variance for emotive trust by the group conditions at T1.

		F Time One			
Source	df	Confidence	Respect	Commitment	Teamwork
		between-subjects			
Between Groups	3	6.214**	1.529	2.899*	6.431**
S within Group error	92	(.126)	(.155)	(.114)	(.008)

Note: (Values enclosed in parentheses represent mean square errors).

*p<0.05, **p<0.01, ***p<0.001

Post-hoc Bonferroni tests to examine significant main effects revealed that significantly less *confidence* was felt between team members in the distal-virtual than the distal-abstract condition, confirming a significant interface effect. Within the *commitment* construct, significantly more was felt in the distal-abstract condition than the distal-virtual condition. *Teamwork* was significantly stronger for teams in the abstract condition than the virtual condition when teams were distal and slight significance was evident between the proximal-abstract and distal-virtual groups, confirming the interaction effects.

Analysis of variance for emotive trust constructs after the experimental time (T2) showed that there was a slight location effect (at the 10% level) F = 2.203, (85); Table 5.5 presents results of MANOVA for between-subject factors of interface and location and the four constructs of the emotive trust dimension as dependent variables after the experimental task (T2).

Table 5.5 Multivariate analysis of variance for emotive constructs by interface and location at T2.

		F Time Two			
Source	df	Confidence	Respect	Commitment	Teamwork
		Between-subjects			
Location	1	2.108	.289	.161	6.238*
Interface	1	8.547**	[illegible]	.309	11.434**
Location x Interface	1	.222	1.614	.189	1.455
S within-group error	88	(.008)	(.008)	(.105)	(.110)

Note: (values enclosed in parentheses represent mean square errors.

*p<.05, **p<.01, ***p<.001

There was a main effect of location within the *teamwork* construct. Significant interface effects within teams were noted for the constructs *confidence*, *respect* and *teamwork*. No interaction effects were present at T2.

150

As this study was concerned with team results, a oneway ANOVA was performed using emotive trust constructs as dependent variables and the four conditional groups (proximal-virtual, proximal-abstract, distal-virtual, distal abstract) as the between factors. Results are presented in Table 5.6.

Table 5.6 Analysis of variance for emotive trust dimension by the four group conditions at T2.

		F			
Source	df	Confidence	Respect	Commitment	Teamwork
		between-subjects			
Groups	3	3.661*	2.624*	.117	6.705***
S within					
Group error	92	(.009)	(.008)	(.107)	(.113)

Note: Values enclosed in parentheses represent mean square errors.

*p<0.05, **p<0.01, ***p<0.001.

Post-hoc Bonferroni tests to examine the significant main effects indicated in Table 5.6 revealed that more *confidence* was felt within the proximal-abstract than the distal-virtual group. There was also a difference between distal groups, with scores favouring the abstract condition. *Respect* scored slightly more in the abstract condition when teams were distal. There were no differences between groups perceived in *commitment* towards the team. Within the *teamwork* construct, differences were noted between the groups using the virtual interface, confirming the slight proximal location effect. Overall, significantly greater *teamwork* was felt in the proximal-abstract group than distal-virtual, but when teams worked in the abstract condition, proximity had no effect, *teamwork* was still strong. These results indicate that even when working remotely (distal), teams felt more *confident* and had more of a sense of team spirit when using the abstract interface; an effect that will be discussed later in this chapter.

5.3.2 Cognitive Dimension

Constructs making up the cognitive dimension are *understand*, *ability* and *expectation*. The data was evenly distributed with the exception of an extreme outlier in the construct of *understand*, where one participant had responded with the same number for each item whichever way the question was worded. Case number 85 was therefore extracted from the data. Scores for cognitive constructs after the experimental task were generally lower at T2 with the exception of the distal-abstract group where the mean score was higher for *understanding*, however two extreme outliers were extracted from this data set as they failed to fall into the 25 to 75 percent range. Case numbers 74, 79 were removed which fell into the distal-abstract group. A table of means for these constructs at both T1 and T2 are presented in Table 5.7 and Table 5.8 respectively.

Table 5.7 Means and standard deviations of trust by group condition for cognitive constructs at T1.

	Time One					
Trust Construct	Understanding		Ability		Expectation	
Group Condition	M	SD	M	SD	M	SD

Proximal-virtual	3.4	(.56)	3.1	(.37)	3.1	(.37)
Proximal-abstract	3.5	(.47)	3.0	(.30)	3.0	(.29)
Distal-virtual	3.4	(.58)	3.0	(.40)	3.1	(.52)
Distal-abstract	3.4[a]	(.25)	3.1	(.44)	3.1	(.31)

Note: [a] n = 23

Table 5.8 Means and standard deviations of trust by group condition for cognitive constructs at T2.

	Time Two					
Trust Construct	Understanding		Ability		Expectation	
Group Condition	M	SD	M	SD	M	SD
Proximal-virtual	3.3	(.67)	3.3	(.42)	3.1	(.37)
Proximal-abstract	3.4	(.43)	3.0	(.41)	3.0	(.28)
Distal-virtual	3.3	(.50)	3.1	(.35)	3.1	(.40)
Distal-abstract	3.6[a]	(.28)	3.1	(.42)	2.8	(.38)

Note: [a] n = 21

A MANOVA for the cognitive trust constructs at T1 by location and interface showed that there were no main effects for either location $F = .229; (89)$, ns, or interface $F = .251; (89)$, ns, respectively. No interaction effects were found, $F = .567; (89)$, ns. These results confirm that team members had an equal perception of trust in terms of *understanding* each other, team *ability* or *expectation* of others before carrying out the experimental task at T1.

A MANOVA for cognitive trust constructs after the experimental task (T2) showed no main location effect of teams F = .486, (87); ns, however an interface effect was present, F = 3.269, (87); ($p<0.05$) in favour of the abstract interface. An interaction effect was also present, F = 3.311, (87); ($p<0.05$). Table 5.9 presents results of a MANOVA for between-subject factors of interface and location and the three constructs making up the cognitive dimension of trust as dependent variables after the experimental task (T2).

Table 5.9 Multivariate analysis of variance for cognitive constructs by interface and location at T2.

		F		
		Time Two		
Source	df	Understanding	Ability	Expectation
		Between-subjects		
Location	1	.838	.037	.549
Interface	1	4.069*	3.900	4.438*
Location x Interface	1	2.006	1.790	2.880
S within-group error	89	(.251)	(.155)	(.135)

Note: (values enclosed in parentheses represent mean square errors.
*p<.05, **p<.01, ***p<.001.

Results show that an interface effect exists within the *understanding* construct. There were no perceived differences in perceived *ability* of team members across interface, however the interaction effect was confirmed as *expectation* of team members, but only at the ten percent level, ($p<0.091$). To test where conditional group differences lay, a oneway ANOVA measured team scores of each trust construct within the cognitive dimension at T2. Results are presented in Table 5.10.

Table 5.10 Analysis of variance for cognitive trust dimension by the four group conditions at T2.

		F		
Source	df	Understanding	Ability	Expectation
		between-subjects		
Groups	3	2.176	1.827	2.801*
S within				
Group error	92	(.251)	(.163)	(.132)

Note: Values enclosed in parentheses represent mean square errors.
*p<0.05, **p<0.01, ***p<0.001.

Although analysis showed a slight difference between groups in the construct of *understanding* (p=<0.10), this was eliminated when a post hoc Bonferroni test was applied, although from the means the distal-abstract group showed the highest, with the distal-virtual groups presenting the lowest score in *understanding*. Differences within the *expectation* construct lay between distal-abstract and distal-virtual groups, with the latter having significantly higher *expectation* of team members.

5.3.3 Behavioural Dimension

Table 5.11 and Table 5.12 show the means and standard deviations at T1 and T2 respectively for the behavioural dimension of trust. No extreme outliers were noted within the training condition for this dimension. At T2 adjustment for non-normality included discarding case numbers 45 and 46 from the *reliability* construct. Case number 69 from the *proactivity* construct; cases 25, 29 and 31 were eliminated from the *performance* construct and cases 57 and 60 from the *quality of interaction* construct. An analysis of variance for behavioural trust constructs after training (T1) by location and interface showed a main effect for location $F = 2.272$; (87), $p<0.05$ and interface $F = 2.743$; (87), $p<0.01$ respectively. No interaction effects were noted. Table 5.13 presents the results of MANOVA between-subject factors of interface and location for behavioural trust constructs as dependent variables.

Table 5.11 Means and standard deviations of trust by group condition for behavioural constructs at T1.

	Time One											
Trust Construct	Honesty		Reliable		Proactivity		Performance		Communication		Q of Interaction	
Group Condition	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Proximal-virtual	3.6	(.32)	3.1	(.44)	3.8	(.52)	3.0	(.55)	3.3	(.48)	3.5	(.42)
Proximal-abstract	3.5	(.29)	3.3	(.38)	3.6	(.37)	3.3	(.29)	3.3	(.35)	3.5	(.33)
Distal-virtual	3.5	(.34)	3.0	(.52)	3.2	(.54)	3.1	(.33)	3.2	(.48)	3.3	(.38)
Distal-abstract	3.5	(.30)	3.4	(.33)	3.6	(.46)	3.3	(.32)	3.3	(.33)	3.3	(.30)

Note: - n= 24 in each group.

Table 5.12 Means and standard deviations of trust by group condition for behavioural constructs at T2.

	Time Two											
Trust Construct	Honesty		Reliable		Proactivity		Performance		Communication		Q of Interaction	
Group Condition	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Proximal-virtual	3.7	(.39)	3.6	(.40)	3.9	(.42)	3.1	(.52)	3.6	(.32)	3.7	(.36)
Proximal-abstract	3.7	(.35)	3.5[b]	(.20)	3.9	(.32)	3.5[c]	(.26)	3.6	(.32)	3.8	(.33)
Distal-virtual	3.6	(.29)	3.4	(.34)	3.4[a]	(.53)	2.9	(.58)	3.4	(.39)	3.3[b]	(.21)
Distal-abstract	3.8	(.43)	3.5	(.30)	3.9	(.50)	3.3	(.49)	3.7	(.25)	3.8	(.38)

Note: - n[a] = 23 per group n[b] = 22 per group n[c] = 21 per group.

Table 5.13 Multivariate analysis of variance for behavioural constructs by interface and location at T1.

				F Time One			
Source	df	Honesty	Reliable	Proactivity	Performance	Comms.	Quality of Interaction
		Between-subjects					
Location1		2.581	0.32	7.282**	.154	. 733	7.976**
Interface	1	.414	10.732**	2.041	7.561**	. 374	.020
Location x Interface	1	.931	1.025	5.177*	.069	. 240	.000
S within-Group error	92	(.101)	(.184)	(.233)	(.152)	(.174)	(.131)

Note: (values enclosed in parentheses represent mean square errors). *p<.05, **p<.01.

Table 5.14 Analysis of variance for the behavioural trust dimension by group conditions at T1.

		F					
		Time One					
Source	df	Honesty	Reliable	Proactivity	Performance	Communication	Quality of Interaction
		Between-subjects					
Groups	3	1.311	3.930*	4.833**	2.595	.449	2.665
S within							
Group error	92	(.101)	(.184)	(.233)	(.152)	(.174)	(.131)

Note: (Values enclosed in parentheses represent mean square errors).

*$p<0.05$, **$p<0.01$, ***$p<0.001$

Location effects were found in the *proactivity* and *quality of interaction* constructs at T1 in favour of the proximal location, meaning teams were proactively motivated towards the task and had a better quality of interaction when proximally located. Interface effects were found within the *reliability* and *performance* constructs; team members perceived that they were more reliable and performed significantly better when in the abstract conditions.

Results of oneway ANOVA measuring between team differences for each trust category are presented in Table 5.14. Results indicate that significant differences were found within the *reliability* and *proactivity* constructs respectively. Post-hoc Bonferroni tests confirmed that significantly less *reliability* was perceived between members of the distal-virtual team than the distal-abstract team. Within the *proactivity* construct, team members were significantly activated in being proactive towards the task when proximally located when in the virtual condition, confirming the location effect, however when using the abstract condition, location had no effect. There was also more *proactivity* perceived in the proximal-abstract team than the distal-virtual team, confirming the interaction effect.

Mean scores for behavioural constructs at T2 were used as dependent variables to test for differences for the two factors of interface and location. The MANOVA showed no main effect of location at T2, (F = 1.362; (79), ns, however there was a main interface effect, F = 4.274; (79), p <0.01 in favour of the abstract interface. An interaction effect, F = 2.258; (79), p <0.05 was also found. Subsequent oneway ANOVA's for each trust factor were conducted and are presented in Table 5.15.

Table 5.15 Summary of analysis of variance for behavioural constructs by interface and location at T2.

		F Time Two					
Source	df	Honesty	Reliable	Proactivity	Performance	Communication.	Quality of Interaction
		Between-subjects					
Location	1	.321	2.202	5.278*	2.373	.447	2.364
Interface	1	.489	.095	3.540	8.565**	4.031*	14.306***
Location x Interface	1	2.465	1.156	4.411*	.000	4.126*	10.850**
S within-Group error	84	(.135)	(.106)	(.219)	(.241)	(.107	(.106)

Note: (values enclosed in parentheses represent mean square errors).*p<.05, **p<.01, ***p<.001

Significant differences were found between interfaces for constructs of *performance*, *communication* and *quality of interaction* in favour of the abstract interface. Interaction effects were noted for the constructs of *proactivity*, *communication* and *quality of interaction*. A oneway ANOVA was used to test the construct differences between conditional groups. Results are presented in Table 5.16. The interaction effect for *proactivity* shows that this increased significantly in the virtual interface condition, only when teams were proximal. Proximity made no difference however when using the abstract interfaces, as both teams were proactive. *Communication* and *quality of interaction* were found to be higher in the abstract condition when teams were distal, but teams found the opposite effect when in the virtual condition, as both only increased when teams were proximal. Post-hoc Bonferroni tests confirmed that the distal-virtual group was significantly less *proactive* than the other three groups. Perceived *performance* was higher in both abstract groups, but greater in the proximal-abstract group and significantly different from the distal-virtual group. These results concur with actual measured performance as the proximal-abstract group achieved highest task performance and the distal-virtual group the lowest, (see section 4.5.2). Within the *communication* construct, significant differences lay between the distal-abstract and distal-virtual group, in favour of the abstract condition. Finally, *quality of interaction* was significantly lower in the distal-virtual group than the other three.

Table 5.16 Analysis of variance for the behavioural constructs by group conditions at T2.

		F Time Two					
Source	df	Honesty	Reliable	Proactivity	Performance	Communication	Q of Interaction
		between-subjects					
Between							
Groups	1	1.038	1.182	5.090**	3.796*	3.524*	10.065***
S within							
Group error	92	(.135)	(.103)	(.204)	(.233)	(.106)	(.108)

Note: (Values enclosed in parentheses represent mean square errors).

*p<0.05, **p<0.01, ***p<0.001

5.3.4 Differences between T1 & T2

A repeated measures MANOVA was conducted to test differences between T1 & T2 for perceived trust in teams (DV) and conditional groups (IV). Each trust dimension (emotive, cognitive & behavioural) will be assessed separately.

5.3.4.1 Emotive Dimension (T1/T2)

Results are presented in Table 5.17 for the emotive constructs between T1 and T2.

Table 5.17 Multivariate analysis of variance for emotive trust constructs by group.

		F			
Trust		Confidence	Respect	Commitment	Teamwork
Source	df				
		Between subjects			
Group	3	8.702***	2.813*	1.312	.781***
S within					
Group error	92	(.125)	(.157)	(.151)	(.125)
		Within-subjects			
Trust	1	20.952***	38.675***	.065	37.164***
Trust x					
Group	3	.487	.154	1.886	.880
S within					
Group error	92	(.009)	(.008)	(.007)	(.006)

Note:- (values in parentheses represent mean square errors) *p<0.05, **p<0.01, ***p<0.001.

Results from Table 5.17 show a main group effect in the constructs of *confidence*, *respect* and *teamwork*, indicating that differences exist between some conditional groups. The main effects observed within the trust constructs indicate that differences exist within the same construct between T1 and T2. No interaction effect was noted from these results. Further repeated measures MANOVA tests were carried out using the three significant constructs (DV), by each conditional group (IV), measuring the difference between T1 and T2. Results are presented in Table 5.18.

Table 5.18 Multivariate analysis of variance for groups by emotional trust at T1 and T2.

Trust			F	
		Confidence	Respect	Teamwork
Source	df	between-subjects		
Group		within-subjects		
Proximal-virtual	1	5.693*	8.489**	7.004*
S within Group error	23	(.009)	(.006)	(.007)
Proximal-abstract	1	5.435*	9.345**	31.319***
S within Group error	23	(.006)	(.008)	(.004)
Distal-virtual	1	8.603**	8.050**	3.903
S within Group error	23	(.119)	(.127)	(.009)
Distal-abstract	1	2.353	16.390***	8.298**
S within Group error	23	(.108)	(.005)	(.005)

Note: - (values in parentheses represent mean square errors).
*$p<0.05$, **$p<0.01$, ***$p<0.001$.

Results show that within the proximal-virtual group all three constructs were seen to increase from T1 to T2. Results were similar in the proximal-abstract group, with a particular increase in the perception of *teamwork* (a sense of team spirit) at T2. Within the distal-virtual group, *confidence* and *respect* increased slightly over time, but not *teamwork*. Within the distal-abstract group there was a very significant increase in *respect* within this team and slightly less increase in *teamwork*, although *confidence* does not seem to have grown over time within this group.

5.3.4.2 Cognitive Dimension (T1/T2)

Differences between T1 and T2 within-group for the cognitive dimension were measured using a repeated measure MANOVA with group condition as the independent variable (IV) and the three constructs of trust as dependent variables (DV). Results for this analysis are presented in Table 5.19.

Table 5.19 Multivariate analysis of variance for cognitive constructs by group.

		F		
Trust Source	df	Understand	Ability	Expectation
		Between subjects		
Group	3	.723	1.201	1.130
S within Group error	92	(.352)	(.227)	(.187)
		Within-subjects		
Trust	1	.523	3.261	.346
Trust x Group	3	2.437	1.876	2.421
S within Group error	92	(.140)	(.008)	(.009)

Note:- (values in parentheses represent mean square errors)

$*p<0.05$, $**p<0.01$, $***p<0.001$.

Results confirm that no were differences within the cognitive constructs between T1 or T2 in any of the conditional groups.

5.3.4.3 Behavioural Dimension (T1/T2)

Six trust constructs made up the behavioural dimension of trust these were; *honesty, reliability, proactivity, performance, communication and quality of interaction.* A repeated measure MANOVA was used to test differences between T1 and T2 within each construct by conditional group. Results for the six trust constructs by conditional group are presented in Table 5.20.

Table 5.20 Multivariate analysis of variance for behavioural trust constructs by group.

		F					
Trust		Honesty	Reliability	Proactivity	Performance	Communications	Quality of Interaction
Source	df	Between subjects					
Group	3	1.43	2.170	6.991**	4.442**	2.209	5.281**
S within Group error	92	(.143)	(.164)	(.265)	(.244)	(.169)	(.165)
		Within-subjects					
Trust	1	13.539***	23.070***	12.791**	1.032	47.906 ***	40.076***
Trust x Group	3	.662	3.399*	.164	1.245	.710	6.997***
S within Group error	92	(.009)	(.125)	(.156)	(.140)	(.169)	(.004)

Note: - (values in parentheses represent mean square errors) *p<0.05, **p<0.01, ***p<0.001.

Results indicate that there is a main group effect for behavioural constructs of *proactivity, performance*, and *quality of interaction*. This indicates that differences exist between T1 and T2 for some conditional groups. The main effect of within-subject trust constructs for *honesty*, *reliability*, *proactivity*, *communications* and *quality of interaction* indicates a difference between T1 and T2 within these constructs. An interaction effect between trust and group was also noted within the constructs of *reliability* and *quality of interaction*. In order to test which groups showed differences between T1 and T2 in these constructs, a further repeated measures MANOVA was carried out for each conditional group by the behavioural constructs. Results are presented in Table 5.21.

Table 5.21 Multivariate analysis of variance for behavioural constructs at T1 & T2.

		F					
Trust		Honesty	Reliability	Proactivity	Performance	Communications	Quality of Interaction
Source	df	Between subjects					
Group		Within-subjects					
Proximal-virtual	1	2.091	16.177**	2.629	.460	7.742	4.056
S within Group error	23	(.006)	(.142)	(.127)	(.323)	(.162)	(.104)
Proximal-abstract	1	2.686	2.166	4.924*	10.105**	10.249**	15.333**
S within Group error	23	(.124)	(.009)	(.140)	(.004)	(.130)	(.004)
Distal-virtual	1	1.527	9.409**	1.228	.571	8.316**	.248
S within Group error	23	(.103)	(.179)	(.249)	(.146)	(.008)	(.005)
Distal-abstract	1	10.159**	.258	6.732*	.000	32.200***	37.375***
S within Group-error	23	(.008)	(.008)	(.111)	(.128)	(.007)	(.009)

Note:- (values in parentheses represent mean square errors)
*$p<0.05$, **$p<0.01$, ***$p<0.001$.

Results of Table 5.21 indicate that within the proximal-virtual group *reliability* increased from T1 to T2. In the proximal-abstract group, teams perceived they were more *proactive* towards achieving the task and their perceived *performance* was higher. *Communication* and the *quality of interaction* between team members also improved from T1 to T2. Within the distal-virtual group, team members perceived that *reliability* and *communication* to improve over time. When in the distal-abstract group, team members perceived a greater increase in *honesty, proactivity* and highly increased *communication* and *quality of interaction.*

5.3.5 Results of Trust category

Mean scores for the general trust category (items 53-56) were calculated for both T1 and T2 and used to compare differences across conditional groups. Examining the data led to extracting four extreme outliers at T1 (case numbers, 13, 49, 64, and 70) however scores were more evenly distributed at T2. Means and standard deviations are presented in Table 5.22.

Table 5.22 Means and standard deviations for trust category at T1 and T2.

Trust Construct	Time One		Time Two	
Group Condition	M	SD	M	SD
Proximal-virtual	3.1[a]	(.25)	3.1	(.16)
Proximal-abstract	3.0	(.34)	3.1	(.20)
Distal-virtual	3.1[b]	(.22)	2.6	(.35)
Distal-abstract	3.1	(.29)	3.0	(.24)

Note: [a] n = 23, [b] n = 21

Scores for T1 and T2 for this category revolved around the mean (moderate amount), however scores in the distal-virtual group seemed to dip at T2. A Oneway ANOVA tested for differences between the four conditional groups. No between-group differences were found at T1 $F = .646$; (88), ns, however a significant group difference was found at T2, $F = 14.796$; (92), $p=<0.001$. Post-hoc tests confirmed that the distal-virtual group perceived significantly less trust than the other three groups at T2.

5.3.6 Summary of Results

An overall interface effect in favour of the abstract condition was found, with some differences in location effect depending upon trust construct.

Within the emotive dimension participants felt more *confident* with each other, and had a greater sense of team spirit (*teamwork*) when working in the abstract condition. Greater *confidence* was felt when teams were proximal, however within the *teamwork* construct location made no difference to participants, as there was still a high sense of team spirit in both abstract conditions. More *respect* was also felt when teams were remote (distal) from each other. Overall there was an increase in *confidence* and *respect* in the virtual conditions over time, but only when proximal. *Teamwork* also increased over time apart from in the distal-virtual condition. After the experiment (T2), when using the abstract interface teams felt a higher sense of *teamwork* and particularly more *respect* when distal; although *confidence* did not significantly increase over time in this condition, possibly because these teams already felt confident enough.

Within the cognitive dimension, no differences were found within *understanding*, *ability* or *expectation* at T1 for either location or interface. This points to teams having an equal cognitive perception of what to expect of other team-members and perhaps the same understanding of the task at T1. A slight interface effect at T2 towards the abstract condition indicated a better *understanding* of the task in this group, however when distal, abstract interface groups had less sense of fulfilling each others *expectation*, whereas the distal-virtual group expressed more *expectation*. This is an interesting result as ultimately the abstract interface groups achieved higher team performance in the task. There were no increased effects of the cognitive dimension over time.

Within the behavioural dimension, a location effect in favour of being proximal was noticed within *proactivity* and *quality of interaction* at T1. *Reliability* and *performance* was perceived to be better in the abstract conditions, confirming a significant interface effect. An interaction effect for *proactivity* meant that team members were motivated and took initiative towards achieving the task in the virtual condition only when they worked together (proximal), however location made no difference to the abstract groups; both were *proactive*. At T2 no location effect was present however a significant interface effect for the abstract condition was found for *performance*, *communication* and *quality of interaction*. Interaction effects were also evident at T2 for *proactivity*, *communication* and *quality of interaction*, the latter two were both higher in the abstract condition when teams were distal, but being in the virtual condition had the opposite effect. Differences between T1 and T2 included an increase in *reliability* in the proximal-virtual group, higher *proactivity*, *performance* *communication* and *quality of interaction* in both abstract conditions, with the perception of *honesty* increasing when teams were distal. Although there was an increase in *reliability* and *communication* in the distal-virtual condition, no other increases were found.

Scores for the category of trust both at T1 and T2 were moderate, although a significant decrease in overall trust was perceived in the distal-virtual group at T2, implying the perception of trust diminished in this group when performing the experiment.

5.3.7 Further analysis

The original questionnaire was developed from thirteen core constructs elicited from engineers in 'real world' domains, (see chapter 3). In order to test for construct validity of these constructs a factor analysis was conducted. Respondent scores were taken from after the experiment (TT) as it was considered these to be a more appropriate perception of team members 'true' perception in relation to trust. As the ratio of respondent to item was lower than 2:1 if all of the items were amalgamated (n=53), analysis was carried out under each trust dimension. The emotive dimension (confidence, respect, commitment and teamwork) included sixteen items with 96 respondents (a ratio of 6:1). A correlation matrix indicated that some variables had little or no correlation with others; and a cut off of .40 or less was therefore set as the lowest level for inclusion of a variable in interpretation of a factor. Out of the original sixteen items, nine remained that had a correlation of .40 or greater and a varimax rotation principal component analysis was chosen. Communality values were fairly high .60 to .85 and three independent factors were extracted accounting for 68% of the cumulative variance (67.664). Results of the component matrix are given in order of factor loading in Table 5.23 and in order of importance. Kaiser's (1974) measure of sampling adequacy reached $\underline{r}$ = .80, which meant factors were confirmed. Tabachnick & Fidell, (1996) advocate $\underline{r}$ is required to reach .60 or over for factors to be confirmed.

The first factor was interpreted as *team commitment*. Items 9 and 12 were items that were originally included in the core construct *commitment* in the questionnaire and had high independent factor loadings of over .80. A further item (item 5) that loaded at a lower extraction (.72) was originally included in the *respect* construct, but fitted into the interpretation of this factor.

Table 5.23 Factor loadings for factor analysis of emotive dimensions.

	Factors		
Item No.	1	2	3
Item 9	.85		
Item10	.83		
Item 5	.72		
Item 4		.83	
Item 1		.77	
Item 3			.92
Item 14			.67

The second factor was interpreted as a *team confidence* factor with two independent items (4 & 1) loading on to it from the original core construct of *confidence*. The third factor was composed of item 3, originally intended to measure *confidence* and item 14 (from the *teamwork* core construct). Item 3 *('members of my team depended upon each other'*) showed a dependency factor and the lower extracted item 14 *('I feel that our team shared a common goal'*) seemed to be a sub-factor of this. Factor three was therefore interpreted as *team interdependency*.

Using factor scores for responses from the three factors, z scores were calculated and used as the dependent variables in a oneway ANOVA by conditional groups as the independent variable. Results are shown in Table 5.24.

Table 5.24 Analysis of variance for emotive trust factors by conditional groups.

		F		
Source	df	Team Commitment	Team Confidence	Team Interdependency
Group	3	.626	2.269	11.180***
S within				
Group error	92	(1.01)	(.961)	(.757)

Note:- (values enclosed in parentheses represent mean square errors).
*p<0.05, **p<0.01, ***p<0.001.

Results show that no group differences were found for factors one or two, although observing the mean z scores, the abstract conditions achieved better scores in both factors irrespective of location. These differences can be seen from the line graph in Figure 5.1. Factor three however showed a very significant group difference. Bonferroni post-hoc tests confirmed that the distal-virtual group showed the least *team interdependency*, with the variance being at least 3 standard deviations away from scores for the abstract conditions; both abstract groups scored significantly higher in *team interdependency*.

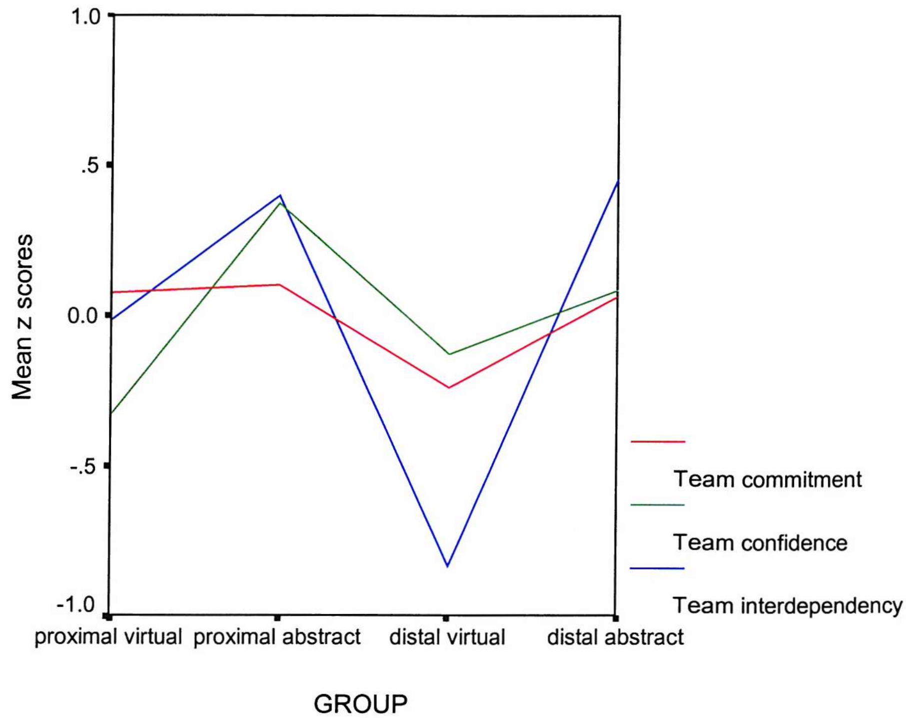

Figure 5.1 Line graph showing inter-group differences of emotive trust factors.

The cognitive dimension was originally developed from twelve items including core constructs of *understanding*, *ability* and *expectancy*. Taking participant scores for each of these constructs after the experiment (T2) gave a respondent ratio of 8:1 in order to perform reduction analysis. An initial correlation matrix resulted in extracting those items that resulted in low (less than .40) or no correlation. Six items were extracted and a varimax rotation factor analysis was carried out on the remaining six. Results are presented in Table 5.25.

Table 5.25 Factor loadings for factor analysis of cognitive dimension.

	Factors	
Item No.	1	2
Item 27	.81	
Item 24	.72	
Item 20	.68	
Item 18		.88
Item 21		.75

The component matrix produced two independent factors, accounting for 64% (64.3) of the cumulative variance. Confirmation of fit with low partial correlations reached adequate levels with Kaiser's measuring sampling adequacy of r = .70. The first factor included a highly correlated item to factor coefficient (item 27), that came under the original *expectation* core construct, (*I think our team fulfilled each other's expectations*). Item 24 however also loaded onto this factor at .72, but was originally intended to measure team *ability*, (*I think our team worked effectively with one another*). Item 20 with a lower extraction of .68 expressed the perception of sharing the same experience, this factor was therefore interpreted as a perception of effecting *team expectation*. The second factor included items 18 (*I think the members of our team shared the same knowledge level*) and 21, (*I think there was a lack of competency within the team*) the latter being a negative statement (which was reverse scored). The items included a perception of sharing the same knowledge and team competency, which was interpreted as sharing the same *team mental-model*. To test any inter-group differences, z scores were calculated from the factor scores and a oneway ANOVA carried out. Results are presented in. Table 5.26.

Table 5.26 Analysis of variance for cognitive trust factors by conditional groups.

Source	df	F Team expectation	Team mental model
Group	3	.647	3.899*
S within			
Group error	92	(1.01)	(.916)

Note:- (values enclosed in parentheses represent mean square errors) *$p<0.05$

Results found no differences between groups for factor one '*effective team expectation*'. A significant between group difference for factor two (*team mental model)* was found at the 5% level. Bonferroni post hoc tests revealed that both abstract groups shared a better *team mental model* than virtual groups and there was a significant difference between the distal-virtual and distal-abstract group. A line graph shows the inter-group differences in Figure 5.2.

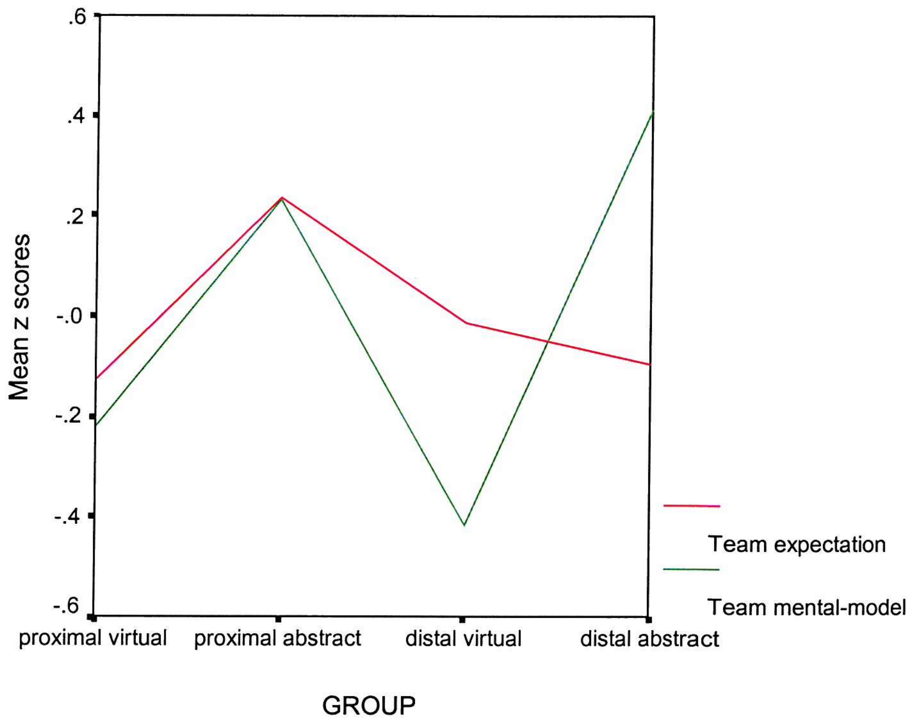

Figure 5.2 Line chart showing inter-group differences of cognitive factors.

The behavioural dimension was originally made up from 24 items across six core constructs; *honesty*, *reliability*, *proactivity*, *performance*, *communication* and *quality of interaction*. An initial correlation matrix revealed some variable correlations, with a maximum of .70. Variables were extracted if they were less than .40. A total of 11 out of 24 variables were left in the final analysis, making an item response ratio of 8:1. A principle component analysis using varimax rotation factor analysis was carried out which resulted in four independent factors being extracted explaining 73% (73.2) of the variance. Results of the component matrix are presented in Table 5.27. Keiser's (1974) measure of sampling adequacy reached $\underline{r} = .76$.

Table 5.27 Factor loadings for factor analysis of behavioural dimension.

	Factors			
Item No.	1	2	3	4
Item 43	.87			
Item 44	.87			
Item 42	.84			
Item 38		.85		
Item 37		.78		
Item 49		.71		
Item 47			.85	
Item 51			.76	
Item 48			.71	
Item 35				.84
Item 34				.78

The first factor was interpreted as *team performance*; all three items that loaded on to this factor originally came from the *performance* core construct, they were highly correlated and unique from other items. This could be considered a valid measure of the team meeting targets. The second factor included items 38 and 37 which were both aiming to measure motivation and initiative taken towards achieving the task. Item 49 (*other members of my team were very approachable*), was aiming to measure a *quality of interaction*, between team members (i.e. were they able to say what they really thought); an element that may have affected their responsiveness to the task and each other. As these items all loaded onto the same factor at a high correlation and were independent of others, it was considered that this factor should be interpreted as *team proactivity* as it included both task and team motivators. Factor three was made up from two items (items 47 & 48) from the original *communication* construct and item 51 came from the *quality of interaction* construct. This factor was interpreted as *team interaction* as it included responses such as appropriate feedback, frequency of feedback and quality of interaction. The final factor included two items originally developed for the *reliability* core construct. Item 35 (*I relied on other members of my team during the task*), was expressing a reliance on other members of the team and item 34 (*members of our team acted reliably towards each other*) was a perception of taking reliable action in the team. It was therefore considered appropriate to interpret this factor as *team reliability.* In order to test group differences, zscores were calculated from the original factor scores for each group and oneway ANOVA's carried out, results of which are presented in Table 5.28.

Table 5.28 Analysis of variance for behavioural trust factors by conditional groups.

		F			
Source	df	Team Performance	Team Proactivity	Team Interaction	Team Reliability
Group	3	1.635	6.690***	4.260**	.345
S within					
Group error	92	(.980)	(.848)	(.907)	(1.02)

Note:- (values enclosed in parentheses represent mean square errors)
*p<0.05, **p<0.01, ***p<0.001

From examining the line graph in Figure 5.3 the same pattern of distribution is apparent, with the lowest scores generally being for the distal-virtual condition. Although there were no significant differences found within the *team performance* factor, the proximal-abstract group perceived that their performance was the best and this was confirmed from the actual scores of task performance (see section 4.5.2). The factor of *team reliability*, although confirmed as a strong factor in the analysis, showed no differences between groups at all; albeit both abstract groups still perceived themselves to be the more reliable team. Results show that there were significant differences between groups for *team proactivity* and *team interaction.* Significant differences were examined using Bonferroni post-hoc tests. Within the *team proactivity* factor, the distal-virtual group was significantly lower than the other three groups and the distal-abstract team had the highest score in this factor. Within the *team interaction* factor, the significant differences lay between the proximal-abstract and distal-virtual groups ($p<0.05$). There was also a slight difference (at the 10% level) between the distal-virtual and distal-abstract groups, confirming the strong interface effect.

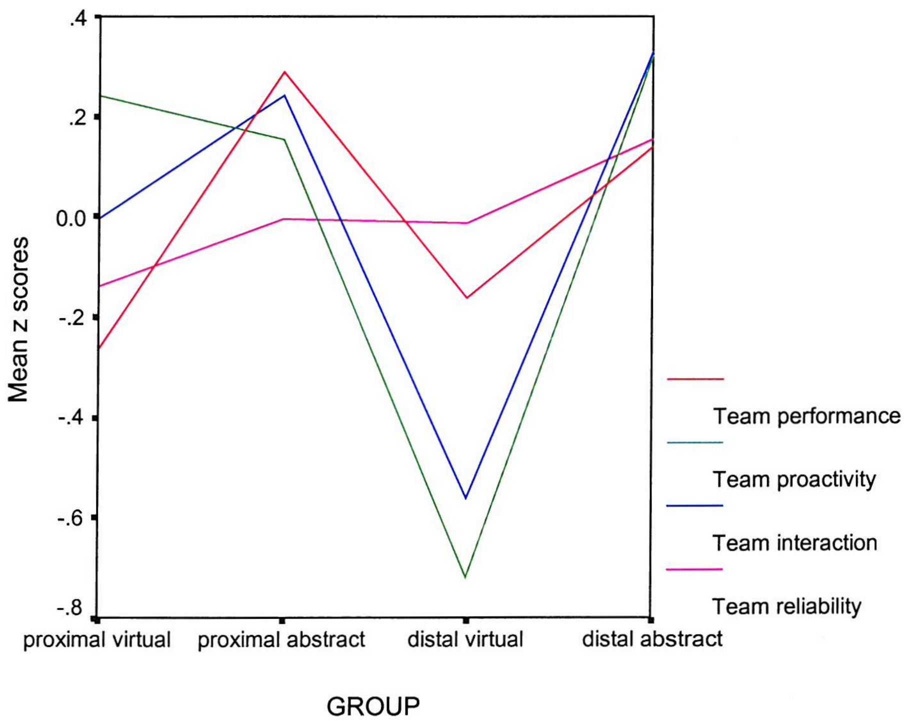

Figure 5.3 Line graph showing inter-group differences of behavioural factors

5.4 Discussion

From this simulated control task, reduction analysis of the initial thirteen core constructs for measuring intra and inter team trust produced a nine independent factor matrix including; *team commitment, confidence, interdependency, expectation, team* *mental-model, performance, proactivity, interaction* and *reliability*. Four factors were found to be prominent in conceptualising trust in teams in this context and significant differences between the four conditional groups were found within *team interdependency*, *team mental-model*, *team proactivity* and *interaction*. Two key results are confirmed from this study, the first is that processing information from a functional top-down approach promotes more trust in teams even when they are remote from each other. Conversely, when controlling the process using a physical functional interface as in the virtual (VR) system, perceived team trust and target performance reduced, particularly in the distal condition. Therefore in order for process control teams to achieve optimum performance target, to trust both the system and each other, the system necessarily has to enhance rather than hinder the whole process of control. The second point is that dependent upon the *type* of information and *how* it is presented affects people's perception of control trust within and between teams and consequently team performance. It is argued therefore that future interface design should not only concentrate on developing human-centred technology, but also endeavour to design the human perception *into* the equation in an attempt to embrace the whole socio-technological relationship, (Hettenhaus, 1992). In support of Vicente's (1997) ecological approach towards HSC, emphasis in design needs to consider system behaviour that matches operator understanding and focus on developing interfaces that are compatible with human cognition, action and perception. From results in chapter four, quality of system performance feedback either enabled or disabled operators to successfully perform the task. It gave them a better *understanding* and therefore promoted higher confidence in the system. Similarly, quantity and *quality of interaction* and *proactivity* also affected perceived trust within and between teams, enabling a better perception of a shared knowledge (*team mental model*) and greater team *interdependency* and *confidence* in each other.

Throughout this study both team perception of trust and actual performance increased when participants were supplied with goal orientated functional information. When using the abstract interface, teams shared a greater sense of *commitment* and *confidence* with each other and significantly more *team interdependency* in terms of team spirit, dependency and in a shared common goal. Abstract conditional groups also had a better *team mental model*; sharing the same knowledge base and a high perception of team competency; a factor that was lacking in the two conditions using the virtual (VR) interface. Furthermore, this perception did not deteriorate in the abstract condition when teams were remote from each other (distal), but were as good as when teams worked together (proximal); the *shared mental-model* factor was in fact greater when teams were in the distal-abstract condition. An explanation for this result could be that by using the abstract interface, participants had a better holistic view of the whole process control task. This enabled them to more easily identify the means-end relationship both with the task and other team members (*team interaction*), therefore giving them a shared knowledge base and mental picture of what the whole process entailed. Because the abstract interface presented end-of day goal orientated information, team members did not have to use extra attentional resources on understanding the different parameters and relating them to performing the task. The interface therefore helped to optimise their processing capacity, so allowing them to concentrate on interacting and working together to achieve best performance even though remote. Coury and Terranova (1991) supported the 'team mental-model' which they maintain is made up of the aggregate of team decision making, characteristics of the user interface and aspects of communication *outside* of the displays. Team members in the present study communicated *outside* of the system interface through continuous video visual communication and audible links through a telephone system. Certainly these three elements were present. Consequently with a strong *team mental-model* the perception of control amongst members was identical and it was therefore easier to reduce any error and deal with disturbing influences in order to achieve best performance.

Team proactivity was significantly less in the distal-virtual conditional group than the other three groups, however in the abstract condition, proximity made no difference to teams. This factor was interpreted as team members being *proactive* in taking the initiative towards achieving the task. It is possible that the task became much simpler and easier to understand using the abstract interface and therefore increased participants' motivation levels in wanting to achieve best performance. Perception of *team interaction* included maintaining a high frequency of interaction and appropriate feedback with each other. This was significantly better in the abstract condition, even when distal. *Team interaction* included collaborative decision making, as team members had to come to joint decisions about how to control the system (e.g. by what amount to change the flow of gas, or how much gas to store and when and how much it was going to cost the team etc.). Earlier research by Andriessen & Van der Velden (1995), into distributed teams and collaborative decision making emphasised that *suitability* and *type* of media (in this case interface) fit for the task is critical in affecting team decision making. This was supported by results in this study as in both abstract conditions better team trust was confirmed by the objective task results.

In considering profitable 'virtual' organisations, Davidow & Malone (1992), maintained that goals are met by dividing the work between various entities based on the perceived competencies of the other actors (organisations) involved. Quick and easy access of information that reduces cognitive workload is considered a core competency of a virtual team or organisation, enabling greater flexibility and expectation of fast responses, so enhancing interdependence and increasing performance. Davidow & Malone point out that an 'expectation of responsiveness' is essential to the success of any virtual corporation, but highlights the need for trust between partners separated in space in order to facilitate that responsiveness. Handy (1995) reiterates that a violation or lack of trust between parties forces the imposition of control mechanisms that impede flexible and quick responses. Therefore for any virtual team to succeed, members must be able to trust each other's competency and responsiveness, again emphasising a greater 'need to respond' (Hawisher & Morgan, 1993) in the absence of social cues. This was definitely present in the current study where the distal-abstract group was the most proactive.

The results of this study show that the benefits of using the abstract interface enabled team members to quickly extract high level information that was necessary to meet the demands of the task. This interface encouraged 'management-through awareness' (Zwaga & Hoonhout, 1994) rather than 'operation-by exception', (Dallimonti, 1972), which in turn enhanced participants perception of control, performance and trust in each other. Hollnagel, (1993) argued that strategic planned control is more favourable than a reactive fire fighting approach. This was confirmed in an applied study of control rooms (Stanton & Ashleigh, 2000) where heterarchical structured teams were involved in more planning activities than hierarchical teams. Centralisation and flexible organisational boundaries are forcing more remote team working in control rooms which means that trust will only be fostered by developing systems that guarantee planned awareness and extraction strategies. In order to develop trust in automation, as well as fostering and maintaining operators' team trust, *quality of interaction* between the human-human-system-human entity is vital. One important reason is to help increase situational awareness and effect team decision making, (Wellens, 1989). An important factor in optimising situational awareness amongst team members is through sharing of information and the level and quality of communication (Salas et al, 1995). Lee & Moray (1994) also stressed that control operators need information and feedback regarding the system as well as their own performance in order to trust and use systems appropriately; this all equates to *quality of interaction*, which supports results of this study. In this context *quality of interaction* represented appropriateness and frequency of feedback between team members, which when high would have helped to promote team situational awareness and the *team mental-model*, which in turn reinforces *team interdependence* and *confidence*. These indices make up valid trust taxonomy for HSC domains that in the next chapter will be embedded into a working model of trust using the framework of Perceptual Control Theory.

6 Chapter Six: Working Model Of Trust

6.1 Introduction

The aim of this chapter is to implement results of this research into a practical model of trust for use in HSC domains through adapting the Perceptual Control Theory (PCT). Initially a summary of the results from the four studies will be discussed in relation to previous research within HSC domains. From the trust factors identified throughout this research a typology of trust will be developed.

6.2 Summary of Chapter Two

To validate the OTI model (Cummings & Bromiley 1996) in an HSC domain, data across two energy distribution companies was analysed. Five independent factors resulted and although similar to the original model, from engineers' viewpoint the emphases were different. There was no distinction found between underlying emotive and cognitive dimensions and factors that were interpreted the same as the OTI model included different items, indicating context differences. Trust indicators from an HSC domain were perceived as; *not taking advantage of others*; *keeping commitments*; *honesty*; *openness* (i.e. sharing information) and *not monitoring compliance.* Greater variance for the first four factors was found between team roles in company A, which may be explained by team structure as teams in this company were strictly hierarchical. Results confirmed a team role difference for engineering roles across the first four factors between company 'A' and 'B', the former being generally higher but with greater variance. Company 'B's team structure being more heterarchical involved operating integrated team roles, encouraging better role interdependency. This may account for the reduced variance of trust scores across roles. Some intra-team engineers however, were physically remote from each other, which may be the reason for Company 'B' engineers perceiving lower trust in the first four factors; all engineers in Company 'A' were co-located. Stammers & Hallam, (1985) maintain that teams should be co-ordinated or structured according to the organisation and task complexity in order to maximise performance; the same may be true in order to maximise trust and an issue that HSC companies could possibly address. Team structure and role integration may also influence how control room personnel *monitor* each other. Results of this factor between roles for both companies, confirmed that higher status roles were more likely to *monitor compliance*. Although some tendency towards such behaviour is expected (i.e. from managers), over-monitoring could lead to a general mistrust and lack of self-confidence or self-esteem in lesser status control-room operators, causing a wider gap in inter-team trust. Rosen (1989) argued that feeling intimidated or exploited impedes trust, which could result from over emphasis of monitoring others or taking advantage of other team members. Hierarchical team structure (company 'A'), may also have accounted for the greater within-company differences found *between* control teams. Generally engineering teams working in the control room perceived managerial and support teams who were located separately as *taking advantage*, less *committed* and less *honest* with control engineers. This was not the case in company 'B' where teams were structured heterarchically; a preferable structure for improved communication processes, planning strategies and social interaction, (Stanton & Ashleigh 2000). This would suggest that team structure is an important variable in control rooms. Porter (1997) emphasises that trust is fostered through flexibility and responsiveness to the changing environment, not by management controls and formal structures. Team structure, role integration and team location all represent part of the wider team environment which could cause unwanted disturbances and is therefore an element that cannot be ignored and should not be always be taken as a given. Team performance is often dependent on team structure and as shown throughout this research trust is also related to performance. Therefore optimising team structures to produce maximum performance could also be of benefit in enhancing team trust.

6.3 Summary of Chapter Three

This study applied the Repertory Grid method to contextualise engineers' conception of trust. *Quality of interaction*, *understanding* and *confidence* were most important constructs across the three groups of contextual elements (intra-team inter-team and technology). Core constructs were categorised into emotive, cognitive and behavioural, (see section 3.3). Differences were found between what control engineers perceived to be important in trusting team members and systems and the level of trust scored, particularly in behavioural constructs. This result is considered to have affected engineers' emotive feelings of trust as expectations of trust were not met. A considerable in-group effect was found in emotive constructs within teams and significantly less for inter-team members. A lower perception of cognitive trust in the inter-team group was likely to be due to a lack of information sharing between shift teams, (i.e. behavioural constructs). This was confirmed by significant reduction in *quality of information* from the inter-team group. This equates to lack of feedback towards those who were outside the immediate shift-team, which was also confirmed by less *communication* between team members. The distinction between intra and inter-team trust in domains where the common goal relies on total interdependency could lead to reduced efficiency and potentially other generic problems. Throughout the 24-hour control process many other personnel are critical to the input of the future prediction of demands, support and maintenance of plant as well as communicating strategy changes to the immediate shift-team who are on duty. It is therefore considered imperative that co-ordination and collectivism is fostered between team members if the shared goal is to be effectively achieved. Teams who display high trust are more likely to enjoy improved collaborative decision making and so ultimately enhance performance, irrespective of ability, (Illgen et al 1995). Trust is therefore a unique team-skill and should be made more prominent by emphasising its impetus on team performance. Levels of trust could be increased across teams and throughout the wider socio-technical system by introducing contextual training programmes. Implementing these in applied domains would be no different from current training of other team skills.

6.4 Summary of Chapter Four

A questionnaire was developed using the constructs identified in chapter three to measure trust in technology in a controlled simulated process-control task using team location and system interface as independent factors. Principal component analysis confirmed a three-factor matrix. Results showed that the level of trust was higher when cognitive workload was lowered (as in the abstract interface) and when participants perceived that the system matched their expectation. This points to engineers having greater trust in systems when the perception of their control matches that of the technology. Trust levels were lower in the virtual interface (VR) but particularly when teams were physically remote. Within the abstract condition, irrespective of location, respondents perceived significantly more *understanding*; (they thought the interface was appropriate and helped them to make sense of the task).

Teams using the abstract interface also felt more *confident* in the system and perceived it to be more consistent and predictable in its behaviour in terms of *quality of interaction*. This could be compared favourably with Muir & Moray's (1996) *predictability* factor as it relates to consistent functioning of machine behaviour from task to task, however it was trust in relation to *understanding* the system-task-fit that was most significant in respondents trusting the technology in this study. This interface was considered more human-centred (Normal 1990). Information was less difficult to extract than from the virtual system (VR) and participants also had an emergent means-end visual output in terms of the polygon display that changed according to how far away participants were from meeting the goal. This supports research into military air crew display systems where the emphasis was to find an optimum configuration between mental processing of humans and continuous feedback from the system in order to decrease workload and increase potential trust, (Dru-Dury, Farrell & Taylor, 2001). From a PCT perspective their research considered that a direct voice input (DVI) from the pilot which imposes less workload, configured with visual output (VO) from the system, incurred shorter settling time in the PCT error feedback loop. This was considered the '*optimum configuration as it decreased workload while maintaining a reasonable level of trust*', (p.102, 2001). Similarly, the abstract interface in this study decreased settling time (comparator with reference signal). Participants had to integrate and emit less information with fewer actions, decreasing the mental workload therefore giving them a greater perception of control. This had an effect on team performance as an inverse relationship was confirmed between increased trust in systems and reduced percentage error (e.g. increased team performance). It cannot be over emphasised particularly in HSC domains that the technical system can have as much bearing on *team* performance as the social system;

a tenet confirmed throughout this research. One cannot examine extracted parts of the system in isolation, (Hettenhaus 1992). Similarly it is argued that trust cannot be measured 'out of context'.

6.5 Summary of Chapter Five

The thirteen core constructs elicited from control engineers (see section 3.2) were developed into a questionnaire to measure respondent's intra and inter-team trust in the simulated control task. Results confirmed an increase in the emotive dimension over time for teams using both interfaces, however they were more favourable in the abstract interface groups. Specifically, emotive trust only increased over time for proximal teams using the virtual (VR) interface, however a significant increase in the same constructs was noted for teams in the abstract condition, irrespective of location. No significant differences were found within the cognitive constructs for teams over time, although the distal-abstract team portrayed a slight increase in *understanding*. Within behavioural constructs, *reliability* was perceived as increasing between team members over time for both virtual (VR) interface teams, this was a surprising result considering respondents did not perceive trust in the virtual interface in terms of its behaviour in the technological study. In fact over time, perceived *quality of interaction* and *performance* in the virtual interface dropped, although not significantly. Teams using the abstract interface however perceived significantly more trust in the system. This obviously increased the team trust over time in terms of *proactivity*, *communication* and *quality of interaction*, in spite of location of the team members. Team members within the distal-abstract condition also considered they were more *honest* with each other from T1 to T2. It is considered that because members felt more comfortable with each other using the abstract interface and had a better understanding of the system, that less anxiety would have been felt, probably less social loafing and self interest, therefore they could be more open with each other. The construct *proactivity* can easily be likened to *action or intended action* that Jarvenpaa & Leidner (1998) found between respondents in their study across global virtual teams. Consistent and predictable interactions, even when conveying negative information to other members, reported higher trust and were more successful in achieving their goal, (see section 1.4.3). The results of this study support previous work from different domains where the emphasis is on the *need to respond* (Hawisher & Morgan 1993).

This behaviour appears to be even more critical when team members are remote. This study was not concerned with type of trust, but people's perception of trust within a controlled experiment. Past research studying teams with no working history and a finite life-span have labelled the development of trust as a *temporary, swift* trust (Meyerson et al, (1996) or *abstract* trust (Nandakumar & Baskerville (2001). These authors claim that the *abstract trust* developed through organisational norms values and routines. In the current study it is considered that trust developed between members sharing a common goal, which was reinforced by the compatibility between the human-system interface making the task more understandable, creating higher confidence and team orientation. This provoked a greater willingness and a need to respond, between team members especially when remote. Nandakumar & Baskervill noted that when communicating through Video Teleconferencing Personal Computers (VTPC) without personal interaction emotive elements of trust were greatly reduced. In fact trust diminished and workers felt isolated and anxious when they perceived any unreliability of the VTCP systems. Likewise in the current simulated control study team trust was not so apparent in teams who were using the virtual interface, especially when remote. In fact team *performance* dropped in the distal-virtual condition over time and no improvement was found in other behavioural constructs of trust. This supports the results of the technology study (chapter four), where generally participants did not have an *understanding* of the task using the virtual interface, therefore did not trust it. In remote HSC shift teams control-engineers do not always have access to social interaction and are not easily able to physically leave the control room during a shift. This is specifically why the *quality* of the human-system and human-human interface is vital in influencing the whole *quality of interaction* with the environment, in whatever context, but particularly so within human supervisory control rooms. This only reiterates the need for systems to be compatible with human mental models and to include system quality of control and display of information that will ultimately influence the wider socio-technical process.

Principal component analysis confirmed a stable nine-factor trust matrix across emotive cognitive and behavioural dimensions. Abstract interface teams perceived higher trust across all three dimensions and it is suggested that an integrated mental model of *understanding* the system as well as sharing a *team mental model* of the task and technology was the key to enhancing trust and consequently increased team performance. Furthermore it is argued that the increase in *quality of interaction* and a propensity towards *proactivity* between team members is not so dependent upon how members are located, but whether the information system configuration concurs with the system-task-fit. Only then can control-operators share a *team mental model*, increase their perception of control and achieve their mutual goal.

6.6 Taxonomy of Trust

From the factors confirmed in this research it is possible to build a taxonomy of trust indices; these are presented in Table 6.1.

Table 6.1 Taxonomy of contextual trust indices.

Study Domains	**Emotive Factors**	**Cognitive Factors**	**Behavioural Factors**
HSC Applied Teams (OTI)	Keeping commitments		Not taking advantage
			Honesty
			Sharing Information
			Not monitoring compliance
Technological Systems	Confidence	Understanding	Quality of Interaction
Teams	Confidence	Expectation	Performance
	Commitment	Mental model	Proactivity
	Interdependency		Interaction
			Reliability

From these identified factors one can develop a practical and systematic way of measuring trust and team performance per se, using the basic principles of the PCT. Within the tenets of the PCT model it is accepted that '*all behaviour results from the control of perception*', (Powers, 1973). Behaviour is therefore considered purposeful and explicit and can be designed to counteract disturbances from the environment, thus minimising the error between perception and its desired reference point (goal). Consequently perception of 'control' or a stable system is achieved by varying action. It requires comparing our current state (perceptual signal) with our perceived goal state (reference signal) which then generates a perceptual error signal. This error feeds into the output function that transforms the error into corrective behaviours. These behaviours then influence the physical environment known as the Complex

Environmental Variable (CEV). From the CEV stimuli are generated that are transformed back into our perception via the Perceptual Input Function (PIF). This then closes the feedback loop, and the cycle begins again. The PCT framework does not have capacity to objectively measure individual internal perceptual variables. If focus is centred on the *desired* perception of the system (whether human or technological) however, it may then be possible to identify where potential errors may lie and so design behaviours to effectively minimise those errors. Researchers have used this same model to develop human-machine interfaces, (Farrell & Semprie, 1997), where the interface focused on the human perception of it. They found that when a human-machine interface is designed from the users perception it is more likely that potential perceptual errors between the two will be identified, and lead to the design of corrective behavioural strategies.

Consequently, the same idea could be applied to an operating team in a control room. The identified factors from this research are variables relating to trust that were initially developed from the 'users' point of view, (see chapter 3). In terms of measuring levels of performance and trust in either systems or team members, these elements were the most significant in the perception of 'simulated control-room operators' It has also been established that certain behavioural factors are more important than others in these working domains. For example if *quality of interaction* between the human-system or the human-human interface is appropriate and adequate, then the perception of *confidence*, *interdependency* and a shared *team mental model* will be reinforced, thus improving both actual and perceived performance.

6.6.1 Perceptual Control Framework

In order to explain how these factors could be used to foster and monitor improvement of trust within control-rooms, the individual elements of the PCT model have been expanded and specified to suit the appropriate elements of an HSC domain. Each node within the PCT framework is described and explained in relation to an energy distribution process control task.

Reference Signal – In HSC terms the reference signal is the perception or mental model of how the individual or teams' interaction will effect the CEV or physical environment.

Input Function – This refers to the perceptual state of the individual in terms of current quality of their human performance and their perception of the quality of the supporting technological systems. These are identified as the way they currently feel and think about the whole socio-technical system.

Comparator – This compares the quality of their perceived current state (input function) to their desired state (reference signal) and generates an error signal.

Output Function – This is the error evaluation stage that involves the mental analysis of the error signal breaking it down into its prime components.

Feedback – In Powers' (1973) original PCT model there is no allowance made for physical feedback between detecting the error signal, and the output quantity in terms of corrective action necessary. This is because in an individual's perception cognitive and emotive processing is a mental activity that is then converted into what and how much corrective action to take. In a team situation however, it is necessary to convert the feedback from the various individuals perception into a team perception in order to create a continuous visual analysis of the necessary corrective action/s. No effective corrective action in the physical domain can be instigated however, without openness and honesty between individuals of the team. Therefore the analysis of error has to be collective and transparent so that people are motivated and perceive it as a positive contribution to improving the overall teams and/or system performance. It is considered that individual's perception of error in either system or team interaction needs to be analysed into a team format to assess the required level of change in each factor. This will then enable the necessary error corrective action into the CEV. Furthermore this analysis needs to take into account the team's location as more or less corrective action may be necessary depending on when teams are distal or proximal. The resolution from the feedback phase then generates the actual output quantity.

Output Quantity – This node relates to the behaviour or action is taken, how much and in what area.

Complex Environmental Variable (CEV) – The CEV in an HSC example is the actual control room including the operating team and the interacting technical systems that aim to achieve the target goal which is to '*safely securely and efficiently distribute the energy around the system*'. The standards and operating parameters set by the company needed to meet this goal are contained within the CEV. The corrective behaviour is injected into the CEV, which changes its performance. The goal is to find the optimum level of control, leading to zero-error. From the environment, actions are transmitted to the input quantity that generates another cycle.

Input Quantity – The effect of actions carried out within the CEV leads to the modified input function.

Disturbances – Disturbances in the HSC model can be categorised under internal and external. Internal disturbances are considered to relate to team functions, e.g. unplanned loss of personnel and operating system failure. External disturbances can be classified as the quality of the physical working environment, environmental support systems security alerts and acts of aggression.

A typical HSC process control cycle will be described using the PCT framework as set out above and is graphically presented in Figure 6.2.

The purpose of the CEV is to ensure that within pre-set parameters energy supplied meets the current demand. The object of the team is to carry out this operation *safely securely and efficiently.* These objectives are dependent upon the quality of both the team and system performance. A high degree of team and system interaction is required for achieving optimum performance throughout the control room, 'perception of control' is therefore likely to have a major impact on its efficiency. Therefore the goal is to constantly improve the *quality* of the operation by varying their actions and interactions towards meeting their common goal. Team operations may have perceived errors in terms of meeting their goal for various reasons, for example background, knowledge, level of expertise, longevity in organisation and sometimes even personality differences. A team's input function therefore may not meet the criterion to satisfy the goal (referent signal). From this research it has been established that potential error laden perceptions could be factors such as *confidence, interdependency*, *commitment expectation* and a *team mental model*. Furthermore depending on team location, role and status of personnel, perception of team members may be negative in terms of some perceiving that they have been *taken advantage of* or are being *continually monitored*, all of which generates a lack or loss of trust. This perceived input signal is compared to the reference signal and the shortfall generates an error signal. This signal is an amalgam of a number of factors that could include *team interaction*, *proactivity, performance* and *reliability*. Each of these factors will have different values compared to the reference signal. These are then mentally evaluated to assess the degree of divergence away from optimum perceived 'control'. This error analysis in the form of negative feedback is transformed into the output quantity (actions or corrective behaviours) that then reduce the perceived error and change the CEV. A signal is then transmitted from the CEV into the input quantity, a new perception of control is generated and the cycle continues. Optimum performance or control is met when the input signal approaches the reference signal.

This research shows that the trust factors identified can be individually measured against the goal with reference to how the human controller focuses their perception of team and technology interaction in a control-room environment. It is therefore hypothesised that to achieve optimum team performance, control and level of trust in human and technical systems within HSC domains, the same principle must apply. Perception of control can only be optimised through continuous visual feedback (i.e. *quality of interaction*). Although it is more difficult to attain such feedback from humans than systems, it is possible that the error feedback loop within and between teams could be made more visible, hence improved.

6.6.2 Perceptual Model of Trust

The factors identified as elements of trust from this research can be transferred into a PCT framework and used to analyse perceptual error within or between teams and or from technology. This will be identified as the Perceptual Model of Trust (PMT). This research confirms that actual measured performance, perceived performance and level of trust are linked (see sections 4.5.2 & 5.3.6). Furthermore results from the technology study support other researchers views (Farrell, 2000), that it is only through continuous visual feedback from the system that users can potentially optimise their level of perceived control of the system and so increase their level of trust in it. As confirmed in this research control operators need to firstly have an *understanding* of their technology in terms of its appropriateness of system-task-fit. For this to exist the *quality of interaction* from the system has to be at an optimum level for human mental processing (e.g. reduce cognitive workload), and machine behaviour in terms of functionality and visual display have to provide continuous feedback. This feedback into the human promotes an enhanced perception of control in terms of *confidence* and reinforced *understanding*. This improves their perceived level of performance as the level of trust in the system increases and so the cycle continues. Similarly it is postulated that humans require the same kind of feedback, the more continuous and visual, the better the level of interaction. The human-human interface is striving for the same results as the human-system interface; optimum performance and level of control. If perception of control is lacking, this will lead to reduction in trust and team performance. For example when a perceived lack of *commitment*, *confidence* or *interdependency* within the team exists, it may be necessary to increase behavioural responses such as *quality of interaction*, *proactivity* or *honesty* etc. Conversely, a lack of *commitment* within the team may be the result of supervisors taking advantage of personnel or monitoring their progress too often.

Table 6.2 Typology of trust indices using PCT framework

Complex Environmental Variable	**Perceptual Input Function (Emotive & Cognitive)**	**Perceptual Output Function (Behaviours)**
Technological Systems	Understanding the system-task-fit	Quality of Interaction (function & visual output)
	Confidence	
HSC Applied Teams (OTI)	Keeping commitments	Not taking advantage
		Honesty
		Sharing Information
		Not monitoring compliance
Team	Commitment	Team Performance
	Confidence	Proactivity
	Interdependency	Interaction (nature & frequency of feedback
	Team Mental Model	Reliability

Table 6.2 shows the two main elements of perceptual input are emotive and cognitive factors whilst the prime elements of the perceptual output function are behavioural factors. The principle of the model is that effective analysis of the output function and appropriate error correction of these behavioural factors will generate a higher level of perceived input quantity, (e.g. perceived control of the operation, hence level of team trust). This will be reinforced in the following cycle as the input signal approaches the perceived desired goal. By constantly improving the behavioural factors, the perceived performance of the individual is improved, resulting in a higher degree of trust in both

teams the technical support systems and confidence in the individuals ability. This could be expressed simply as illustrated in Figure 6.1

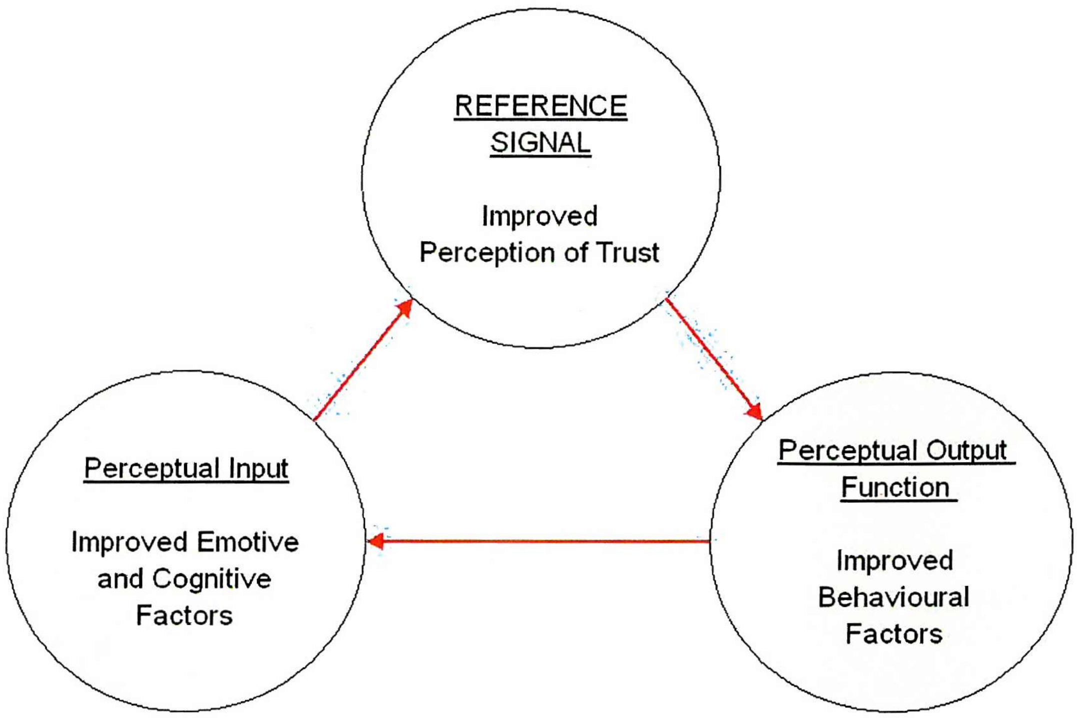

Figure 6.1 Perceived trust improvement cycle

and could represent the perception of one individual, a team or a human-system interface. By applying all the factors of trust into the model, a more comprehensive illustration is shown in Figure 6.2 that includes the environment, thus incorporating the whole of the socio-technical system.

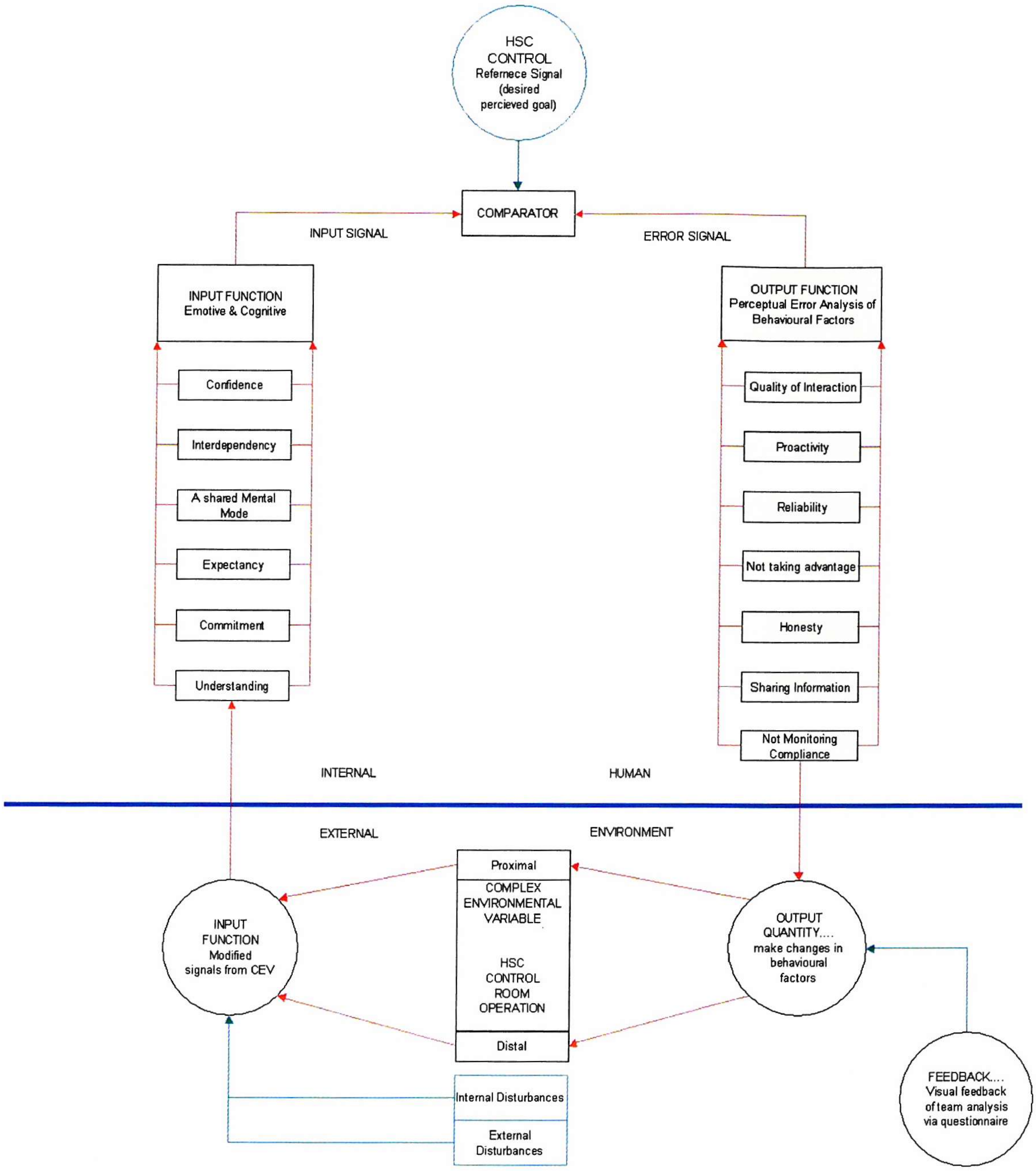

Figure 6.2 Perceptual Model of Trust (PMT)

Consequently the trust level is relative to the rate of improvement in behavioural factors with the consequent improvement in cognitive and emotive factors together with the number of times positive corrective action is carried out. In addition, the time taken between feedback to improvement in behavioural factors is also an element of improving the trust level. A cycle can be defined as an activity loop; this could be a team working on a repetitive operation or a team working on various operations or events.

It is expected that the initial error level is going to be relatively high, as control-operators begin to set team parameters and analyse and monitor their error signals. It is emphasised that in order for quality of interaction and trust to increase the feedback monitoring system has to be completely open and systematic. It is postulated that as the number of cycles and consequently the number of error corrections takes place, the rate of improvement will reduce the closer the error gets to zero, although it is not realistic to assume that the error will ever actually be zero. As the error measurement reaches closer to zero, so the higher level of trust there will be. If a graph is drawn on this basis with the y axis indicating the reduction of error for each cycle of corrective action and the x axis indicating the number of cycles, then one would expect this to produce an exponential decay curve. This curve could well represent the *ideal* improvement in the error between each cycle. The time taken for each corrective cycle to be completed is also a function of the level of trust as the quicker the cycle is completed the sooner the respondent receives tangible performance feedback. This is particularly important relating to trust in technological interfaces as discussed in section (6.1.3).

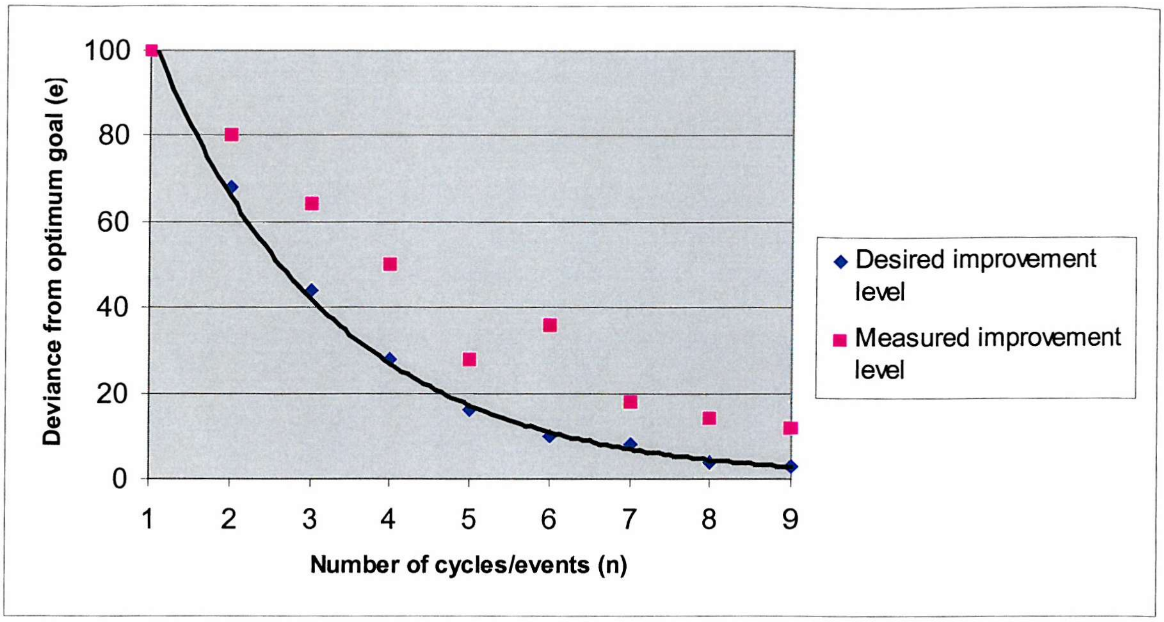

Figure 6.3 Example of trust index as measure of improvement for behavioural factors.

Results of the error feedback analysis in a control room environment however may not always follow the exponential curve and therefore use of this curve to determine levels of improvement in trust would not be realistic.

Figure 6.3 presents a hypothetical example, giving an ideal and a possible measured improvement rate for each cycle as behaviours are changed and varied. Unlike feedback from technological interfaces however, feedback between humans in this environment could only be measured between points of feedback. Therefore feedback from analysing different or repetitive cycles or events may produce steps of improvement rather than a continuous curve. Measurement of the improvement in one or all of the behavioural factors for each progressive cycle would provide a useful tool in HSC domains and could act as a benchmark for monitoring future improvements.

There are potentially two methods of generating a trust index. The first is simple improvement in level of error between each progressive feedback stage. This is based on the initial error being given a trust index of zero and perfection having a trust index of one. Second is to assess the relative rate of improvement of error between each stage of feedback. This could be useful as it indicates the improvement of rate of error correction from the previous stage. Either format could be used to evaluate the reduction in error and consequently a level of improvement in trust. For simplicity and ease of use in this thesis the first example will be taken.

To generate a trust index using this method would necessitate the comparison of the error levels at each cycle. For example if E1 (e) is the first error measurement and En is the error measurement for that current cycle or event being considered (n), then this would result in the following formula.

Trust index (TI) = $$TI_n = \frac{E_1 - En}{E_1}$$

This would give a range for the trust index of zero to one, and the higher the resultant numbers the higher the trust index.

Considering the data points marked on the graph Figure 6.3 and using the formula mentioned for those points, values of TI would be as follows; -

$TI_1 = 0.00$ $TI_2 = 0.20$, $TI_3 = 0.36$, $TI_4 = 0.50$, $TI_5 = 0.72$, $TI_6 = 0.64$, $TI_7 = 0.82$, $TI_8 = 0.86$, $TI_9 = 0.88$, etc. This can apply to an individual behavioural factor or a weighted summation of all the factors considered together. The latter would give an accurate indication of the teams' level of trust and improvement as a whole.

6.6.3 Method of Feedback

As previously mentioned the method used for feedback error is critical to achieving realistic results. Objectives of the feedback analysis system must include ease of use, quick and easy data retrieval and generation of an open environment that encourages honesty. Contextually the method must be appropriate to users and the scoring system must be standardised. More importantly the method of scoring should be weighted relative to the importance of the factor being considered in relation to the operating domain. It is essential that the feedback system be closely monitored but also that the team members can relate to it and even input the data themselves. Monitoring the feedback system would have to be done independently in order to provide a balanced view to meet the standards set. The method of feedback is considered critical to the success of measuring any level of improvement and is currently being developed by the author, however this is outside the scope of this thesis.

7 Chapter Seven: Conclusions and Future Work

7.1 Conclusions

To conclude this thesis an outline of each aim will be given (see section 1.11) followed by a summary of how each one has been met, together with some generic conclusions from this thesis. Finally, several points will be discussed with a view to how this research might be extended in the future.

- Aim one was concerned with the issue of context in relation to trust. This was met as findings show that the importance of conceptualising trust varies dependent upon the contextual domain and that measures of assessing trust between teams do not necessarily generalise across different working environments. Results from studies one and two confirm that control room engineers express trust according to the task, team structure, roles and the environment in which they work. Conclusions are that the impetus and interpretation of trust is different; engineers' emphasis was on making trust observable and tangible with confirmed factors of *not taking advantage*, *not monitoring compliance*, *openness* and *honesty*, but they did not discriminate between cognitive and emotive factors.

- Aim two was to identify the dimension and level of trust within HSC working domains. This was met as examination of trust from the 'user's perception provided a clear conception of the importance of trust in a complex engineering environment. Core constructs were reliably confirmed across emotive, cognitive and behavioural dimensions. Important findings related to *quality of interaction*, *understanding* and *confidence* and significant differences were found across three bespoke sets of elements in a working control room.

- Aim three was to establish whether proximity of team or type of interface affected the development of trust within a simulated control task. This aim was met as results confirm that using an abstract functional approach to process control increases optimum system-task-fit, reduces cognitive workload and enhances trust in the system as well as task performance. These results also give some empirical support to other research, (see sections, 4.7, & 6.4).

- Aim four was to develop a contextual framework of strategies for the perception of trust. This aim was met as a validated matrix of emotive, cognitive and behavioural factors were identified for conceptualising trust in and between teams and technology in HSC domains. Trust was perceived to be better when there was a prominence in some of these factors, particularly behavioural ones. Perceived levels of performance and actual task performance and team interaction were enhanced when behavioural factors increased. It is concluded from this research that measures of trust should not be taken in isolation but need to be task and context orientated, encompassing the whole socio-technical system.

- Aim five was to develop a working model of trust. A novel and an appropriate model was developed for contextualising the perception of trust into an engineering domain by adapting the systems based framework of Perceptual Control Theory, (PCT). Using the same tenets of this perspective the validated factors of trust from the current research were implemented into a Perceptual

Model of Trust, (PMT). This is the first practical tool for measuring and monitoring trust development. It therefore provides an appropriate instrument for improving performance in human-human and human-interface interaction in HSC domains.

- This research measured trust in relationship to human- human and human-system interfaces and related it to task performance. Confirmation that contextual constructs from 'real world' perceptions could be generalised to laboratory studies was established through evidence from a simulated human supervisory control task. A three-factor validated matrix emphasised the existence of these factors as being important in the perception of trust in technology. A generic conclusion from this thesis is that measures may more easily generalise from applied to laboratory settings if the process and methodology is contextually orientated.

- This thesis has demonstrated that frequent visual feedback improves levels of trust. It was also established that an association between level of perceived trust in technology and actual task performance exists, establishing a positive link between level of trust in technology, the human-system interface and team performance.

- A significant finding was established relating to the proximity effect of team interaction. It was demonstrated that where participants received continuous visual feedback, levels of trust in the human-human, human-system interface were enhanced and task performance was more effective; the location variable had little effect. It is concluded therefore that frequency and quality of interaction has a critical impact on trust in technology, team trust and performance. When this is at an optimum for task-system-fit, the effects of remote working are moderated.

- Through adopting the PCT framework it has been demonstrated that prominent elements of a process-control operation can be simply implemented into a systems based model. It is concluded that trust development can be linked to the reduction in levels of perceptual error between current and desired status. By varying action according to the measured error, cognitive and emotive perceptions can be enhanced, thus team and technological trust can be improved as the desired goal is reached. The PMT is considered to be theoretically and practically appropriate for HSC and, subject to an appropriately developed feedback system, wider engineering domains. It is therefore postulated that this model will be of benefit both academically and commercially.

- This research has established that the concept of trust equates to a set of contextually defined factors that if systematically and openly monitored and modified can only improve human-environment interaction. If all these trust factors were maintained at an optimum level within socio-technical systems, transaction costs could be reduced, resources could be preserved and added value would increase. It is therefore beneficial to promulgate the use of the PMT into organisations as a continuous monitoring device.

7.2 The Future

- It is considered that, combined with an appropriate visual feedback analysis system, the PMT will provide a powerful tool for measuring trust in many wider engineering applications. This feedback analysis system is currently being developed to target data input and analysis by the user.

- In order to establish reliable norms for the PMT model within different engineering contexts, an opportunity for further research in several different sectors is anticipated. Specifically research into the railway transport industry has become available and is a domain where many of the same working processes as HSC exist, the only difference being the actual task.

- Although developed for measuring levels of trust in HSC domains, it is considered that the PMT could be adapted to measure any single variable that needs improvement within any system. Any team task, project, operation or organisation that seeks to achieve a shared common goal needs to find ways of *improving quality of interaction* towards reaching the optimum. Whether it is quality of a product, service or process, improvement in time or budget, this model has the capability of being adapted to any systems based situation.

- The construction industry is an engineering sector that would benefit from using this model. Within any construction project there are many complex layers of human-human and human-system interfaces that do not naturally foster trusting relationships. For example the client/design team, the contractor/subcontractor team and the subcontractor/supply chain. All of these interfaces are operating to achieve one shared common goal in a highly competitive market. Implementing the PMT as an appropriate systematic measuring tool would help to improve levels of trust and performance and go some way towards meeting the ambitions of the 'partnering in construction' philosophy to which the industry has long aspired, (Latham, 1994; Egan, 1998).

8 Appendices

Appendix 1 Organisational Trust Inventory

Dear Team member

We are investigating people working in controlled environments and their perception of the concept of trust in team working. The following questions are trying to investigate your perception of: -

1) The level of trust **within your immediate shift team**.
2) The level of trust **between different shift teams.** We would be grateful if you would complete the following questions which should only take you five minutes. **Please answer each statement honestly and openly, not spending too long on each one.**

We would emphasise that we do not want to know who you are and the following information will be used purely for coding purposes.

Your Job Title: (e.g. goc/goe/support)...........................

Your Team number: (e.g. 'A', 'B', 'C' etc.) ....

No of Years/months in current position: Less than 1 year, 1-3 years, 4-6 years, 7-9 years, 10 years or more.

Length of time spent working in the industry: Less than 1 year, 1-3 years, 4-6 years, 7-9 years, 10 years or more.

Each team member should complete a questionnaire for their own team and a subsequent one for every other team that they are in contact with. For example if you are in team 'A' you complete the questionnaire once as a member of team A. You then complete it again for teams B.C.D.& E etc. Should you consider you do not have enough interactions with a n other team to comment, then you are not obliged to complete a questionnaire, but please comment in the space provided as to your reasons.

Your support in this research is greatly appreciated. All results will be available to you on request and should you have any questions or require any further information concerning this project, please do not hesitate to contact the undersigned.

Many thanks,

Melanie Ashleigh
Southampton University
Southampton SO17 1BJ
email: mja@soton.ac.uk

Organisational Trust Inventory[5]

These items refer to your own team and members of other teams and should be completed by every team member. Please read each statement very carefully, before circling the number to the right of each statement that most closely describes your opinion of other members of **your own team first and then subsequently for every other team that you are in contact with.**

Strongly Disagree	Disagree	Slightly Disagree	Neither Agree nor Disagree	Slightly Agree	Agree	Strongly Agree
1	2	3	4	5	6	7

1.	I think the members of this team tell the truth.	1 2 3 4 5 6 7
2	I think that members of this team meet their obligations.	1 2 3 4 5 6 7
3.	In my opinion the members of this team are reliable.	1 2 3 4 5 6 7
4.	I think that some members in this team succeed by stepping on other people.	1 2 3 4 5 6 7
5.	I feel that some team members try to get the upper hand.	1 2 3 4 5 6 7
6.	I think that some team members take advantage of our problems.	1 2 3 4 5 6 7
7.	I feel that members negotiate honestly within this team.	1 2 3 4 5 6 7
8.	I feel that members in this team keep to their word.	1 2 3 4 5 6 7
9.	I think that some team members mislead the team.	1 2 3 4 5 6 7
10.	I feel that some team members try to get out of their commitments.	1 2 3 4 5 6 7
11.	I feel that members of this team negotiate joint expectations fairly.	1 2 3 4 5 6 7
12.	I feel that some members take advantage of others in this team.	1 2 3 4 5 6 7
13.	I monitor other member's compliance in fulfilling team agreements.	1 2 3 4 5 6 7

---

[5] Short Form version of OTI, (Cummings & Bromiley, 1996), Used with permission of authors.

14. I don't check on whether other members meet their obligations to this team. 1 2 3 4 5 6 7

15. I tread carefully with other members of this team. 1 2 3 4 5 6 7

16. I watch for misleading information from other members of this team. 1 2 3 4 5 6 7

17. I work openly with other members of this team. 1 2 3 4 5 6 7

18. I share information openly with other members of this team. 1 2 3 4 5 6 7

Please make sure that for each completed questionnaire you have indicated which team numbers (e.g. A, B, C, D, E, F, management, support) you are giving your opinions about.

Reasons why I cannot comment about team

Appendix 2 Example of repertory grid and bespoke elements.

Repertory Grid Sheet																						
	Intra-team							Inter-team							Technology							
Similar	The Team member I work most with	Another engineer on my shift	Somebody I totally trust	Person I am physically closest to in my team	Somebody I don't trust at all	My best friend	My immediate Supervisor	My Departmental Manager	Someone with my job on another team	Someone who works in another control room	Recs/maintenance/districts)	A member of the technical support team	A member of the planning team	The overall Boss	The email system	Logging system	Video/TV monitor/conferencing	SCADA system	Demand Forecasting system	Alarm Management system	Telephone system	Different
Honesty	4	3	5	3	1	5	3	2	3	3	1	2	4	5	n/a	n/a	n//a	n/a	n/a	n/a	3	**Not open**
Shared goals	5	3	5	3	1	4	4	4	3	2	4	3	3	2	3	2	1	3	2	2	4	**Self Interest**
Understanding	3	4	5	3	2	5	4	3	4	2	3	4	3	2	4	3	3	4	5	4	5	**Little knowledge**
Commitment	3	3	5	4	1	4	4	3	4	2	2	3	4	3	3	3	2	4	4	3	4	**Disinterested**

Appendix 3 Example of Laddering crib sheet

<u>This example is for the researcher guide only</u>

I want you to think of the features that may contribute to the way you feel about the concept of trust when interacting with someone or something. They can be feelings, behaviours and/or thoughts based on the way **you personally** view the concept of trust.

Please tell the interviewer what characteristic you feel is similar to two of the elements and different from the third. Then I would like you to think of a polarised word to match your characteristic (example Honesty – Never tells the truth)
Can you tell me **why** this characteristic is important to you? Can you tell me **how** these people are different in your own words?

Triads of Elements

Me The team member I work most with Somebody with my job on another team	Being there for each other - no interaction
Somebody with my job on another team Somebody I totally trust Another engineer on my shift	Empathy - scepticism
Another engineer on my shift Somebody I don't trust at all The person I am closest to in my team	Reliable - unreliable
The person I am closest to in my team My best friend Departmental Manager	Honest with me - two faced
Departmental Manager My immediate supervisor Someone who works in another control room	Friendly- rude
Someone who works in another control room An outside agent (e.g. Rec. Generator) A member of the support team	Share information - lack of information

A member of the support team	Always ready to help - very unhelpful
A member of the admin. team	
The Overall Boss	
email system	
logging system	
Video TV Monitor system	Time lag on feedback - instant feedback
SCADA system	
Demand forecasting system	Consistent - inconsistent
Alarm management System	
Telecom system	
Telephone	
Face to Face meeting	Can read non-verbal cues- open to misinterpretation.

Appendix 4 Breakdown of constructs for Repertory Grid.

Core Constructs

Note: Underlined words are definitions according to Oxford English Dictionary.
Words in each category are all the subordinate words elicited by participants

Emotive Constructs

Confidence - Lack of Confidence
Reliance, faith, belief, dependence.
Positive attitude, security, belief, comfortable with, doesn't check up on, dependency.

Respect - Lack of Respect
Appreciation, consideration, recognition.
Considerate, caring, helpful, kind, appreciation, valued, acknowledged, supportive, fairness, rapport, worthwhile.

Commitment - Not committed
Duty, engagement, responsibility, liability.
Accountability, responsibility, interested.

Teamwork - Self interest
Co-operative work by team acting as one unit.
Shared goals, values, same level, unselfish, same sense of direction, bonding.

Cognitive Constructs

Understanding - Lack of Understanding
To know and comprehend, knowledgeable, experience.
Mutual understanding, knowledge, experience, familiarity, awareness, intimacy, rapport.

Ability - Incompetent
Capability competence, effectiveness.
Competency, effectiveness, good judgement.

Expectancy - No expectation
Optimism, prospect, hope anticipation, assumption.
Optimistic, expectancy.

Behavioural Constructs

Honesty - Not being open
Integrity, value, principled, truthful, fairness.
Openness, sincerity, genuine, honest, integrity, truthful, freedom of speech.

Reliability - Unreliability
Loyalty, dependability, faithfulness, consistency.
Reliable, fulfils expectancy, dependency, stability, loyalty.

Proactivity - Reactive
Acting in a positive way, active responsiveness, looking forward, predicting.
Predict, alertness, ambition, positive, motivated.

Performance - Non performance
Accomplishment, achievement, efficiency, operation, completion, output.
Accurate functioning, works, essential, accuracy, optimum performance, fulfils expectancy.

Communication - No interaction
Impart, convey, exchange information.
Sharing information, feedback, confidentiality, frequent contact, communicate, interacting.

Quality of Interaction – Lack of feedback
Personable, people orientated, informal, focused, approachable, quantifiable, feedback, quantity and quality of information, better interpretation, factual, active listening, proximal, sociable, assertiveness, control, correct information.

Appendix 5 Technical trust questionnaire.

The following statements relate to your perception of ***trust in the process control system*** that you have just used. Please rate how ***you felt about the system*** by clicking on one of the buttons along the continuum.

1	2	3	4	5
Not/none at all	**quite low**	**moderately**	**quite high**	**extremely high**

1. I felt confident that the system would perform its function properly. 1 2 3 4 5
2. The system gave me appropriate feedback when I required it. 1 2 3 4 5
3. The system was competent in its function. 1 2 3 4 5
4. I understood how the system worked. 1 2 3 4 5
5. The interface was appropriate for the task. 1 2 3 4 5
6. The interface helped me to make sense of the task. 1 2 3 4 5
7. I felt I could depend on the system to do its job. 1 2 3 4 5
8. The system was consistent in the way it functioned throughout the task. 1 2 3 4 5
9. The system was reliable throughout the task 1 2 3 4 5
10. I had faith in the system. 1 2 3 4 5
11. I felt I interacted well with the system. 1 2 3 4 5
12. The system's behaviour was predictable from one task to another 1 2 3 4 5
13. I expected the system to give me the correct information. 1 2 3 4 5

Appendix 6 Rules for the distal abstract condition of the simulated process control task.

DISTAL ABSTRACT CONDITION

Introduction

The aim of this task is to operate a gas network so that all demands are supplied, and that the operational cost is kept as low as possible. This means that over a day there is an approximate supply and demand balance. In this context a day refers to D1 0600 to D2 0600.

Gas is a compressible fluid so supply does not necessarily equal demand on a minute by minute basis. If supply is greater than demand then the pressure in the pipes rise until the maximum pressure is reached (38 bar), at which time the flow will decrease. If demand is greater than supply then the pressure in the pipe will decrease until zero pressure is reached and then network fails. There is a pressure drop down the system which is affected by the flow rate, average pressure, pipe length and diameter.

The main network is supplied by the National Supplier and delivers gas to the four Areas. The 4 area networks are; North, East, South and West. The regulators are set to supply gas at a constant rate and will not allow the pressure to exceed 38 bar. If the pressure reaches 38 bar then the flow rate will decrease. All the Area networks have a working pressure range of 10bar to 38 bar. The higher limit (38 bar) is set by law and will not be breached. The lower limit (10 bar), will incur penalties and could eventually lead to system failure.

Area Network

Each Area network is depicted by a Polygon with six nodes. Each node gives you information about balancing your Area Network. As operators you have no control over the gas consumers, so during the day demand might increase or decrease. This could be due to various factors (e.g. weather changes). You will only be aware of changes after they have happened. Demand can change at any time, and a response may be needed to cope with these changes.

If demand is higher than supply then either additional gas is taken from holder **or** supply can be increased through the regulator.

If demand is lower than supply then either surplus gas has to be stored in the holder, or supply can be decreased through the regulator.

As a team of operators you are taking over from another group. The regulator and/or holder might not be set up correctly for the day. For example, the holder might be on when it is not really needed or the regulator flow might not equal the network demand. The information on the graphs show predictions of how the network will behave over the next simulated 24 hours if you do nothing.

Your contract as a team with the suppliers is to take gas at a constant flow rate over a day. Any changes in the Area supply regulator flows will affect the flow rate nationally very quickly. Joint action by all the Area operators might avoid this.
There are two types of intervention:

1. Local control (e.g. operating your own network via the holder or unilaterally changing your flow rate on the regulator)
2. Co-ordinated global control (e.g. changing flow rate on two or more regulators after communicating with other team members).

NB YOU HAVE TO COMMUNICATE WITH OTHER TEAM MEMBERS VIA THE TELEPHONE SYSTEM. EACH AREA RELATES TO A DIFFERENT CHANNEL ON THE TELEPHONE AND VIA VIDEO LINK
North = channel 4
South = channel 3
East = channel 2
West = channel 1

However there are costs associated with control.

Local control Costs are increased by:-

0 Allowing minimum pressure to be less than 10 bar - an escalating cost
1 Not having the same level of gas in your holder at the start and end of day (0600) - an escalating cost
2 Operating the holder too frequently - a relatively low cost

Global costs are increased by:-

Changing the flow rate on your regulator, which will indirectly change the national supply - a relatively high cost.

Only by co-ordinating flow rate changes with other areas can you prevent or minimise flow rate changes Nationally. For example: - If North were to increase their flow by 0.2MCM @ 10.00 hours, East would have to decrease their flow by 0.2 MCM @ 10.00 hours in order for NO additional cost to be incurred.

Costs may be minimised by:-
1. Emptying holder only when necessary (filling is free)
2. Changing the regulator flow only when absolutely necessary or by co-ordinated action
with other areas.

The Holder

As operators you have control of whether the holder supplies gas into the network, does nothing or is filled from the network. The holder contains 0.350 Million Cubic Metres (MCM) of gas and takes 14 hours to empty. It can however be refilled in only

7 hours. Once it is full it cannot take any more gas and once it is empty it cannot supply gas. Normal operation is to fill at night and empty during the day.

The Supply Regulator

You also have control over the flow through the supply regulator. It is however expensive to keep changing the flow rate. The flow is always calculated in Million Cubic Metres (MCM) per day. (e.g. 0600 to 0600hrs)

Examples:

- If the demand increases from 10 MCM to 11 MCM at 0600 and you do not notice until 12:00 hours, then the regulator will have to be set to 11.33 MCM. This can be calculated by the following:

(24 x new demand (11) - old demand (10) x hours passed (6)) / (hours remaining (18)).

Views/screens/information

For each task we will show you the following six parameters marked around a polygon. The optimum levels will be shown as a green line and the predicted as a red line. All information is in the form of a prediction for the next 24 hours (e.g. D1 0600 to D2 0600).

1. Overall balance of the system (the difference between supply and demand plus any changes in the holder) - optimum is zero
2. Holder level at end of Day (e.g. D2 0600) - optimum is full
3. Minimum pressure in local area Network - optimum is 10 bar
4. Inlet flow minus Demand (difference between total supply and total demand only over 24 hours) - optimum is zero.
5. Pressure at end of day (D2 0600) - optimum is 38 bar
6. Number of hours the system is at 38 bar over 24 hours - optimum is 1

Your task is to:-

Make sure the level of stock on D2 0600 is within 10% of your starting stock level on D1 0600
Minimise number of hours system is running at 38 bar
Keep minimum pressures above 10 bar
Operate system as close to the optimum levels as possible
Minimise use of holder
Minimise cost

Appendix 7 Rules for the distal-virtual condition of the simulated process control task.

DISTAL-VIRTUAL CONDITION

Introduction

The aim of this task is to operate a gas network so that all demands are supplied, and that the operational cost is kept as low as possible. This means that over a day there is an approximate supply and demand balance. In this context a day refers to 0600 to 0600.

Gas is a compressible fluid so supply does not necessarily equal demand on a minute by minute basis. If supply is greater than demand then the pressure in the pipes rise until the maximum pressure is reached (38 bar), at which time the flow will decrease. If demand is greater than supply then the pressure in the pipe will decrease until zero pressure is reached and then network fails. There is a pressure drop down the system which is affected by the flow rate, average pressure, pipe length and diameter.

The main network is supplied by Bangton and delivers gas to the four Areas. The 4 area networks are; North, East South and West. The regulators, (NOUT, EOUT, SOUT, & WOUT) are set to supply gas at a constant rate and will not allow the pressure to exceed 38 bar. If the pressure reaches 38 bar then the flow rate will decrease. All the Area networks have a working pressure range of 10bar to 38 bar. The higher limit (38 bar) is set by law and will not be breached. The lower limit (10 bar) will incur penalties and could eventually lead to system failure.

Area Network

Each Area network consists of input (the regulator), four pipes to transport and store the gas, a holder to store the gas and four consumers. In general consumers do not take gas at a constant rate. As operators you have no control over the gas consumers, so during the day demand might increase or decrease. This could be due to various factors, (e.g. weather changes). You will only be aware of consumer changes after they have happened. Demand can change at any time, and a response may be needed to cope with these changes.

If demand is higher than supply then either additional gas is taken from the pipes or holder **or** supply can be increased through the regulator.

If demand is lower than supply then either surplus gas has to be stored in either pipes or holder, or supply can be decreased through the regulator.

As a team of operators you are taking over from another group. The regulator and/or holder might not be set up correctly for the day. For example, the holder might be on when it is not really needed or the regulator flow might not equal the network demand.

The graphs show predictions of how the network will behave over the next simulated 24 hours if you do nothing.

Your contract as a team with the Bangton suppliers is to take gas at a constant flow rate over a day. Any changes in the Area supply regulator flows will affect the flow rate at Bangton very quickly. Joint action by all the Area operators might avoid this.

There are two types of intervention:

1. Local control (e.g. operating your own network via the holder or unilaterally changing your flow rate on the regulator).
2. Co-ordinated global control (e.g. changing flow rate on two or more regulators after communicating with other team members).

N.B. You have to communicate with other team members via the telephone system. Each area relates to a different channel on the telephone and via video link.

North = channel 4
South = channel 3
East = channel 2
West = channel 1

However there are costs associated with control.

Local control Costs are increased by:-

3 Allowing average pressure to be too high - a relatively low cost
4 Allowing pressure to fall below 10 bar - an escalating cost
5 Not having the same volume of gas in your Area network at the start and end of day (0600) - an escalating cost
6 Operating the holder too frequently - a relatively low cost

Global costs are increased by:-
Changing the flow rate at Bangton - a relatively high cost
Note that any flow rate change will automatically affect the flow rate at Bangton

Only by co-ordinating flow rate changes with other areas can you prevent or minimise flow rate changes at Bangton. For example: - If North were to increase their flow by 0.2MCM @ 10.00 hours, East would have to decrease their flow by 0.2 MCM @ 10.00 hours in order for NO additional cost to be incurred at Bangton.

Costs may be minimised by:-
1. Emptying holder only when necessary (filling is free)
16. Changing the regulator flow only when absolutely necessary or by co-ordinated action with other areas.

The Holder

As operators you have control of whether the holder supplies gas into the network, does nothing or is filled from the network. The holder contains 0.350 Million Cubic Metres (MCM) of gas and takes 14 hours to empty. It can however be refilled in only 7 hours. Once it is full it cannot take any more gas and once it is empty it cannot supply gas. Normal operation is to fill at night and empty during the day.

The Supply Regulator (NOUT, EOUT, SOUT & WOUT)

You also have control over the flow through the supply regulator. It is however expensive to keep changing the flow rate. The flow is always calculated in Million Cubic Metres (MCM) per day. (e.g. 0600 to 0600hrs)

Examples:

- If the demand increases from 10 MCM to 11 MCM at 0600 and you do not notice until 12:00 hours, then the regulator will have to be set to 11.33 MCM. This can be calculated by the following:

(24 x new demand (11) - old demand (10) x hours passed (6)) / (hours remaining (18))

Views/screens/information

For each task we will show you the following :
The current pressures, flows and state of your network
The predicted state of the system over the next 24 hours.
The current performance level or score (for your own network & as a team)

Your task is to:-

7 Make sure that total stock at 0600 on day two is within 10% of your starting stock level on Day one
8 Minimise flow variation at Bangton
9 Keep all pressures above 10 bar
10 Operate the system down to as close to 10 bar as possible
11 Minimise use of holder.

Appendix 8 Development of team trust questionnaire.

Trust Questionnaire

Not/None at all	Very low	Moderate	Quite High	Extremely High
1	2	3	4	5

Confidence

1.	I feel confident with other members of the team.	1 2 3 4 5
2.	I do not have faith in other team members.	1 2 3 4 5
3.	Members of the team depended on each other.	1 2 3 4 5
4.	I felt secure with members of the team.	1 2 3 4 5

Respect

5.	I felt members of the team respected each other.	1 2 3 4 5
6.	Other team members recognise my contribution.	1 2 3 4 5
7.	I did not feel valued as a team member.	1 2 3 4 5
8.	Team members were considerate towards each other during the task.	1 2 3 4 5

Commitment

9.	I felt a sense of responsibility towards other team members.	1 2 3 4 5
10.	Some members of the team seem disinterested in what we trying to achieve.	1 2 3 4 5
11.	The team was committed to achieving the team goal.	1 2 3 4 5
12.	I felt a sense of loyalty towards other team members .	1 2 3 4 5

Teamwork

13	Our team worked together as a co-operative unit.	1 2 3 4 5
14.	I feel that the team shared a common goal.	1 2 3 4 5
15.	I feel members of the team were mostly concerned with achieving their own interests, rather than the teams.	1 2 3 4 5
16.	There was a sense of bonding within the team.	1 2 3 4 5

Understanding

17.	I think the team had a mutual understanding of the task.	1 2 3 4 5
18.	I think the members of the team shared the same knowledge level.	1 2 3 4 5
19.	Team members were not always aware of each other's needs.	1 2 3 4 5
20.	I think the team shared the same experience.	1 2 3 4 5

Not/None at all	Very low	Moderate	Quite High	Extremely High
1	2	3	4	5

Ability

21. I think there was a lack of competency within the team. 1 2 3 4 5
22. I think some members of the team were more capable than others. 1 2 3 4 5
23. I think I carried some of the other team members. 1 2 3 4 5
24. I think team members worked effectively with one another. 1 2 3 4 5

Expectancy

25. I was optimistic that the team would achieve its goal. 1 2 3 4 5
26. I was pessimistic that our team would achieve its goal. 1 2 3 4 5
27. I think the team fulfilled each other's expectations. 1 2 3 4 5
28. Other team members do not fulfil my expectations. 1 2 3 4 5

Honesty

29. I was always honest with other team members. 1 2 3 4 5
30. Other team members seemed to be open with one another. 1 2 3 4 5
31. Team members were not always truthful in their negotiations. 1 2 3 4 5
32. Members of the team were sincere with each other. 1 2 3 4 5

Reliability

33. Other team members were not always consistent in their actions. 1 2 3 4 5
34. Members of the team acted reliably towards each other. 1 2 3 4 5
35. I relied on other members of the team to do what they said they would.. 1 2 3 4 5
36. Other project team members relied on me during the task. 1 2 3 4 5

Proactive

37. Other members of the team acted positively towards achieving the task. 1 2 3 4 5
38. Members of the project team were motivated to do the task. 1 2 3 4 5
39. We were a proactive team. 1 2 3 4 5
40. Some members of the team waited for others to take action. 1 2 3 4 5

Performance

41. The team's performance was poor . 1 2 3 4 5
42. The team shared high levels of achievement. 1 2 3 4 5
43. The team's performance was good. 1 2 3 4 5
44. The team accomplished the team objective. 1 2 3 4 5

Communication

45. Members of the team openly shared all information with each other. 1 2 3 4 5
46. There is a lack of communication within our team. 1 2 3 4 5
47. Team members gave each other appropriate feedback. 1 2 3 4 5
48. I interacted frequently with the other team members. 1 2 3 4 5

Not/None at all	Very low	Moderate	Quite High	Extremely High
1	2	3	4	5

Quality of interaction

49.	Other members of the team were very approachable.	1	2	3	4	5
50.	Some members did not always actively listen to each other.	1	2	3	4	5
51.	There was a high quality of interaction within the team.	1	2	3	4	5
52.	There was good social interaction within the team.	1	2	3	4	5

Trust Category

53.	I trust other members of the project team.	1	2	3	4	5
54.	There was no feeling of trust within the team.	1	2	3	4	5
55.	I considered other members of the team to be trustworthy.	1	2	3	4	5
56.	I felt other team members did not trust me.	1	2	3	4	5

Appendix 9 Team trust questionnaire with mixed categories.

Team Trust Questionnaire.

Having completed your team task we would like you to rate the following statements regarding your interaction with other team members. Please circle the number that best describes **how you feel** about each of the following statements.

Not/None at all	Very low	Moderate	Quite high	Extremely high

1.	I felt confident with other members of the team	1 2 3 4 5
2.	I think the members of the team shared the same knowledge level	1 2 3 4 5
3.	I did not feel valued as a team member	1 2 3 4 5
4.	I think there was a lack of competency within the team	1 2 3 4 5
5.	Our team worked together as a co-operative unit	1 2 3 4 5
6.	Other team members recognised my contribution	1 2 3 4 5
7.	Members of the team depended upon each other	1 2 3 4 5
8.	Team members were considerate towards each other during the task	1 2 3 4 5
9.	We were a proactive team	1 2 3 4 5
10.	Some members of the team seemed disinterested in what we were trying to achieve	1 2 3 4 5
11.	I was pessimistic that our team would achieve its goal	1 2 3 4 5

12.	I Felt a sense of loyalty towards other team members	1 2 3 4 5
13.	I felt members of the team respected each other	1 2 3 4 5
14.	Other team members relied upon me during the task	1 2 3 4 5
15.	I felt members of the team were mostly concerned with achieving their own interests, rather than the teams	1 2 3 4 5
16.	There was a sense of bonding within the team	1 2 3 4 5
17.	I think the team had a mutual understanding of the task.	1 2 3 4 5
18.	I did not have faith in other members of the team.	1 2 3 4 5
19.	I think the team worked effectively with one another	1 2 3 4 5
20.	I think the team shared the same experiences	1 2 3 4 5
21.	I felt secure with members of the team	1 2 3 4 5
22.	Our team accomplished its team objective	1 2 3 4 5
23.	I think I carried some of the other team members	1 2 3 4 5
24.	Team members were not always aware of each other's needs	1 2 3 4 5
25.	I was optimistic that our team would achieve its goal	1 2 3 4 5
26.	The team was committed to achieving the team goal	1 2 3 4 5
27.	I think the team fulfilled each others' expectations	1 2 3 4 5

28.	The team shared high levels of achievement	1 2 3 4 5
29.	There was good social interaction within the team	1 2 3 4 5
30.	Team members appeared to be open with one another	1 2 3 4 5
31.	There was no feeling of trust within the team	1 2 3 4 5
32.	Members of the team were sincere with each other	1 2 3 4 5
33.	Other team members were not always consistent in their actions	1 2 3 4 5
34.	The team's performance was good	1 2 3 4 5
35.	I relied on other members of my team during the task	1 2 3 4 5
36.	I feel that the team shared a common goal	1 2 3 4 5
37.	Other members of the team acted positively towards achieving the task	1 2 3 4 5
38.	Members of the team were well motivated to do the task	1 2 3 4 5
39.	I felt a sense of responsibility towards other team members	1 2 3 4 5
40.	Some members of the team waited for others to take action	1 2 3 4 5
41.	The team's performance was poor	1 2 3 4 5
42.	Other team members did not fulfil my expectations	1 2 3 4 5
43.	Members of the team acted reliably towards each other	1 2 3 4 5

44.	I think some members of the team were more capable than others	1	2	3	4	5
45.	Members of our team shared all information with each other	1	2	3	4	5
46.	Team members were not always truthful in their negotiations	1	2	3	4	5
47.	Team members gave each other appropriate feedback	1	2	3	4	5
48.	I interacted frequently with other members of the team	1	2	3	4	5
49.	I felt other members of the team did not trust me	1	2	3	4	5
50.	Some members did not always actively listen to each other.	1	2	3	4	5
51.	There was a lack of communication within the team.	1	2	3	4	5
52.	I was always honest with other team members.	1	2	3	4	5
53.	I trusted other members of the team.	1	2	3	4	5
54.	There was a high quality of interaction within the team.	1	2	3	4	5
55.	I behaved in a trustworthy manner towards other members of the team	1	2	3	4	5
56.	Other members of my team were very approachable	1	2	3	4	5

9 References

Alavi, M. Wheeler, B.C., & Valacich, J.S. (1995). Using IT to reengineer business education: An exploratory investigation of collaborative telelearning. MIS Quarterly, 19, 292-312.

Amit, R. & Schoemaker, P. J. H. (1993). Strategic assets as organisational rent. Strategic Management Journal, 14, 33-46.

Anderson, J. R. (1982). Acquisition of cognitive skill. Psychological Review, 89, 369-406.

Anderson, J.R. (1987). Skill acquisition: Compilation of weak method problems. Psychological Review, 94, 192-210.

Andreissen, J.H.E. & Van der Velden, J. M. (1995). Teamwork supported by interaction technology: The beginning of an integrated theory. In J.M. Peiro, F.Pieto, J.L. Melia, & O. Luque (Eds.), Organisational Psychology: European contributions for the nineties. Proceedings of the sixth European congress of work and organisational psychology. Erlbaum (UK): Taylor & Francis.

Annett, J. & Stanton, N.A. (2000). Teamwork – a problem for Ergonomics? Ergonomics, 43, 1045-1051.

Arrow, K. (1974). The limits of organisation. New York: Norton.

Ashleigh, M.J. & Stanton, N. A. (2001). Trust – Key Elements in Human Supervisory Control Domains. Cognition, Technology & Work, 3, 92-100.

Axelrod, R. (1984). The evolution of co-operation. New York: Basic Books.

Bainbridge, L. (1987). Ironies of automation. In J. Rasmussen, K. Duncan & J. Leplat (Eds.), New technology and human error. (pp. 271-283) New York: Wiley.

Barber, B. (1983). The Logic and Limits of Trust. New Brunswick, NJ: Rutgers, University Press.

Barnett, B.J., & Wickens, C.D. (1988). Display proximity in multicue information: The benefits of boxes. Human Factors, 30, 15-24.

Barrett, P. & Kline, P. (1981b). The observation to variable ratio in factor analysis. Journal of Personality and Group Behaviour, 1, 23-33

Bateson, P. (1988). Biological evolution of co-operation and trust. In D. Gabetta (Ed.), Trust: Making and breaking co-operative relations. New York: Basil Blackwell.

Belasco, J.A. (1989). What went wrong? Executive Excellence, 6, 13-14.

Bentler, P.M., & Bonnet, D.G. (1980). Significance tests and goodness of fit in the analysis of covariance structures. Psychological Bulletin, 88, 588-606.

Bhattacharya, R., Devinney, T. M., & Pillutla, M. M. (1998). A formal model of trust based on outcomes. Academy of Management Review, 23, (3), 459-472.

Bianco, W.T. (1994). Trust: Representatives and constituents. Ann Arbor: University of Michigan Press.

Boomsma, A. (1987). The robustness of maximum likelihood estimation in structural equation models. In P. Cuttance, & R. Ecob (Eds.), Structural modelling by example. (pp.160-168). New York: Cambridge University Press.

Boon, S.D., & Holmes, J.G. (1991). The dynamics of interpersonal trust: Resolving uncertainty in the face of risk. In R. A. Hinde & J. Groebel (Eds.), Co-operation and pro-social behaviour. (pp. 190-211). Cambridge, UK: Cambridge University press.

Bradach, J.L., & Eccles, R.G., (1989). Price, authority, and trust: From ideal types to plural forms. Annual Review of Sociology, 15, 97-118.

Brewer, M. B., & Kramer, R. M. (1986). Choice behaviour in social dilemmas: Effects of social identity, group size and decision framing. Journal of Personality and Social Psychology, 50, 543-549.

Brown, R.B. (1988). Group Processes: Dynamics within and between groups. Oxford: Blackwell.

Burt, R.S. (1992). Structural Holes: The Social Structure of Competition. Cambridge, Massachusetts: Harvard University Press.

Burrough, B., & Helyar, J., (1990). Barbarians at the gate: The fall of RJR Nabisco. New York: Harper & Row.

Butler, J.K., (1983), Reciprocity of trust between professionals and their secretaries, Psychological Reports, 53, 411-416

Carletta, J., Anderson, A. .H., & Crewan, R. M., (2000). The effects of multimedia communication technology on non-collocated teams: A case study. Ergonomics, 43, 1237-1251.

Cerulo, K.A. (1997). Technologically Generated Communities, Reframing Sociological Concepts for a Brave New (Virtual?) World. Sociological Inquiry, 67, 48-58.

Cook, J., & Wall, T., (1980). New work attitude measures of trust, organisational commitment and personal need non-fulfilment. Journal of Occupational Psychology, 53, 39-52

Coury, B.J. & Terranova, M.(1991). Collaborative decision making in dynamic systems. Proceedings of the Human Factors Society 35th annual meeting 944-8. 2-6 September, Santa Monica, CA: HFS.

Creeds, S. .L., Fabrigar, L. R., & Petty, R. E., (1994). Measuring the affective and cognitive properties of attitudes; Conceptual and methodological issues. Personality and Social Psychology Bulletin, 20, 619-634.

Cummings, L..L., & Bromiley, P. (1996). The Organisational Trust Inventory (OTI): Development and Validation. In: R. .M. Kramer, & R. R. Tyler, (Eds.), Trust in Organisations: Frontiers of theory and research. (pp 302-330). London: Sage Publications.

Currall, S. C., (1990). The role of interpersonal trust in work relationships. Unpublished doctoral dissertation, Cornell University.

Dallimonti, R., (1972). Future operator consoles for improved decision making and safety. Instrumentation Technology, 19, 23-8.

Davis, F.D. (1993), User acceptance of information technology: system characteristics, user perceptions and behavioural impacts. International Journal of Man-Machine Studies. 38, 475-487.

Davidow, W. H., & Malone, M. S. (1992). The Virtual Corporation Structuring and revitalising the corporation for the 21st century. New York: Harper Collins.

Dawes, R. M., & Thaler, R. (1988). Anomalies: Co-operation. Journal of Economic Perspectives, 2, 187-197.

Dawes, R. M., Van de Kragt, A. J. C. & Orbell, J. M. (1990). Co-operation for the benefit of us-not me, or my conscience. In J. Mansbridge, (Ed.), Beyond self-interest (pp. 16-55). Chicago: University of Chicago Press.

Deutsch, M. (1958). Trust and Suspicion. Journal of Conflict Resolution, 2, 265-279.

Deutsch, M. (1962) Co-operation and trust: some theoretical notes. Nebraska symposium on motivation, 275-319.

Dru-Dury, R. Farrell, P.S. E., & Taylor, R. (2001). Cognitive cockpit systems: voice for cognitive control of tasking automation. In: Don Harris (Ed.), Engineering psychology and Cognitive Ergonomics, 5, 99-107.

Duck, S., & Perlman, D. (1985). (Eds.), Understanding personal relationships. Beverly Hills, CA:Sage.

Dunphy, D., & Bryant, B. (1996). Teams: Panaceas or prescriptions for improved performance? Human Relations, 49, 677-699

Dyer, J. L. (1984). Team research and team training: A state-of-the-art-review. In F. A. Muckler (Ed.), Human Factors Review (pp. 285-323). Santa Monica, CA: Human Factors Society.

Egan, J. (1998). Rethinking Construction: The report of the Construction Task Force. Department of the Environment Transport and the Regions (DETR). London: HMSO.

Erickson, E. H. (1978). Childhood and society. New York: Norton.

Farrell, Philip, S.E. (2000). Appendix B DVI Applied to FOAS Storyboard for cognitive cockpit. Ontario, Canada: Defence & civil institute of environmental medicine.

Farrell, P. S. E., & Semprie, M. A. H. (1997). Layered Protocol Analysis of a Control Display Unit. DCIEM report No 97-R-70. North York: Department of National Defence.

Fukuyama, F. (1995). Trust: The Social Virtues and the Creation of Prosperity. New York: The Free press.

Gambetta, D. (1988). Trust: Making and Breaking Co-operative Relations. Oxford: Basil Blackwell.

Gaines, J. H. (1980). Upward communication in industry: An experiment. Human Relations, 33, 929-942.

Gibson, J. J. (1986). The Ecological Approach to Visual Perception. London: Lawrence Erlbaum Associates.

Golembiewski, R. & McConkie, M. (1975). The centrality of interpersonal trust in group processes. In C Cooper (Ed.), Theories of group processes. (pp 131-134). London: Wiley.

Good, D. (1988). Individuals, interpersonal Relations, and Trust. . In: Diego Gambetta (Ed.), Trust: Making and Breaking Co-operative Relations. Oxford: Basil Blackwell.

Goldman, S. L., Nagel, R. N. & Preiss, K. (1995). Agile Competitors and Virtual Organizations: Strategies for enriching the customer. New York:Van Nostrand Publishing.

Greaney, J., & MacRae, A. W. (1996). Diagnosis of fault location using polygon displays. Ergonomics, 39, 400-412.

Greaney, J. & MacRae, A.W. (1993). Check-reading instrument displays in compressed formats. In A.G. Gale (Ed.), Proceedings of the 3rd International Conference on Visual Search. London: Taylor & Francis.

Greenhalgh, L., & Chapman, D. I. (1994). Joint decision making the inseparability of relationships and negotiation. Paper presented at the Stanford Conference on the Social Context of Negotiation, Stanford Graduate School of Business. CA.

Griffin, Em. (1997). A First Look at Communication Theory. New York: McGraw-Hill, Inc.

Handy, C. (1995). Trust and the virtual organisation. Harvard Business Review, 73, 40-50.

Hart, K. (1988). Kinship, Contract, and Trust. In D. Gambetta (Ed.), Trust: Making and Breaking Co-operative Relations. Oxford: Basil Blackwell.

Hawisher, G. E., & Morgan, C. (1993). Electronic mail and the writing instructor. College English, 55 , 627-643.

Hettenhaus, J.R. (1992). Changing the way people work: a socio technical approach to computer-integrated manufacturing in a process industry. In H Kragt (Ed.), Enhancing Industrial Performance. London: Taylor Francis.

Hirschman, A. O. (1984). Against parsimony: Three easy ways of complicating some categories of economic discourse. American Economic Review Proceedings, 74, 88-96.

Hollnagel, E. (1993). Human Reliability Analysis Context and Control. London: Academic press.

Hosmer, L. T. (1995) Trust: The connecting link between organisational theory and philosophical ethics. Academy of Management Review, 20, 379-403.

Ilgen, D. R., Major, D.A., Hollenbeck, J. R., & Sego, D. J. (1995). Raising an individual decision-making model to the team level: A new research model and paradigm'. In R. A. Guzzo & E. Salas (Eds.), Team effectiveness and decision making in organisations. San Francisco, USA: Jossey-Bass.

Jacob, R. J. K., Egeth, & Bevan, W. (1976). The face as a data display. Human Factors 18, 189-200.

Janis, I. L. (1982). Groupthink: Psychological studies of policy decisions and fiascoes. Boston, MA: Houghton Mifflin.

Jarvenpaa, S., & Leidner, D. (1998). Communication and Trust in Global Virtual Teams. Journal of Computer-Mediated Communication and Organisation Science: A Joint Issue, 3, 1-38.

Jones, G. R., & George, J. M. (1998). The experience and evolution of trust: Implications for co-operation and teamwork. Academy of Management Review, 23, (3), 531-546.

Kee, H.W., & Knox, R. E. (1970). Conceptual and methodological considerations in the study of trust and suspicion. Conflict Resolution,14, (3), 13-14.

Kelly, G. (1955). The Psychology of Personal Constructs. New York: Norton.

Kipnis, D. (1996). Trust and Technology. In R. M. Kramer & T.R. Tyler (Eds.), Trust in Organisations, Frontiers of Theory and Research. London: Sage Publications.

Kline, P. (1998). The New Psychometrics: Science, Psychology and Measurement. London: Routledge.

Kragt, H. (1994). Enhancing Industrial performance. London: Taylor & Francis.

Kramer, R., & Brewer, M. A. (1986). Social identity and the emergence of co-operation in resource conversation dilemmas. In H. Wilke, C. Rutter & D. M. Messick (Eds.), Experimental studies of social dilemmas. Frankfurt, Germany: Peter Lang.

Kramer, R. M. (1993). Co-operation and organisational identification. In K. Murninghan (Ed.), Social Psychology in organisations: Advances in theory and research. (pp. 244-268) Englewood Cliffs, NJ: Prentice Hall.

Lassiter, D. L., Vaughn, J. S., Smaltz, V. E. Morgan, B. B. Jr., & Salas, E. (1990). A comparison of two types of training interventions on team communication performance. Proceedings of 34th Annual Meeting Human Factors Society, 1990, (pp. 372-1376).

Latham, Sir Michael, (1994). Constructing the team. London HMSO.

Lee, J. D. & Moray, N. (1994). Trust, self-confidence and operators' adaptation to automation. *International Journal of Human-Computer studies*, 40, 153-184.

Lewicki, R. J., & Bunker, B. B. (1996). Developing and Maintaining Trust in Work Relationships. In: R.M. Kramer & T.R. Tyler (Eds.), Trust in Organisations, Frontiers of Theory and Research. London Sage: Publications.

Lewis, J. D., & Weigert, A. (1985). Trust as a social reality. Social Forces, 63, 967-85.

Lewis, M. (1989). Liar's poker: Rising through the wreckage of Wall Street. NY: Norton.

Limerick, D., & Cunnington, B. (1993). Managing the new organisation. San Francisco: Josey-Bass.

Lipnack, J. & Stampts, J. (1997). Virtual Teams: Reaching Across Space, Time and Organisations with Technology. New York: John Wiley.

Luhmann, N. (1980). Trust and power. New York: Wiley.

Mark, G. Grudin, J., & Poltrock, S. E. (1999). Meeting at the Desktop: An empirical study of virtually collocated teams. The 6th European conference on Computer Supported Co-operative Work. (pp. 159-178). Copenhagen, Denmark.

Martens, R., & Peterson, J. (1971). Group cohesiveness as a determinant of success and member satisfaction in team performance. International Review of Sport sociology, 6, 49-61

Mayer, R.C., Davis, J. H., & Schoorman, F. D. (1995). An integrative model of organisational trust. Academy of Management Review, 20, 709-734.

Mayo, E. (1993). The human problems of an industrial civilisation. New York: Macmillan.

McGrath, J.E. (1991). Time matters in groups. In J. Galegher, R. Kraut & C. Egido (Eds.), Intellectual Teamwork: Social and technological foundations of co-operative work. (pp. 23-61). Hillsdale, N.J: Lawrence Erlbaum.

Meyerson, D., Weick, K. E., & Kramer, R.M. (!996). Swift Trust and Temporary Groups. In R.M. Kramer & T.T. Tyler (Eds.), Trust in organisations; Frontiers of Theory and Research. London: Sage Publications.

Miles, R. E. & Snow, C. C. (1995). The new Network Firm: A Spherical Structure built on a Human investment Philosophy. Organisational Dynamics, 5, 5-18.

Misztal, B. A. (1996). Trust in Modern Societies. Oxford: Polity.

Moorhead, G., Ference, R. & Meck, C. (1992). Groupthink Decision Fiascoes Continue: Space Shuttle Challenger and a Revised Groupthink Framework. Human Relations, 44, 539-550.

Moray, N., Hiskes, D., Lee, J., & Muir, B. M. (1995). Trust and Human Intervention in Automated Systems. In: Jean-Michel Hoc, P.C. Cacciabue & E. Hollnagel (Eds.), Experts and Technology: Cognition and Human-Computer Co-operation. Hillsdale, NJ: Lawrence Erlbaum Associates.

Muir, B. M. (1994). Trust in automation: Part I. Theoretical issues in the study of trust and human intervention in automated systems. Ergonomics, 37, (11), 1905-1922.

Muir, B. M., & Moray, N. (1996). Trust in Automation: Part II. Experimental studies of trust and human intervention in a process control simulation. Ergonomics, 39, (3), 429-460.

Nandhakumar, J., & Baskerville, R. (2001). Trusting online: Nurturing trust in virtual teams. Proceedings of the 9th European Conference on Information. Bled, Slovenia.

Norman, D. A. (1990). The 'problem' is with automation; inappropriate feedback and interaction, not 'over automation. In: D. E. Broadbent, A. Baddeley & J. T. Reason (Eds.), Human Factors in Hazardous Situations. (pp. 585-583). Oxford: Clarendon Press.

Nunally, J. O. (1978). Psychometric Theory. New York: McGraw-Hill.

Ogilvy, J. (1995) The Economics of Trust, Harvard Business Review. Nov-Dec, 1995, 46-47

O'Hara-Devereaux, M., & Johansen, R. (1994). Global work: Bridging distance, culture and time. San Francisco, CA: Jossey-Bass Publishers.

Porter, G. (1997). Trust in Teams: member perceptions and the added concern of cross cultural interpretations. Advances in interdisciplinary studies of work teams, 4, (pp. 45-77), JAI Press Inc.

Porter, L. W., Lawler, E.E., & Hackman, J. R. (1975). Behaviour in Organisations. New York: McGraw-Hill.

Powers, W. (1973). Behaviour: the control of perception. Chicago: Adline.

Praetorius, N. & Duncan, K. D. (1991). Flow representation plant processes for fault diagnosis. Behaviour and Information Technology, 10, (1), 41-52.

Preston, Scott. M. (1999). Virtual organization as process: Integrating cognitive & social structure across time and space. Journal of Computer-Mediated Communication & Organization Science on Virtual Organization. (http://www.msu.edu/-prestons/virtual.html).

Rasmussen, J. (1986). Information Processing and Human Machine Interaction An Approach to Cognitive Engineering, Amsterdam; North Holland.

Reason, J. (1990). Human Error. Cambridge: Cambridge University Press.

Rempel, J. K., Homes, J. G., & Zanna, M. P. (1985) Trust in Close Relationships. Journal of Personality and Social Psychology, 49, (1), 95-112.

Rentsch, J. R., Heffner, T. S. & Duffy, L .T. (1994). What you know is what you get from experience: Team experience related to teamwork schemas. Group & Organisation Management, 119, (4), 450-474.

Roberts, A., Stanton, N. A., Ashleigh, M. J., & Xu, F. (1999). The Perceptual Salience of Control Interface Symbols in a Binary Discrimination Task'. ESRC Virtual Society project, Human Supervisory Control in Virtual Environments. Report No. 4, Psychology Department,University of Southampton.

Rosen, N. (1989). Teamwork and the Bottom Line. Hillsdale, NJ: Lawrence Elbaruam Associates.

Rotter, J.B. (1967). A new scale for the measurement of interpersonal trust. Journal of Personality, 35, 651-665.

Rotter, J. B. (1980). Interpersonal trust, trustworthiness, and gullibility. American Psychologist, 35, 1-7.

Rouse, W., Cannon-Bowers, B., Janis, A. & Salas, E. (1992). The role of mental models in team performance in complex systems. IEEE Transactions on systems; man and cybernetics, 22, (6), 1296-1308.

Salas, E., Montero, R. C., Glickman, A. S. & Morgan, B. B. (1988). Group development teamwork skills, and training. Paper presented at the American Psychological Association Meeting, Atlanta, Georgia

Sharpiro, D., Sheppard, B .H. & Cheraskin, L. (1992). Business on a handshake. Negotiation Journal, 8, (4), 365-377.

Shapiro, S. P. (1987). The social control of impersonal trust. American journal of Sociology, 93, 623-658.

Shaw, R. B. (1997). Trust in the balance; Building successful organisations on results, integrity and concern. San Francisco: Jossey-Bass.

Sheridan, T. (1988). Human and computer roles in supervisory control and telerobotics: musings about function, language and hierarchy. In: L .P. Goodstein, H. B. Andersen & S. E. Olsen (Eds.), Tasks, Errors and Mental Models. London: Taylor & Francis.

Sitkin, S. B., & Roth, N. L. (1993). Explaining the limited effectiveness of legalistic 'remedies' for trust/distrust. Organisational Science, 4, 367-392.

Stack, L. (1978) Trust. In: H. London & J.E. Exner, Jr. (Eds.), Dimensions of personality, (pp. 561-599). New York: Wiley.

Stammers, R. J., & Hallam, J. (1985). Task allocation and the balance of load in the multiman-machine system: some case studies. Applied Ergonomics, 16,: 251-257.

Stanton, N. A., & Ashleigh, M. J. (2000). A field study of team working in a new human supervisory control system. Ergonomics, 43, (8), 1190-1209.

Stanton, N. A., Ashleigh, M. J., Roberts, A. D., & Xu, F. (2001). Testing Hollnagel's contextual control model: Assessing team behaviour in a human supervisory control task. International Journal of Cognitive Ergonomics, 5, (1), 21-33.

Stewart, V. & Stewart, A. (1981). Business Applications of Repertory Grid. London: McGraw Hill.

Stout, R. J., Cannon-Bowers, J. A., Salas, E. & Morgan, B. B. Jr. (1990). Does crew co-ordination behaviour impact performance? In: Proceedings of the. 34th Annual Meeting Human Factors Soc., (pp. 1382-1386).

Tabachnick, B. G., & Fidell, L. S. (1996). Using Multivariate Statistics. (Third ed.). New York: Harper Collins.

Tajfel, H., & Turner, J. (1979). An integrative theory of inter-group conflict . In: W. G. Austin & S. Worchel (Eds.), The social psychology of inter-group relations, (pp. 33-47). Pacific Grove, CA: Brooks/Cole.

Thompson, J. D. (1967). Organisations in action. New York: McGraw- Hill.

Tuckman, B. (1965). Development sequence in small groups. Psychological Bulletin, 63, 384-99.

Turner, J.C. (1982). Towards a cognitive redefinition of the social group. In: H. Tajfel (Ed.), Social identity and Intergroup Relations. Cambridge: Cambridge University Press.

Tyler, T. R., & Kramer, R. M. (1996). Whither Trust? Trust in Organisations: Frontiers of theory and research, London: Sage Publications:

Valley, K., Neale, M. & Mannix, B. (1995). Friends, lovers, colleagues, strangers: The effects of relationship on the process and outcome of negotiation. In: R. Bies, B.H. Sheppard, & R.J. Lewicki (Eds.), Research on negotiation in organisations.5, 65-94, Greenwich, CT: JAI.

Vicente, K. J. (1997). Interface Design: Is it always a good idea to design an interface to match the operator's mental model?' Ergonomics Australia On-line 22, (2).

Vicente, K. J., Christoffersen, K., & Pereklita, A. (1995). Supporting Operator Problem Solving Through Ecological Interface Design.. IEEE Transactions on Systems, Man and Cybernetics, 25, (4).

Venturino, M. & Eggemeir, F. T. (1988). Special Issue Preface. Human Factors, 30 (5), 535-538.

Walther, J. B. & Burgoon, J. K. (1992). Relational Communication in Computer-Mediated Interaction. Human Communication Research, 19, (1), 50-88.

Wellens, A. R., (1993). Group situation awareness and distributed decision making: From military to civilian applications. In J. Jr. Castillian (Ed.), Individual and group decision making, current issues. London:Lawrence Erlbaum Associates.

Wellens, A. R. & Ergener, D. (1988). The C.I.T.I.E.S. game: A computer-based situation assessment task for studying distributed decision-making. Simulation and Games, 19, 304-327.

Wellens, A. R., (1989a, June 16). Effects of communication bandwidth upon group and human-machine situation awareness and performance. Medical Research Laboratory. Wright-Patterson Air Force Base, OH: Armstrong Aerospace.

Wickens, C. D., (1992). Engineering psychology and human performance. New York (NY): Harper Collins.

Wiener, E. L. & Curry, R. E. (1980). Flight-deck automation: promises and problems, Ergonomics, 23, 995-1011.

Wilson, J. R., & Rajan, Jane, A. (1995). Human-machine interfaces for systems control'. In R. J. Wilson & E. M. Corlett (Eds.), Evaluation of Human Work: A practical ergonomics methodology. London: Harper Collins.

Williams, B. (1988). Formal structures and social reality. Trust: Making and Breaking Co-operative Relations. New York: Basil Blackwell.

Williamson, O. E. (1993). Calculativeness, trust, and economic organisation. Journal of Law and Economics, 34, 453-502.

Woods, D., Wise, J., & Hanes, L. (1981). An evaluation of nuclear power plant safety parameter display systems. In R.C. Sugarman (Ed.), Proceedings of the 25th annual meeting of the Human Factors Society. Santa Monica, CA: Human Factors Society.

Xu, F., Stanton, N.A., Roberts, A., & Ashleigh, M.J. (1999). Levels of application for energy distribution systems. ESRC Virtual Society Program, Report No. 5 (grant reference: L132251038).

Zand, D. E. (1972). Trust and managerial problem solving. Administrative Science Quarterly, 17, 229-239.

Zenger, J. H., Musselwhite, E., Hurson, K., & Perrin, C. (1994). Leading teams: Mastering the new role. New York:Irwin.

Zwaga, H. J. G. & Hoonhout, H. C. M. (1994). Supervisory control behaviour and the implementation of alarms in process control. In N. A. Stanton (Ed.), Human Factors in Alarm Design. London: Taylor & Francis.