Training decision making using serious games

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Contents

1 Executive Summary

Decision making is central to all military operations both in terms of mission success and also the safety of personnel and equipment. The importance of training decision making in the military cannot be underestimated, whether it be for those undertaking the highest levels of command and control through to personnel on the ground engaged in combat and peacekeeping operations.

Decision making has been researched from a number of paradigms, including the classical decision making approach which advocates a logical, rational, analytical approach to decision making suited to military planning, and naturalistic decision making which reflects decision making in uncertain and dynamic military operational environments. Decision making is not a single entity. Six decision event types have been identified which vary according to how well a decision making problem is defined, and whether options exist or need to be created.

Decision making may be improved through training or structuring decision making. Whilst it is not possible to provide generic decision making training, a number of trainable decision making skills have been identified including situation awareness, metacognition and resource management, in addition to specific skills which can be trained according to the different decision event types.

Well developed serious games which leverage the properties of games, digital games, and simulation appear to present exciting opportunities for creating immersive experiential learning environments for decision making training, enabling students to become active learners in a safe benign environment, but one which encourages them to take risks and explore the solution space, with the benefit of immediate feedback, and subsequent review of performance.

Whilst there are a number of serious games designed for the military which train decision making in specific contexts, there are currently no serious games designed specifically to train decision making skills to enhance performance of the six decision making strategies identified by Orasanu (1993). It is recommended that a serious game to train decision making skills to enhance the performance of the six decision making strategies identified by Orasanu (1993) be developed. Work has already commenced with an initial evaluation of the suitability of different commercial games for re-purposing as serious decision making training game. It is recommended that this is now developed into a more extensive study using proficient computer games players as subject matter experts

There have been a number studies which have demonstrated that serious games accelerate learning and support the development of higher level cognitive skills. However, there is a paucity of empirical evidence demonstrating the learning benefits of serious games and demonstrating behavioural change in the operational environment. It is recommended that every opportunity be taken to evaluate serious games.

2 Introduction

2.1 Military decision making

'*An essential component of expertise in military command and control is the ability to make and implement decisions in a timely, efficient and effective manner, most often with very limited information, in an increasingly fluid and multidimensional battle space*' (Serfaty, MacMillan, Entin and Entin, 1997). Serfaty et al were commenting on Army battle-field command and control, but complex decision making environments are not the sole preserve of the Army. Military pilots frequently combine a psychomotor flying task with delivering weapons, troops or equipment (Kaempf and Orasanu, 1997), or intercepting and attacking enemy aircraft, which require skilled real-time decision making ability. Similarly the submarine commander undertakes rapid decision making based on limited information gathered for example from the attack periscope, upon which decisions must be made on the identity of other vessels and any attacking action, whilst maintaining the safety of the boat and her crew.

Across the armed forces, operational, strategic and tactical decisions are taken on a daily basis, which determine mission success and the safety of personnel and equipment. The change in the nature of warfare from fighting a cold war enemy with a fairly well known military doctrine, to asymmetric warfare incorporating terrorism with no doctrine or history to study, also presents new decision making challenges for the highest levels of command and control through to personnel on the ground either engaged in combat or peacekeeping operations.

Decision making is at the centre of all military operations and as such the requirement for training in military decision making cannot be underestimated. However, there is no evidence to indicate that it is possible to provide generic decision making training. Orasanu (1993) identified six different decision making strategies, the application of each depending on the structure of the decision task and surrounding conditions; how well the decision problem is defined; familiarity with the problem; whether a response is prescribed or needs to be generated; how many options are readily available; the clarity of the nature of the problem; and the availability of time (Orasanu and Fischer, 1997), and each requires specific skills to be developed.

2.2 Training decision making

It is widely acknowledged that decision making training needs to be taught in an environment in which the decision maker can learn experientially. However, live training is expensive and it is argued that a novice decision maker will not gain as much from live training as a more experienced decision maker due to their undeveloped ability to recognise prototypical events from contextual cues, it may not be appropriate for a novice to be making decisions in certain situations, and feedback may be limited since it may not be practical or safe to witness the outcome of decisions made.

2.3 Serious games

Serious games, which are developing rapidly for military training by virtue of leveraging commercial off the shelf games technology, appear to present a viable media for training decision making in that well designed games can provide immersive experiential learning environments in which students can develop decision making skills such as cue pattern recognition, situation awareness, handling negative information, resource management etc. Serious games provide a low cost benign environment within which students can take risks, explore options, and can learn from their actions, with the benefits of immediate feedback from the game and comprehensive after action review.

This report provides a review of the literature on decision making, decision making error and improving decision making through training and structuring. It then reviews games, and serious games before beginning to develop a requirement for a serious decision making game (or games) to develop the skills needed to enhance decision making performance for Orasanu's (1993) six decision making event types.

3 Decision Making

3.1 Introduction

Decision making is a broad topic that has been on the research agenda since the mid eighteenth century (Edwards, 1954). During this time decision making has been investigated using a number of approaches which have yielded numerous models and a wealth of research. As a result, decision making can be seen in terms of the decision making event, i.e. the choice between two or more alternatives, one of which may, of course, be to do nothing (Lehto and Nah, 2006), or in terms of the process that leads to the commitment to an action, the aim of which is to produce satisfying outcomes (Yates, 2001). These two simple definitions differentiate the focus of two contrasting paradigms, whose work is relevant to military decision making, Classical Decision Making (CDM) and Naturalistic Decision Making (NDM). CDM is seen to focus on the decision event and on normative prescriptions that guide people to make optimal decisions. In contrast NDM, focuses on how experienced people actually make decisions in dynamic, uncertain environments (Zsambok, 1997), and on the broader task in which a decision event is embedded.

The NDM approach focuses on experienced decision making in dynamic, uncertain environments and so is ideally suited, for example, to the military decision making examples presented in Section 2. Indeed NDM has its roots in military, first person responder and safety critical industry decision making research domains. However, it is the case that the more analytical/rational approaches from the CDM paradigm have a role in military decision making especially during the planning stages of operations, when the Combat Estimate comes into play. The CDM approach is also important for drawing attention to the use of heuristics and biases in decision making. Accordingly, this section of the report provides a review of the CDM and NDM approaches to decision making and then considers decision making error, and provides a discussion on improving decision making.

3.2 Classical decision making paradigm

The classical concept of prescriptive, analytical decision making was introduced to the field of psychology by Edwards in 1954 (Beach and Lipshitz, 1993). Classical decision making theory has its roots in the normative decision making models of economics and statistics which specify optimal decision solutions (Lehto and Nah, 2006). Classical models are, therefore, seen as the text book ideal processes to follow when making a decision (Lehto and Nah, 2006). Allied to this ideal is the classical decision making view of the decision maker or 'Economic Man', who is seen as being completely informed, infinitely sensitive and rational (Edwards, 1954). This concept of rationality is central to classical decision making. Buchannan and Huczynski (2004, p.740) define rationality as *'the use of scientific reasoning […] and the use of decision criteria of evidence, logical argument and reasoning'*. With this notion of rationality a decision maker is seen to act logically about a decision being taken, first formally recognising and describing what is known about the decision problem (Lehto and Nah, 2006) by means of a process of information collection, and analysing options by applying principles of utility (i.e. utility theory, including subjective or multiattribute utility theories) and uncertainty and risk (i.e. probability theory, including Bayesian Inference) (Beach and Lipshitz, 1993) to choose an optimal solution from a range of alternatives.

Principles of utility are accounted for in preference and choice models which are characterised by a set of four elements which are used to represent a decision. They include a set of potential actions; a set of events; a set of consequences for each combination of action and event; and a set of probabilities for each combination of action and event. Decisions are then represented in terms of these elements, after which choices are made between alternatives by applying decision rules which are based on basic axioms, or assumptions, of rational choice. Two of the best known decision rules are Subjective Utility Theory (SUT) and Multiattribute Utility Theory (MAUT). Subjective utility theory describes how people make decisions under uncertainty, and works by weighing the utility of outcomes against their probability of occurrence, whereas Multiattribute Utility Theory extends Subjective Utility Theory to a situation when the decision maker has multiple objectives. Both SUT and MUAT are normative approaches.

Principles of uncertainty and risk are accounted for in statistical models which are adopted by decision makers to determine whether a hypothesis about the world is true (Lehto and Nah, 2006). Past and present states of the world are diagnosed, from which inference is then made to determine future states.

The stages of rational economic decision making are clearly articulated by Janis and Mann (1977) who have identified seven ideal criteria for vigilant information processing, which they argue will enable decision makers to have a better chance of attaining their objectives.

'The decision maker, to the best of his ability and within his information processing capabilities

1. *Thoroughly canvasses a wide range of alternative courses of action;*

2. *Surveys the full range of objectives to be fulfilled and the values implicated by the choice;*

3. *Carefully weighs whatever he knows about the costs and risks of negative consequences, as well as the positive consequences, that could flow from each alternative;*

4. *Intensively searches for new information relevant to further evaluation of the alternatives;*

5. *Correctly assimilates and takes account of any new information or expert judgement to which he is exposed, even when the information or judgement does not support the course of action he initially prefers;*

6. *Re-examines the positive and negative consequences of all known alternatives, including those originally regarded as unacceptable, before making a final choice; and*

7. *Makes detailed provisions for implementing or executing the chosen course of action, with special attention to contingency plans that might be required if various known risks were to materialise.'*

(Janis and Mann, 1977, p.11).

Janis and Mann's rational economic model is useful in helping to understand the workings of the classical approach. The model assumes that the decision maker wants to achieve an optimal outcome and, therefore, emphasises the need for the decision maker to act rationally through the seven criteria to attain his objective. It is clear from the model that the classical approach assumes that the decision maker has access to complete and reliable information concerning all aspects of the decision being taken, and that the decision maker can process all of the information needed to define the problem, so that it is clear and unambiguous. Further, it assumes the decision maker will be able to identify all possible solutions to the problem, is aware of their consequences, and can evaluate them by means of applying weightings to decision options. It can also be implied from the model that the decision maker is not time constrained in undertaking the decision making process.

The classical rational approach is useful under certain conditions. For example Drillings and Serfaty (1997) suggest that when there is sufficient information about a situation and alternative courses of action, and the implications of these courses of action are known, a decision maker may hold adequate information to adopt a rational approach, i.e. multiattribute utility theory. However, they point out that in a battle situation it is rare to hold complete information and time constraints may preclude a full application of rational choice methods.

From an experimental study of command and control decision making, Pascual and Henderson (1997) found that experienced decision makers made greater use of naturalistic decision approaches than analytical ones. However, the decision making scenarios used in the study were familiar to the decision makers, which would have enabled them to draw on past experience, leading Pascual to argue that with more novel situations there would have been greater utilisation of classical approaches, due to a lack of experience with the situations, and an absence of typicality. So, when a decision maker has little experience of the decision making domain, holds full information, has clear goals, and time pressure is low, the classical decision making approach would appear to be well suited to building up his professional domain knowledge and expertise. Similarly, when the cost of evaluating alternatives is low, and problems are simple with relatively few decision options, the rational model provides an accurate description of the decision process (Robbins, 2003).

The CDM approach is, however, criticised for being too highly reliant on laboratory experiments designed to reach an optimal solution. It is argued that they prescribe how decision makers should behave if they acted rationally and were completely informed, but they do not explain how people actually behave when making decisions. For example, Klein, Calderwood and McGregor (1989) observed that decision makers in difficult situations and under stress did not appear to use classical approaches despite having been trained in analytical decision making. Other authors suggest that rational approaches do not meet the needs of the decision maker, for example, Drillings and Serfaty (1997) argue that the use of classical analytical tools do not represent what commanders do, or want to do, in the command process. Instead decision makers perform tasks that are analytically correct. It has also been argued, that adhering to rational approaches may be detrimental to command decision making. For example, a recent review of the Perisher (submarine command course) noted that analytical decision making is often undertaken by submarine commanders. However, the study authors identified that those who struggle on the Perisher course were those who were often solid analytical decision makers who perceived certainty with their methodology (Casciano, Elsensohn, Jensen, Mulholland, Richardson and Slater, 2005), whereas good commanders were seen as those who also made use of more intuitive methods.

From the above discussion it is evident that classical approaches assume that problems are well defined, information is structured in a clear and accessible format, time is adequate, and decision makers have full information on the background, objectives, alternative courses of action and range of possible consequences. These assumptions are feasible for laboratory based studies, however, a reliance on laboratory experiments has led to the criticism that classical approaches do not take into account the effects of real-world contextual factors and their influences on decision making (Zsambok, 1997). For example, in a dynamic environment, an evaluation of the pros and cons of each option may be impractical due to time constraints, a decision maker may not be aware of all possible alternatives, and the consequences and the quality of outcomes may not be known until after the event (Thunholm, 2004). Rather than having access to perfect information, Kirschenbaum (2001) points out that in the field, information is often ambiguous, unreliable, and difficult or time consuming to obtain, and in the case of the military may be deliberately distorted. It is also possible that information may not reach the decision maker (Flin, Slaven and Stewart, 1996), or that the decision maker may be constrained by time.

Classical rational approaches also assume that the decision maker seeks to optimise the outcome of choice (Orasanu and Connolly, 1993). Whilst this may be the objective of some decision making contexts, it may be that all that is sought is a ‘good enough’ choice. Indeed, Simon (1955) argues that the information processing requirements of rational decision making exceed limited human cognitive capacities, necessitating the use of heuristics to reduce cognitive load and speed up decision making, and as a result decision makers seek satisfactory rather than optimal decisions.

Simon (1956) argued that decision makers do not operate within the confines of perfect rationality, instead they make decisions by simplifying models that extract the essential elements of the problem, without their full complexity, i.e. individuals operate within a ‘*bounded rationality’*. According to Huczynski and Buchanan (2001) bounded rationality acknowledges that the definition of the problem is likely to be incomplete; it is impossible for the decision maker to generate all of the possible alternatives; the decision maker cannot predict the consequences of each of the alternatives; and final decisions may be influenced by personal and political factors.

An implication of bounded rationality is that decision makers are *satisficers* rather than maximisers, as implied by the rational decision making model. Satisficing means that decision criteria and alternatives are developed within the confines of a simplified model. These alternatives are then reviewed in light of previous experiences and current knowledge. Satisficers do not perform a full review of alternatives, but they continue until a 'good enough' alternative is identified (one that is satisfactory or sufficient). A downside to this approach, however, is that the best option may never get to the evaluation stage.

There are a number of heuristics used in making decisions under uncertainty, from which Tversky and Kahneman (1974) identified three particularly common principles *'which reduce the complex task of assessing probabilities and predicting values to simpler judgemental operations'* (Tversky and Kahneman, 1974, p. 1124): (i) representativeness, (ii) availability, and (iii) adjustment and anchoring. However, although cognitively efficient a consequence of using heuristics is that they can result in systematic and predictable errors as a result of cognitive biases.

The representativeness heuristic is the tendency to judge someone or something according to how representative it appears to be of a particular category, i.e. *'probabilities are evaluated by the degree to which A is representative of B […]. When A is highly representative of B, the probability that A originates from B is judged to be high [… and conversely] if A is not similar to B, the probability that A originates from B is judged to be low'* (Tversky and Kahneman, 1974, p. 1124). Huczynski and Buchanan (2001) describe it as how well an item represents or matches a prototype. However, Tversky and Kahneman (1974) identified that this heuristic leads decision makers to ignore relevant information through being insensitive to base-rate frequencies of outcomes; sample size; chance and predictability; by holding illusions of validity; and insensitivity to predictability; the illusion of validity; and misconceptions of regression.

The availability heuristic is the tendency to consider an instance or event as being more probable if it can be easily imagined, as opposed to being difficult to bring to mind, with *'instances of large classes […] usually recalled better and faster than instances of less frequent classes'* (Tversky and Kahneman, 1974, p. 1127). However, availability is affected by more than just frequency or probability, and as such the heuristic can lead to systematic biases/errors. The retrievability of instances; the effectiveness of a search set; imaginability; and illusory correlation are all biases to which the availability heuristic leads the decision maker.

There is evidence that when additional information is received, or even when decision makers actively seek further information, that there is a tendency to give more weight to evidence that is consistent with their initial hypothesis (or 'anchor') than to contrary information. Anchoring, therefore, seems to represent a sort of 'primacy' in memory, and the biases associated with it include making insufficient adjustment, or making inappropriate calibrations.

Reason (1990) reports two further common biases: over confidence bias and confirmatory bias. When a decision maker remains uncertain about his assessment he will tend to seek more information. However, there is a considerable amount of evidence that suggests that people are in general overconfident in the correctness of their diagnosis, hypothesis formation, and action selection. If the decision maker is more confident than is justified then it is likely that she will prematurely close off her search for information. Wickens and Hollands (2000) argue that overconfidence bias is strong and pervasive.

Confirmatory biases occur when a decision maker seeks information and cues that confirm their tentative hypothesis, yet fails to seek (or discount) information that supports a contrary view (Wickens and Hollands, 2000). Research has shown that when cues are ambiguous and not amenable to diagnosis then decision makers will interpret the data to support their hypothesis, and decision makers have been shown to fail to encode or process negative information i.e. information inconsistent with their initial hypothesis. Wickens and Hollands (2000) provide three reasons for decision makers failing to take account of negative information: (i) people have greater cognitive difficulty dealing with negative, rather than positive information (Clark and Chase, 1972 cited in Wickens and Hollands, 2000); (ii) changing a hypothesis requires greater cognitive effort than maintaining the search for information consistent with the original hypothesis; and (iii) the decision makers diagnosis may influence the outcome of the action, thereby creating a false 'self fulfilling prophecy' (Einhorn and Hogarth, 1978, cited in Wickens and Hollands, 2000).

Whilst it could be easy to form the opinion that the heuristics and biases paint a dim view of human decision making, heuristics are economical and usually effective, especially in pressured, uncertain contexts, when more time consuming rational analytical approaches could not be used (Klein, 1997c). In addition, having an understanding of the different types of systematic decision making biases makes it possible to suggest '*training, procedural, and design remediations, which can lessen their degrading impact on diagnosis in the circumstances when those impacts may be severe or safety compromising'* (Wickens and Hollands, 2000, p.314).

3.3 Naturalistic decision making paradigm

The naturalistic decision making (NDM) framework it the most recent decision making paradigm. It was initiated in 1989 at a conference sponsored by the Army Research Institute for researchers who had stepped away from the classical paradigm, and were studying the cognitive processes that underlie *'the way people use their experience to make decisions in [dynamic] field settings'* Zsambok (1997, p.4). Unlike the economists and statisticians of the CDM approach, the conference attendees were predominantly psychologists from the domains of military command and control, emergency services, aircraft cockpit research, and safety critical industries. From their research a number of coherent themes were identified, which for all intents and purposes define the scope of the NDM paradigm.

The themes identified were codified by Orasanu and Connolly (1993) and included: (i) ill structured problems; (ii) uncertain dynamic environments; (iii) shifting, ill-defined, or competing goals; (iv) action/feedback loops; (v) time stress; (vi) high stakes; (vii) multiple players; and (viii) organisational goals and norms. These features are seen to complicate the decision task, albeit that it would be unlikely that extremes of each factor would present themselves at any one time. However, as noted in the criticism of the CDM paradigm above, they are frequently absent in CDM research.

Ill structured problems. Unlike the assumptions of the CDM approach, naturalistic decision problems rarely present themselves in a *'neat, complete form'* (Orasanu and Connolly, 1993, p.7), which means that decision makers need to generate hypotheses about what is happening before they can determine whether or not the situation is one where a decision is required, and before they can generate response options, i.e. the decision maker requires situational awareness to assess the nature of the problem. However, acquiring this can be complicated by causal links and interactions between the observable features of the situation. There may also be several equally good ways of solving a problem, requiring the decision maker to select, or even invent an approach.

Uncertain dynamic environments. Naturalistic decision making is typified by incomplete information, i.e. a decision maker may hold information concerning only part of a problem. Information may also be imperfect, i.e. it is of poor quality or may come from an ambiguous or unreliable source. A dynamic, changing environment may also mean that information rapidly becomes out of date.

Shifting, ill-defined, or competing goals. Outside of a laboratory environment, decisions driven by a single and well understood goal are rare. More commonly, decision makers are driven by multiple goals, some of which may not be clear, and some may directly oppose others which can lead to conflict between goals, resulting in goals having to be traded, one for another. However, it may not always be clear what the trade off should be. These conflicts and trade-offs may be made more complex by virtue of the dynamic environment in which they exist, since as a situation changes new goals emerge or goal priorities may shift.

Action/feedback loops. Unlike the CDM approach which focuses on a single decision action, it is more common in naturalistic decision making to encounter a series of decision actions, which may be iterative in nature, through which a decision maker deals with a problem or establishes more about it, with feedback loops serving to benefit the decision maker.

Time stress. A noticeable feature of naturalistic settings is that decisions may be made under significant time pressure. As a result, decision makers often experience high levels of personal stress, which may lead to exhaustion or loss of vigilance. Orasanu and Connolly also suggest that time stress may lead to decision makers opting for less complicated reasoning strategies, i.e. moving away from time consuming sequential evaluations of multiple options such as advocated by the CDM approach, towards a serial evaluation of a limited number of options, as illustrated in Simon’s satisficing model (Simon, 1956).

High stakes. Making a decision in a naturalistic environment may have particularly high stakes attached, such as financial loss or the potential loss of one’s own life or the lives of others and it is, therefore, a feature which can be readily envisaged in a military context. Although the stakes attached to decision making may not always be quite so high, Orasanu and Connolly (1993) stress that when individuals in a naturalistic environment have a stake in the outcome they may become more invested in the task than perhaps they would in a laboratory environment.

Multiple players. Many of the decision making problems in a naturalistic environment involve more than a single decision maker. A decision making team may comprise a number of individuals co-located or geographically disparate, who may act co-operatively or competitively with each other in achieving goals. This presents challenges in terms of ensuring that team members have a shared situational awareness and an understanding of the goals in order that information needed to make decisions is brought forward when needed.

Organisational goals and norms. Finally, Orasanu and Connolly (1993) suggest that naturalistic decision making often takes place in organisational settings. Accordingly, decision making goals will reflect the goals of an organisation in addition to those of the individual decision makers, and certainly in terms of a military context, decision making approaches may be enshrined in standard operating procedures or service doctrine.

It is evident from the above summation of the underpinning features of NDM research that *'decisions are embedded in larger dynamic tasks, made by knowledgeable and experienced decision makers'* (Orasanu and Connolly, 1993, p.19). It also *'relocates the study of decision making and makes it part of the study of action rather than a study of choice'* (Brehmer, 1990, p.26, cited in Orasanu and Connolly, 1993).

More recently, the emphasis of the NDM paradigm has shifted from a focus on naturalistic or field settings to a focus on the use of experience by decision makers (Pruitt, Canon-Bowers and Salas, 1997), which has led to a richer definition of NDM: *'the study of NDM asks how experienced people, working as individuals or groups in dynamic, uncertain, and often fast-paced environments, identify and assess their situation, make decisions and take actions whose consequences are meaningful to them and to the larger organisation in which they operate'* (Zsambok, 1997, p.5). The NDM approach thus places *'the human (and hence boundedly rational) proficient decision maker at its centre of interest [. . .]'* (Lipshitz, Klein, Orasanu and Salas, 2001, p.333). Rather ironically, with the shift in focus to the experienced decision maker there are also calls, such as from Klein (1997a), for methods that can ensure that naturalistic decisions can be studied in more controlled settings.

In essence, therefore, there are four defining markers for NDM research. These are given by Zsambok (1997) as: (i) the task and task setting (cf Orasanu and Connolly, 1993); (ii) the research participants are experienced decision makers, rather than being naïve; (iii) the purpose of NDM is to discover how people actually make decisions in naturalistic environments, not how they should make decisions according to a prescribed standard; and (iv) interest focuses on the decision episode, including situation awareness, not just choice selection.

Emanating from the NDM perspective are a number of models. Lipshitz (1993) described nine different NDM models, which he classified as either processing models, i.e. models which describe the sequences of decision making phases, or topological models which classify decision process as either intuitive or analytical, and describe the conditions under which intuitive and analytical decision processes should be used. Lipshitz (1993) found that all nine models included elements of situation assessment, which he defined as *'the sizing up and construction of a mental picture of the situation'* (Lipshitz, 1993, p.132), contributing either to action selection or initiating a process of evaluation of alternatives.

Although the number of models that fall within the NDM framework has increased as the paradigm has evolved, according to Lipshitz et al (2001, p.335) the '*Recognition Primed Decision Making [RPD] can serve as the prototypical NDM model*'.

Klein, Calderwood and Clinton-Cirocco (1986) observed that experienced decision makers did not undertake a concurrent evaluation of decision options. Instead experienced decision makers maintained situational awareness, recognised the situation as an example of a past event and acted without conscious awareness of having made a choice, rarely reporting having considered more than one option in making a time critical decision. Klein et al (1986) identified that what defined experienced decision makers was their situational awareness, and that this formed the basis of their ability to recognise prototypical events. As a result, Klein et al (1986) proposed a Recognition Primed Decision (RPD) Model to account for their findings. The model takes account of an assessment of the situation which is matched to a prototype based on the similarity of goals, perceptual cues and knowledge of causal factors. The prototype generates expectancies in terms of which goals make sense, and what cues to expect, and generates a set of options, with the most typical option being generated first. This action is evaluated for plausibility using mental simulation, and is either implemented, modified or rejected. If it is rejected, the next most typical option is then selected for evaluation.

The RPD model accounts for three levels of complexity in decision making cases (Klein, 1993a), and is shown in Figure 3-1. With the simplest case the decision maker recognises the situation and obvious solutions are implemented. With a more complex case the decision maker performs some conscious evaluation of the solution, typically using imagery to uncover problems prior to carrying it out. With the most complex case, the decision maker's evaluation of the situation reveals that the solution requires modifications, or is judged inadequate and rejected.

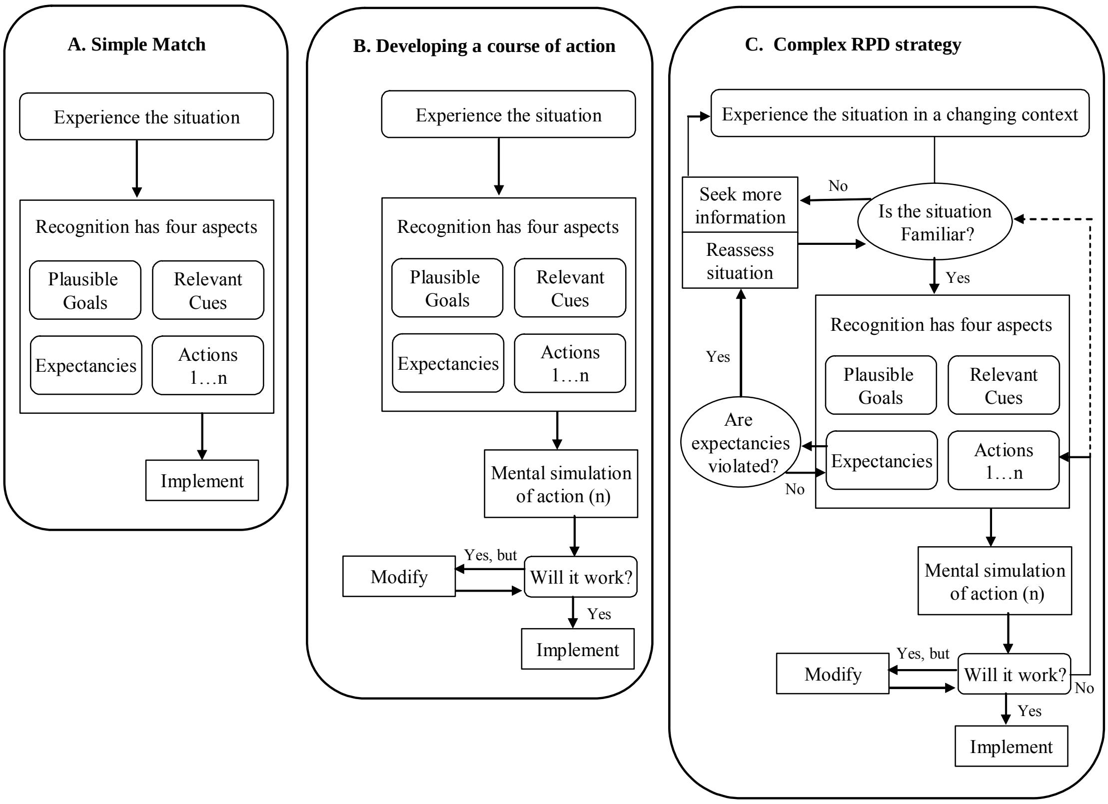

Figure 3-1 ***Recognition-Primed Decision Model (Klein, 1993a)***

It is evident from the above description that RPD encompasses serial evaluation of options, rather than concurrent evaluation of options, which was favoured by the CDM approach, and which would be impossible in a time critical decision making. RPD is, therefore, consistent with Simon's (1955) notion of satisficing (Klein et al, 1986), in that experienced decision makers do not typically work to ensure an optimal decision, merely a workable one (which may be the first action they consider). It also shows the positive contribution of the availability and representativeness heuristic (Klein, 1997b) as well as demonstrating that it is situational awareness that defines an experienced decision maker.

Despite the appeal and broad applicability of the RPD model, experienced decision makers do not appear to use an RPD approach all the time (Orasanu, 1997). Even in naturalistic high pressure environments, experts may use different styles of decision making (Flin, Salas, Strub and Martin, 1997). An examination of a set of decision episodes from the Aviation Safety Reporting system (ASRS) database and National Transportation Safety Board (NTSB) accident investigations by Orasanu and Fischer (1997) indicated systematic variations in the decision strategies used by experienced pilots, which appeared to reflect variations in the situations to which the pilots were responding (Orasanu, 1997).

Decision strategies differ according to the structure of the decision task, and surrounding conditions; how well the decision problem is defined; familiarity with the problem; whether a response is prescribed (rule based) or needs to be generated (knowledge based); how many options are readily available; the clarity of the nature of the problem; and the availability of time Orasanu and Fischer (1997). Orasanu (1993) identified six different types of decisions, and these are shown in Figure 3-2.

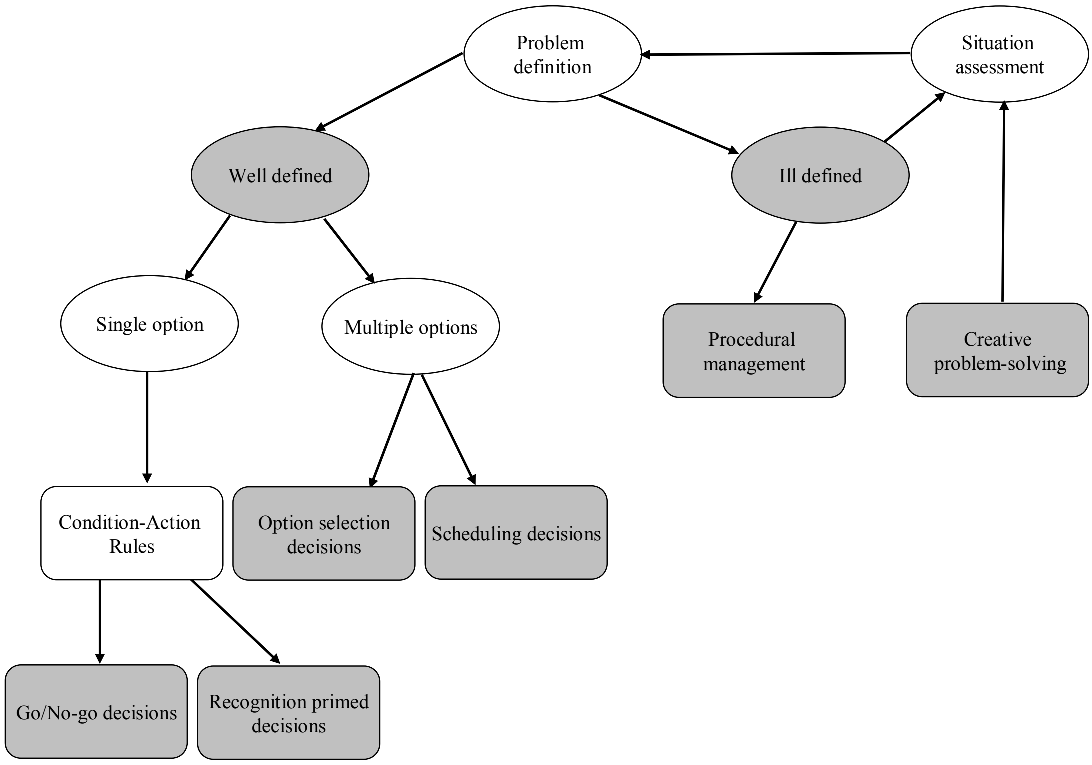

Figure 3-2 - Taxonomy of decision types (from Orasanu, 1993)

The different decision types can be defined in terms of the properties of the situation in which they need to be applied:

Go, no-go decisions. An action is anticipated, or in progress, and a cue triggers a decision to terminate that action.

Recognition-primed decisions. Decision makers interpret a cue pattern as a particular type and match it with an action according to standardised procedures.

Option/response selection decisions. Several legitimate options/actions are available which the decision maker needs to evaluate in terms of the specific requirements of the problem, and from which one option needs to be selected for action.

Resource management decisions. The decision maker needs to co-ordinate several time consuming tasks so their products are available when required.

Procedural management. Typically a decision maker faces ambiguous high risk situations requiring a diagnosis of the problem, and can then act according to standardised procedures.

Creative problem solving. A decision maker is first required to diagnose and define a problem, and then needs to create an action to meet the needs of the situation since no specific guidance (i.e. standard operating procedures, manuals or checklists) is available to guide the decision maker.

It can be readily identified that the six decision categories increase in complexity from go-no-go decisions through to creative problem solving.

An analysis of Orasanu and Fischer's (1997) study shows that of decision episodes included in the ASRS and NTSB accident investigations databases, 40.5%, were recognition-primed, 36% were option/response selection decisions and 13.5% were go, no-go decisions. In addition, 4% were scheduling decisions; 3% were procedural management decisions; and 2% were creative problem solving decisions. It does have to be borne in mind, however, that the distribution of the decision events will be dependent upon the decision making situation and the nature of the decision maker.

It is evident from the previous review of classical and naturalistic decision making literature that although the two paradigms approach decision making in very different ways, yet both approaches are relevant to military decision making and so need to be viewed as coexisting rather than conflicting. The CDM approach, which advocates a rational, analytical and logical approach to decision making is wholly appropriate during planning stages of operations, where time and information exist in sufficient quantity to engage in a rational decision making approach, or where there is a need to resource such an approach. The NDM approach, on the other hand, would appear to fully reflect the operating environment of much military decision making, such as high stakes, high tempo, high stress, uncertain and dynamic decision making environments.

Orasanu's (1993) decision event taxonomy makes it clear that decision making is not a singularity, but comprises a number of decision making event or strategy types according to the structure of the decision making task, how well the problem is defined, whether options exist or need to be created, and the nature of the decision maker. These six different event types would apply broadly across military decision making and could provide a robust framework to structure military decision making training.

4 Improving Decision Making

4.1 What are the common errors in decision making?

The disastrous launch in 1986 of the Space Shuttle Challenger (Vaughan, 1996), the accidental shoot down by friendly fire of two US Black Hawks over Northern Iraq killing 26 peacekeepers onboard (Snook, 2000), and the shooting down of an Airbus 300, Iran Air flight 655, by the USS Vincennes (Klein, 1999) can all be attributed to errors in decision making. Whilst the majority of day to day decisions do not result in such catastrophic outcomes, errors in human decision making are major causes of accidents in safety critical operations, for example in the aviation domain pilot decision errors were involved in 42.6% of military aviation accidents between 1978 and 2002 (Li and Harris, 2005), and Diehl (1991, cited in Orasanu, 1993) found that decision errors contributed to over 50% of accidents in the military and civil aviation industry between 1987 and 1989. In view of these indicative accident statistics, an understanding of decision making error would appear crucial to inform the design of complex interfaces and decision making training to reduce the instance of human decision making error and improve decision making performance.

Within the CDM paradigm, decision making errors are seen to have different causes according to the level of cognitive action involved (Rasmussen, 1993, cited in Lipshitz, 1997). At a skill based level, errors are related to variability of sensorimotor co-ordination (Reason, 1990). At the rule based level, which is applicable for dealing with problems where the solutions are governed by rules or productions, errors are typically associated with the misclassification of the situations leading to the application of the wrong rule (Reason, 1990). At the knowledge based level, the decision maker faces novel situations which require the formulation of goals and situation analysis, so errors are associated with inappropriate information search or inadequate reasoning (Lipshitz, 1997).

According to Reason (1990), knowledge based errors have two causes: incomplete or inaccurate information and bounded rationality. Associated with bounded rationality, of course, are the cognitive biases which were discussed in Chapter 3, which included: the availability heuristic (where undue weight is given to facts that come readily to mind, and those not immediately present are ignored); confirmatory bias (where a decision maker favours one interpretation and is reluctant to part with it, focusing on supporting evidence and failing to regard negative information); and overconfidence bias (where the information search is closed sooner than is warranted). The USS Vincennes incident noted above revealed the operation of the confirmatory bias, in failing to take into account contradictory (but correct) information, also provided by the radar system, which identified the inbound aircraft as neutral.

Orasanu's (1993) decision event taxonomy classifies decision events according to whether their action options are rule based or need to be generated. Accordingly, cognitive biases need to be borne in mind when considering the knowledge based decision making types. It is also highly relevant to bear these cognitive biases in mind when considering the Recognition Primed-Decision (RPD) model as similarity matching which underpins RPD is a heuristic, and is vulnerable to the biases noted above.

Klein (1997b) points out that one of the challenges for NDM research is accounting for errors. Unlike the CDM approach of using laboratory controlled experiments to detect and study systematic biases, which they attribute to limited cognitive processing capacity or inappropriate strategies, evaluating decisions in naturalistic contexts is difficult. *'There is often no clear standard of 'correctness' [. . . and] there is a loose coupling of event outcome and decision process so that outcomes cannot be used as reliable indicators of the quality of the decision'* (Orasanu and Martin, 1998, p.100). As a result the NDM paradigm seeks to move their understanding of error away from the cognitively biased individual decision maker to the systematic causes underlying outcomes (Orasanu, Martin and Davison, 2001). *'Bad outcomes are thus caused not by the failure of individuals but by the failure of systems'* (Lipshitz, 1997, p.155).

According to Orasanu and Martin (1998), and Orasanu, Martin and Davison (2001), there are two major ways in which errors may arise. Either decision makers make errors in their situational assessment which lead to the wrong decision, or they make errors in their action selection. Errors in situation assessment may arise through misinterpreting or ignoring cues, whereas errors in choosing a course of action may vary according to the type of decision strategy, i.e. errors with rule based decisions may depend on failing to retrieve a response from memory, or perhaps the response was not known. Errors with choice decisions again may result from failing to retrieve responses from memory, or the factors determining the adequacy or outcomes of the decision options may be unavailable. Lastly, creative decisions may be prone to error due to the absence of support, requiring the decision maker to invent a solution. Klein (1993b, cited in Orasanu et al, 2001) has analysed decision errors across a number of naturalistic domains and identified three causes of error: lack of experience; lack of information, and inadequate mental simulation, which lend support to the Orasanu and Martin (1998) and Orasanu et al (2001) and their two basic classes of error in naturalistic situations.

By combining an understanding of systematic cognitive biases, with an understanding of faulty situation assessment and faulty action selection, it should be possible to provide support for decision makers operating in dynamic naturalistic environments where they are known to be subject to decision error, either by behavioural means (such as training, checklists and procedures) or through the design of systems.

4.2 Previous attempts at improving decision making

4.2.1 Training decision making

As equipment, for example aircraft, have become increasingly more reliable, human factors have been identified as playing an increased role in the cause of accidents. As a result there has been a shift in focus towards attitudes, supervision and organisational culture, and increased demand for better training of decision making in critical and hazardous situations such as in the military.

We understand from the heuristics and biases approach that cognitive biases can lead to error prone decision making, and that these biases are most prevalent when decision makers are employing decision strategies requiring knowledge-level, creative generation of decision actions. Bearing in mind that biases are systematic and are well understood it is possible to tailor decision making training to target decision making error. This approach is often known as debiasing. Wickens and Hollands (2000) report a number of successful debiasing studies including that of Cohen, Freeman and Thompson (1997) which addressed overconfidence bias through encouraging forecasters to question why their forecasts may not be correct, and who worked on restoring confidence calibration by providing comprehensive and immediate feedback in predictive and diagnostic tasks, enabling forecasters to focus on the outcome of their rules.

Since the proponents of the NDM paradigm do not consider error in decision making to emanate from the individual but from a system they are inherently sceptical of the debiasing approach which they perceive as '*trying to extinguish natural or intuitive ways of thinking*' (Means, Salas, Crandall and Jacobs, 1993). Means et al (1993) report on a number of studies which found a reduction in cognitive biases, but not elimination. However, there are two factors which need to be considered. Firstly is the objective to seek to eradicate biases or to train decision makers to be more aware of the operation of biases, and the outcomes of biased and non biased decision making? Debiasing research has, as with research into heuristics and biases more generally, been centred on the laboratory and not the dynamic 'real' world. It would, therefore, seem apposite to consider the use of immersive training environments, such as serious games, to enable decision makers to experience making decisions in an environment which provides the opportunity for biased and non biased decision making according to how decision makers account for information, to experience the outcomes of the decisions made. Means et al (1993) argue that simulation offers great advantages, and may provide a better opportunity for experiential learning than the live environment.

The proponents of the NDM paradigm have been quick to propose decision making training strategies to accelerate the proficiency of decision makers in the military, emergency services and safety critical industries. However, Means et al (1993) and Orasanu (1993) point out that there is no evidence to indicate that it is possible to provide generic decision making training, rather, specific skills need to be developed.

Orasanu (1990, cited in Orasanu, 1993) identified four aspects of crew behaviour that can be associated with effective crew performance. These include: (i) good situational awareness, (ii) high levels of metacognition i.e. '*defining the problem and working out a plan to solve it, determining that a decision must be made, and deciding what information and resources are needed and what are available*' (Orasanu, 1993), (iii) shared mental models and (iv) efficient resource management. Accordingly, Orasanu argues that training in these areas cuts across all decision types and is essential to decision making training. However, she has also proposed the training focus for each of the six different decision event types which make up her taxonomy of decision types (see Figure 3-2). These are summarised in Table 4-1.

Table 4-1 - Cognitive work requirements and training focus (based on Orasanu, 1993)

Decision type	Training focus
Go/No-go decisions	Develop perceptual patterns in memory that constitute the conditions for aborting an action. Conduct under realistic time pressure and include borderline cases.
Recognition-primed decisions	Develop recognition of situational patterns constituting the condition side of a condition-action rule. Learn the response/action side of the rule and the link between condition and action. Develop evaluation skills (what will happen if I take/don't take this action, or is there a reason not to take this action?).
Option/response selection decisions	Train crew to use heuristics i.e. Satisficing (Simon, 1955), Elimination by aspects (Tversky, 1972), and Dominance-structuring (Montgomery, 1989 and 1993).
Resource management decisions	Acquire knowledge of the time required to complete various tasks, and the interdependencies among tasks. Develop scheduling strategies.
Procedural management	Develop situation assessment and risk assessment skill.
Creative Problem-solving	Develop situation assessment and risk assessment skill. Develop skill in goal setting, planning, strategizing and evaluation (i.e. case based reasoning involving presenting many examples of others' experiences).

Canon-Bowers and Bell (1997) have looked beyond what should be trained to consider how decision makers should be trained, i.e. the context, methods, strategies and media, and have turned their attention to the use of simulations and guided practice and feedback. Canon-Bowers and Bell (1997), like Means et al (1993), and Klein (1999), have noted the importance of simulation in training. According to Canon-Bowers and Bell, simulation provides decision makers with experience akin to situations they may experience in the live environment, yet for decision making training, simulation has advantages over the live environment such as the ability to control the characteristics of the decision problem, situational cues and cue patterns. Unlike the live environment decision makers can see and learn from the outcome of decisions made, which Canon-Bowers and Bell (1997) see as a valuable aid in the development of situation awareness, pattern recognition, and template building. They do caution, however, that the effectiveness of simulation based training largely depends on the extent to which the scenarios capture and display cues and associated responses. Simulations are also seen as effective media in the training of reasoning, metacognitive and risk-assessment skills.

Canon-Bowers and Bell (1997) stress the importance of providing feedback to decision makers on their practice. They argue that feedback is crucial to reinforce cue-strategy associations, and they see this guided practice as providing managed experience. Klein (1999) sees simulation as a good way of providing comprehensive and immediate feedback (Wickens and Hollands, 2000). According to Klein (1999) *'a good simulation can sometimes provide more training value than direct experience. A good simulation lets you stop the action, back up to what went on, and cram many trials together so a person can develop a sense of typicality'*.

Simulation and feedback do not just support training requirements of the NDM paradigm, but the use of simulation and feedback support the training in developing an awareness of the operation of biases, and individual decision maker's proneness to biases. Interestingly, when debiasing is seen in this way, it is arguably akin to training in metacognition.

4.2.2 Structuring decision making

Acronym or mnemonic-based methods have also been utilised to improve decision making in tactical environments, the aim being to '*foster a systematic or vigilant approach to decision making that should be less affected by […] heuristics and biases*' (O'Hare, 2003). However, Li (2006) identified that there was no evidence to support that these aviation decision making mnemonics have improved the quality of pilots' decision making. Accordingly, Li and Harris (2005) evaluated five mnemonic-based methods which could form the basis of aeronautical decision making training, to identify the most appropriate strategy to structure decision making to meet the different demands imposed by each of Orasanu's decision event types (Orasanu, 1993). Whol's (1981) SHOR method (stimuli, hypotheses, options, response), and Murray's (1997) DESIDE method (detect, estimate, set safety objectives, identify, do, evaluate), were identified as the most suitable mnemonic methods to improve military pilots' decision making, with SHOR being most appropriate for time-limited urgent situations and DESIDE guiding knowledge based decision making where more comprehensive consideration is required. These two methods subsequently formed the basis of classroom based decision making training which was found from an evaluation of learning to improve pilots' decision making. On the basis of this study, mnemonic methods would seem to have some utility in improving decision making performance.

4.3 Instructional overlay

It is important to remember that even with an awareness of decision making skills which can be developed through training, the first step when considering the introduction of any training intervention should be a training needs analysis to systematically determine the real training needs. Failure to take a systematic approach to training needs could result in the training failing to transfer to the operational environment. The training needs analysis of technically based skills can be addressed with a task analysis, since to optimise the effectiveness of training it is important to understand the skills which need to be developed, and the decision making tasks which need to be performed and the operating conditions under which they are performed (Kaempf and Orasanu, 1997). Kaempf and Orasanu (1997, p.87) advocate the use of cognitive task analysis to identify the *'judgements and decisions that must be made, the cues and factors to which the decision maker attends, and the factors that make the decision difficult'*. The decision requirement can then guide the development of training objectives to include the cognitive skills training for proficient decision making.

Training interventions per se are of no value unless skills and knowledge are acquired and transferred to the operational environment. It is, therefore, essential that training interventions are evaluated. Kirkpatrick (1998) advocates a four level evaluation of training programs starting with a measure of the reaction of the students/learners to the program i.e. assessing their 'customer satisfaction'. Evaluation should then measure the extent to which students acquire or increase skill, improve knowledge or change their attitudes in response to the training received, i.e. a learning evaluation. This should be followed by a measure of the transfer of this learning to the operational environment. The final assessment then focuses on the result of the training intervention in terms of the result to an organisation such as through cost savings or reductions in errors/accidents. However, with each level the evaluation is progressively more difficult and time consuming, and inevitably the higher level evaluations tend to be neglected.

4.4 Conclusions

Although it has been argued (eg by Means et al, 1993, and Orasanu, 1993) that it is not possible to provide generic decision making training, a number of decision making skills have been identified which cut across Orasanu's (1993) decision event types, such as situation awareness, metacognition and resource management. In addition, Orasanu has identified specific skills which can be trained for each of the decision event types, including developing perceptual patterns, operating under strict time pressure, and risk assessment.

It is clear that biases caused as a result of using heuristics can have a very strong influence on the reliability of decision making. As a result, decision making training needs to include opportunities for learners to train using scenarios which present the chance for biased decision making, together with the opportunity to safely experience the outcome of decisions taken.

So far in this report it has been identified that the military operational environment is complex, dynamic, and high pressured, and where decisions often have to be made using incomplete or dubious information. It has also been identified that there a number of skills which can be trained to enhance decision making across a range of decision making types which operate in naturalistic environments, and it has been established that decision making training must include debiasing approaches.

Over recent years serious games technology has evolved as a result of exploiting commercial off the shelf PC gaming technology, presenting opportunities to create immersive experiential learning environments for military training. Well designed serious games leverage the properties of games, such as rules, challenge, competition, and the properties of digital games, such as instant feedback in real time or above real time. According to Prensky (2001) digital games are by their nature a set of fast paced decision making events, with the player or gamer (either as an individual or group of individuals) assuming the role of decision maker (Sauve, Renaud and Kaufman, 2005). Serious games would appear, therefore, to present an exciting opportunity to train the skills which underpin effective decision making and in a naturalistic, yet safe and benign, environment, enabling novice decision makers to learn experientially and with instant feedback.

5 Serious Games

5.1 Games

Intuitively we all know what games mean, after all we have, after all, been playing them from infancy, starting with developmental role playing games, and later through the use of a variety of interfaces such as boards, playing cards, personal computers, racquets, sticks and bats. However, the broad scope of games makes defining them quite challenging and there is little consensus between game theorists on how games are defined.

Abt (1970, cited in Salen and Zimmerman, 2004) focuses his definition on competition, rules and one or more players: *'an activity among two or more independent decision-makers seeking to achieve their objectives in some limiting context. A more conventional definition would say that a game is a context with rules among adversaries trying to win objectives'.* According to Huizinga (1955, cited in Michael and Chen, 2006) games are a voluntary activity; pretend; immersive; are played within certain limits of time and place; are based on rules; and create social groups out of the players. These two approaches alone have yielded a number of characteristics of games, however, Salen and Zimmerman have analysed eight definitions from game historians and theorists from which they have identified a number of game elements. These are shown in Table 5-1.

Table 5-1 - Elements of game definitions (From Salen and Zimmerman, 2004)

Elements of game definitions	
Proceeds according to rules that limit players	Artificial/Safe/Outside ordinary life
Conflict or contest	Creates special social groups
Goal-orientated/outcome-orientated	Voluntary
Activity, process, or event	Uncertain
Not serious and absorbing	Make-believe/Representational
Never associated with material gain	Involves decision making

The game element that was shared by most definitions was that of rules, either that a game proceeds according to a set of rules, or takes place within a context with rules.

Game rules are the *'roots of gameplay and form a system by which a game is progressed'* (Thompson, Berbank-Green and Cusworth, 2007, p.13). Common game rules include luck or random chance, strategy, diplomacy, resource management and territory control (Thompson et al, 2007). Random chance, achieved for example by the throwing of dice may be used for movement or conflict resolution. Strategy, the opposite of luck, requires players to plan their turns and moves such as in a game of chess. Diplomacy, determines how players interact, i.e. whether they act collaboratively or selfishly. Resource management requires game players to manage assets, where as territory control, requires them to control the game space. Complex games, such as military strategy games may utilise a combination of game rules, such as strategy, diplomacy and the management of assets and territory.

Absent from the list of characteristics of games included in Table 2, however, is the element of fun, and yet intuitively one of the attractions of games is that they are enjoyable. Koster (2005) argues that rather than being a property of a game, fun is derived from actually playing a game. According to Csikszentmihalyi (1990, cited in Hays, 2005), there are several elements that make activities enjoyable, such as when activities provide challenge requiring skill; when they enable an individual to lose themselves in the activity they are engaged in; when clear goals are set and feedback is provided; when they enable an individual to exercise control in difficult situations; when an activity is so engrossing that an individual loses their self consciousness; when the activity means that time is transformed; and when an activity is intrinsically rewarding. These elements exist in games and as such may account for the attraction of games, and why players spend time on task.

Prensky (2001) has further developed the theme of why games are engaging by suggesting that games have 12 elements which make them absorbing. He suggests that games are fun, which provides enjoyment; games are a form of play which provide intense involvement; they have rules which provide structure; they have goals which provide motivation; they are interactive which ensures the player is an active not passive participant; and they have outcomes and provide feedback which supports learning. In addition, Prensky suggests that games are adaptive which engenders a flow state in the player; they provide win states which are gratifying; they provide challenge and competition which are motivating; they involve problem solving which sparks creativity; and they require interaction between the player and the game, which again ensures that the player is an active participant. Finally, they provide representations and stories which provide emotion, and meaningful context in which the player can immerse himself.

Clearly not all games have all of the elements identified by Csikszetmihalyi and Prensky, but arguably all of these elements can be found in games to varying degrees and can be exploited within serious games to provide stimulating and challenging immersive learning experiences.

5.2 The rise of the computer game

For all intents and purposes digital games (also known as video games) are games played on a number of digital platforms, either game consoles, PCs, hand held gaming devices or mobile phones. Akin to the definitions of games noted above Zyda (2005, p.25) defines video games as *'a mental contest, played with a computer according to certain rules for amusement, recreating, or winning a stake'*. The rules of video games (or game dynamics) are also primarily the same as the rules for non-digital games i.e. they are *'directly concerned with the actions players take and the outcomes of those actions'* (Salen and Zimmerman, 2004, p.149). However, this does not tell us about the unique properties of video games.

Salen and Zimmerman (2004) suggest that to define digital games you need to understand what digital media can do. They have identified four properties of digital media: immediate but narrow interactivity; information manipulation; automated complex systems; and networked communication.

Immediate but narrow interactivity. One of the most compelling qualities of digital technology is that it can offer immediate, interactive feedback. Digital technology, therefore, enables real time (and above real time) game play that *'shifts and reacts dynamically to player decisions'* (Salen and Zimmerman, 2004, p.87). It does have to borne in mind, however, that interacting with a PC is generally limited to a mouse, keyboard and joystick input devices, and screen and sound speaker output devices.

Information manipulation. Digital games manipulate vast quantities of information such as text, images, video, audio, animation, 3-D content, and every aspect of its program in a way that cannot be achieved in non-digital game formats. For example, with traditional games at least one player needs to learn the rules of the game before starting game play, whereas with some digital games rules are learned as part of the game (Narayanasamy, Wong, Fung and Rai, 2006). Salen and Zimmerman (2004) also point out that digital games are excellent at hiding information such as the location and activities of red forces in a strategy game, and revealing them only as the player's units explore the game map, in so doing replicating the 'fog of war'.

Automated complex systems. Digital games automate complicated procedures such as manipulating game pieces according to explicit instructions, and thereby facilitate the play of games by moving the game forward without direct input from the player.

Networked communication. A final property of digital games, although not shared by all games, is that they facilitate communication between two or more players, either by means of e-mail or text chat, real-time video and audio communication. This means that players do not have to be co-located to engage in joint game play. For example massively multiplayer online role-playing games (MMORPGs) such as *Entropia Universe* and *Everquest* are played simultaneously by millions of people across the globe via their PCs.

These four properties generally overlap and operate simultaneously during any actual game, and together they provide the overall play experience (Salen and Zimmerman, 2004).

5.3 The rise of serious games

Over recent years there has been exponential growth in the take up of commercial PC based games. According to Beck and Wade (2004) approximately five out of every ten Americans play video games (the generic term for games played on PC based, digital and handheld gaming platforms). The growth in commercial gaming has caused some authors to brand an entire generation, those born after 1970, the ‘gamer generation’ (Beck and Wade, 2004), ‘twitchspeed generation’ or ‘digital natives’ (Prensky, 2001) in view of their never having ‘*known a world without PCs, computer games, e-mail, the Internet, Instant Messaging, cell phones, PDAs and IPods*’ (Ware and Craft, 2006).

Cognisant of the interest in video gaming, the United States Army developed *America’s Army* a PC based game, as a recruiting tool. The take up of the game from teenagers, potential recruits and serving military personnel was so substantial that there began a revolution in thinking about the potential role of video games for non entertainment domains (Zyda, 2005). America’s Army and its assets have subsequently been repurposed within the Army as a training and testing environment for mission rehearsal, intelligence skills training, first aid and survival training (Michael and Chen, 2006).

America’s Army is often viewed as one of the most successful serious games. Abt (1987, cited in Michael and Chen, 2006) defines serious games as games with *‘an implicit and carefully thought-out educational purpose [that] are not intended to be played primarily for amusement’*, although he does point out that this does not mean that *‘serious games are not, or should not be, entertaining’*. Indeed to fail to exploit the enjoyment opportunities, such as those identified by Csikszentmihalyi and Prensky, could undermine the game and reduce buy-in from learners. Zyda (2005, p.26) picks up on the need for entertainment in defining serious games as *‘a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives’*.

Serious games, therefore, are video games that are intended to educate and train, while at the same time engaging and entertaining the user. They provide the opportunity for the game player to make decisions and experience the consequences of their decision making, in so doing developing the critical thinking, judgement and decision making skills needed to survive in the operational field.

5.4 The growth of serious games in a military context

As virtual reality struggled with high costs acting as a barrier to entry (Lewis and Jacobson, 2002), the potential of computer games to solve accessibility and affordability problems for serious military applications was being recognised.

The construction of serious games depends on leveraging high quality commercial-off-the-shelf (COTS) computer games software, including the game engine software and content generation packages, such as those underpinning first person shooter and role playing games These tools are proving to be affordable, accessible and highly usable (Stone, 2006). With these tools being available free or for affordable licence fees, being capable of delivering high quality synthetic environments (Stone, 2006), and facilitating a very quick development cycle, they have attracted the interest of the *'serious applications community, including those responsible for designing training and real-time visualisation systems […]'* (Stone, 2005, p.142).

5.5 Properties of well designed serious games

The properties of games and the properties of video/digital games were discussed under Sections 4.1 and 4.2, and in using serious games for training it is possible to exploit these properties to influence the amount and quality of learning. Of particular note for exploitation purposes are the properties which make games enjoyable and engaging, and the opportunities which can be gained from delivering games in digital format such as enabling player interaction with the game, the provision of immediate feedback and the ability to manage complex amounts of information and complex systems without detracting the player from engaging with game play. In a well designed serious game these properties can be leveraged to provide experiential learning opportunities, to motivate students, to enable students to become active participants in their own learning, to provide a benign environment which encourages students to explore the solution space, and to provide learners with feedback on their actions.

According to Raybourn, Deagle, Mendini and Heneghan (2005, p.3) well designed *'serious games provide the opportunity for experiential learning [. . . and] they provide an environment for active, critical learning'. E*xperiential learning opportunities enable game players to '*learn from contextual information embedded in the dynamics of the game […], and through the risks, benefits, costs, outcomes and rewards of alternative strategies that result from decision making'* (Raybourn et al, 2005, p.3). Unlike some classroom based 'chalk and talk' training sessions, serious games ensure that learning is an active rather than a passive process. According to Gee (2004, p.17) '*good learning requires that learners feel like active agents (producers) not just passive recipients (consumers)*'. *'Training games [i.e. serious games] allow learners to actively engage in the content they are learning, which is likely to produce positive learning outcomes'* (Belanich, Mullin and Dressel, 2004, p.3). Put very simply, serious games require players to participate in the action. Games do nothing until a player acts and then the game responds, presenting the player with feedback and new decision making events (Gee, 2005).

Serious games can be highly motivating, and as such encourage players to commit time and effort to a game. According to Abt (1987, cited in Michael and Chen, 2006) *'Games are effective teaching and training devices for students of all ages and in many situations because they are highly motivating, and because they communicate very efficiently the concepts and facts of many subjects'*. Intrinsic motivation appears to be increased as games encourage curiosity and competition, or as Gee (2005) suggests, motivation comes from being challenged by a game.

Serious games may encourage exploring and trying new things (Gee, 2005). According to the design of a game, serious games enable learners to explore the solution space, i.e. they enable players to actively explore alternative decision making strategies, and to learn from experiencing the outcome of their decisions. Belanich et al (2004) identified that the ability to provide feedback to students about their performance was important and should be provided according to the learners' needs and the task at hand. An advantage of using serious games for training is the ability to provide this timely feedback.

In addition to being able to leverage the properties of games and digital games for learning, serious games also possess many of the properties of simulator based training devices. For example, serious games may provide the opportunity for after action review, either by being designed to collect objective data, such as the route taken in executing a task, which can then be benchmarked against an optimal course of action, or by means of a replay of action from either a first person or bird's eye view. Serious games also provide students with a safe benign learning environment which enables students to explore decision making under a range of hazards and in dangerous activities and to learn from the outcomes of their actions without risk to life or equipment. They enable training to take place 24 hours a day, seven days a week regardless of weather conditions; and without damage to the environment (Rolfe and Staples, 1986). They can be easily tailored to the skill levels of the training audience and are readily accessible, the only limiting factor being the accessibility of the training overlay, which may be embedded within the game, or may require the use of trainers. From a military perspective, serious games, as with simulation, can represent a range of assets, red and blue forces and a range of operational scenarios.

It is acknowledged that serious games, just as with simulator training devices, have limitations, for example they cannot replicate morale, fear, fatigue or physical adaptations to extremes of climate which are best trained in the live environment. This does not undermine the use of serious games for military training, but acknowledges that serious games are not the media solution for all training needs. However, they certainly appear to be particularly suited to training higher level cognitive skills i.e. different types of decision making for a range of eventualities, and for developing situational awareness, cue pattern recognition, metacognition, for which they may provide a highly cost effective training solution.

5.6 Pedagogy and serious games

As a cautionary note, it is important not to fall into the trap of thinking that once a game has been developed, and is available on line or can be distributed by mail in CD format, that training, i.e. decision making training, has been delivered. Just as with simulator-based military training where it is acknowledged that *'simulation by itself cannot teach'* Farmer, van Rooij, Riemersma, Jorna and Moraal (1999, p.ix), but requires a training overlay, the same is true with serious games, i.e. serious games by themselves will not necessarily train.

Zyda (2005) argues that pedagogy (i.e. the activities to educate and instruct) is the component of a video game that makes the game a serious game, although he sees pedagogy as subordinate to the entertainment element of a game to ensure learners become immersed in the game, but nevertheless he emphasises that '*Researchers must have training and education objectives for their serious game […]'* (Zyda, 2005, p.30). Belanich et al (2004, p.6) agree that *'The pedagogical focus of the game must also be clearly described; otherwise the game may not train what it should train'*. Accordingly serious games need to be integrated with good instructional techniques (Belanich et al, 2004). Instructors must facilitate and guide the instruction, and ensure that training objectives are being met (Belanich et al, 2004). Roberts, Diller and Schmitt (2006) argue that serious game based training requires direction, clearly established training objectives, constraints and leadership as with any other training exercise. This emphasises the need to address clearly articulated training requirements (i.e. serious games applications should respond to a training need and not lead it), and for game designers to work with human factors specialists, content subject matter experts, and instructors.

5.7 Validation

Clearly it is not enough that students have fun and play the game. Training objectives need to be achieved and positive training benefit needs to demonstrably transfer to the live environment. As serious games for military training is still relatively new there have been a few empirical studies of skill acquisition or transfer of training, which presents a challenge to all serious game developers. However, there have been a number of studies which have demonstrated that games accelerate learning, increase motivation and support the development of higher level cognitive skills (deFreitas and Jarvis, 2006). Baker, Prince, Shrestha, Oser and Salas (1993) tested the reaction of pilots to the use of computer games for CRM skills training, and found that providing the scenarios were designed carefully that aircrews of all experience levels appreciated the value of the training system and became engaged in the scenarios. Green and Bavelier (2003) found that video game players between the ages of 18 to 23, all regular FPS (first person shooter) gamers, performed better on tests of visual attention, monitoring complex environments and managing multiple tasks than non game players. Gopher, Weil and Bareket (1994) found that pilots who received training on a video game performed significantly better than a no-game group on subsequent test flights. It is inevitable that if empirical evidence can demonstrate the efficacy of serious games for training, and with the acceptance of games as a significant part of everyday life (Prensky, 2001) that the use of serious games for military training will increase.

Alexander el al (2005) and Hays (2005) highlight the paucity of validation studies. The challenge, therefore, to serious game designers is to move beyond the first stage of Kirkpatrick's (1998) evaluation approach to include robust evaluation of learning and behaviour.

5.8 Types of computer games

Due to the vast number of computer games in existence there is a need for a taxonomy to distinguish one game or a set of similar games from another. However, due to the variety of games in terms of content, game play, medium and reasons for play, there are a number of approaches to the subject (Bjork and Holopainen, 2006). Bjork and Holopainen (2006) argue that computer games are most commonly marketed by their genres i.e. according to their style, form and content such as first person shooter and strategy games etc. Although, they do point out that the granularity of genre definitions is affected by the popularity of games being played, rather than any design differences. There are a number of genres which are well recognised. Those relevant for leveraging for military serious gaming purposes are noted below.

First person shooter (FPS) games

With this genre, the player sees their world through the eyes of their on-screen counterpart (or avatar), typically down the barrel of a weapon. Aldrich (2005) has identified a number of features of first person shooter games which have a decision making dimension for example, deciding on which weaponry to use, choosing between evading or killing opponents, and choosing whether or not to integrate with vehicles as an alternative to walking. Aldrich (2005) also suggests that first person shooter games facilitate learning in terms of problem solving and building complicated mental models of changing environments.

'Despite the stigma of violence and gore associated with first person games' (Lewis and Jacobson, 2002, p.27), in serious gaming hands where the emphasis shifts from sheer firepower to decision making and analysis (Herz and Macedonia, 2002), first person shooter games have been widely accepted for military training. A number of computer games currently in use in military serious gaming contexts have been developed by repurposing the games engines of commercial off the shelf first person shooter games. For example, the US Army's game America's Army was developed using Epic Games Unreal game engine; the British Army's Dismounted Infantry Virtual Environment (DIVE II) has been developed from Valve's Half-Life game engine; and the HFI DTC Trauma Trainer and Dillon Minigun Trainer were developed using Crytek's Cry Engine.

Similar to first person shooter games are third person shooter games which allow players to see their character, rather than seeing the 'world' through their character's perspective.

Real time strategy (RTS) games

Real time strategy games allow the game player to command some type of operation, typically a military operation. According to Aldrich (2005, p.139) they may also offer the most '*intense learning experience*' of all game genres. Aldrich has identified a number of general features of real time strategy games which map neatly onto the features of naturalistic environments. These include the need to co-ordinate multiple tasks, balancing long and short term goals, and moving between small (i.e. tactical) and big (i.e. strategic) pictures, requiring the need to prioritise, make tradeoffs, change strategies and react on a minute-to-minute basis in a changing environment, as well as developing longer term philosophies. There are a number of commercial off the shelf military RTS games, such as *Rome Total War,* and in addition the military has a long tradition of using wargames for training strategic and tactical decision making. It must be pointed out that whilst termed 'real time', RTS games are actually played above real time, since game play is considerably faster than the actual campaigns upon which they are based. Similar to real time strategy games are real time tactics games.

Role playing games (RPGs)

With role playing games, players manage either a person or a team through challenging scenarios, usually in a fantasy or science fiction setting, building the character's skill set and inventories to meet increasing and evolving conflicts.

Simulation games

It is important to draw a distinction between simulations and simulation games. Simulations are methods for implementing representations of systems, entities, phenomena or processes over time, for example '*microworlds are simulations that attempt to capture the relevant aspect of some topic or phenomena so learners can interact within it to observe the effects of their interactions*' (Hays, 2005, p.10) and are widely used for experimentation purposes (eg Fong, 2006). A simulation game is a simulation which incorporates aspects of games (i.e. rules, challenge and competition) for example *Bottom Gun* (Garris and Ahlers, 2001), a submarine periscope trainer developed for the US Navy, is a simulation of a naval task but which incorporates features such as scoring and fantasy which are not present in the actual task (Garris, Ahlers and Driskell, 2002) making it a simulation game.

According to Narayanasamy et al, 2006) there are four different types of simulation games. Participatory games place a player within the game and require the player to perform various actions. Iterative simulation games provide an opportunity for a player to create a business model or computer simulation model. With procedural simulation games a player completes a process following a well-documented set of procedures such as *Microsoft Flight Simulator*, customised versions of which are used by the military. For example, the United States navy issue a customised version to all student pilots and undergraduates enrolled on the Naval Reserve Officer Training Courses (Herz and Macedonia, 2002). Finally, situational simulation games such as *The Sims 2* deal with the behaviour and emotions of people that relate closely to a group of circumstances.

5.9 The structure of computer games

In addition to there being a number of different genres of computer games there are two dominant game structures: linear and sandbox, which represent how a game fits together, i.e. '*how the levels are laid out and how higher objectives are staged*' (Thompson et al, 2007, p.32), and which can combine with any one of the game genres discussed under Section 4.8 above.

Linear games provide a single path for the players to follow with explicit goals that must be achieved in a set sequence to progress through the game. Sandbox games, on the other hand, allow the player to approach different goals and challenges in almost any order, the name 'sandbox' being derived from the unrestricted games that children play in a sandbox (or sandpit). From a serious games point of view linear games provide structure to the game and focus the player's action and attention on relevant parts of the game and are valuable for training in as much as they effectively allow the training overlay to be embedded in the game. For example '*Subsafe*', a spatial orientation trainer for the Trafalgar class submarine currently being developed by the Human Factors Integration Defence Technology Centre (HFI DTC), can be played in a treasure hunt mode which directs players' interaction with the game to achieve certain training objectives. However, sandbox games give the player more freedom and control over the game play and may better enable the player to fully explore the solution space, and to take risks and try different options, although from a serious gaming point of view there is less external control over how students are playing the game.

Previous uses of games in military training contexts

According to Perla (1990, p.1) *'games about warfare have probably existed nearly as long as war itself'*. Sun Tzu, the Chinese general and military philosopher is generally credited with the invention of the first wargame, *Wei Hai*, some 5,000 years ago (Perla, 1990). Wargames progressed in a chess game format until Weikhmann developed 'King's Game' or Koenigspiel in the mid-17th century which added military detail, and then in the hands of the Prussians in the early 19th century wargames became more detailed and realistic with game mechanics derived from a study of military manoeuvres and battles (Dunnigan, 1992). Wargames still play a role in military training in exercising strategic and operational decision making, and with increases in computer processing power they continue to develop. For example the Joint Operations Command and Staff Training System (JOCASTS) game engine is used at the Joint Service Command and Staff College (JSCSC) to support large team based wargaming exercises on the staff courses.

The use of serious games for military training purposes is not new. The military invest heavily in the design, development and implementation of serious games for training and recruitment purposes (Stapleton, 2004), with the US Military being the '*world's largest spender on and user of digital game based training*' (Prensky, 2001, p.296). Battlezone was published in 1980 and a year later was developed for the US Army as a trainer for the Bradley military vehicle (Stone, 2006). However, in the 1990s a raft of commercial games emerged such as *Wolfenstein*, *Doom*, *Quake*, *Heretic*, *Hexen*, *Unreal* and *Half Life* (Stone, 2006) all of which had potential for exploitation for serious gaming applications. These games set the scene for a decade of development of serious games for military applications such as *America's Army*, *Marine Doom* for team work and co-ordination skills of four soldier fire teams and *Full Spectrum Warrior* to train squad leaders in urban warfare (Alexander, Brunye, Sidman and Weil, 2005).

Serious game development is continuing at a rapid pace with three new games being show cased at recent military training and simulation conferences. Steel Beasts Professional and VBS 2 were both being demonstrated at the 2006 International Training and Education conference (ITEC). Steel Beasts provides armoured company and platoon scale tactical training and has been developed by eSim Games by re-purposing their commercial game Steel Beasts (http://www.esimgames.com). VBS 2 has been developed by Bohemia Interactive, and provides collective and tactical training and mission rehearsal opportunities in complex areas. The UK MoD has recently acquired an enterprise licence for VBS2 (http://www.vbs2.com) enabling it to utilise the Real Virtuality game engine. Future Force Company Commander (F2C2), created by Science Applications International Corporation (SAIC) was showcased at the 2006 Interservice/Industry Training, Simulation and Education Conference (I/ITSEC) and is intended to help explain the Future Combat System program to soldiers in an interactive environment. It is seen as the successor to America's Army, and is now freely available on the internet (http://www.army.mil/fcs/f2c2).

5.10 Current UK military applications

In the UK, the Dismounted Infantry Virtual Environment (DIVE II), has recently been developed by Qinetiq and Maverick Development, with funding from the Directorate of Analysis, Experimentation and Simulation (DAES), and utilises Valve's Half Life game engine. The game provides a multiplayer PC training system for sections to train against computer generated and team mate controlled red forces (Stone, 2005). Sections train using real tactics and techniques practicing drills and for mission rehearsal, in an urban search and clearance environment, modelled on Copehill Down village, which is then followed by comprehensive post session feedback. The game has been elevated to front line status for pre deployment training, and it is understood that DIVE is being received fairly warmly by troops outside of working hours (QinetiQ, 2006).

Other UK military applications include the Interactive Trauma Trainer, a proof of concept demonstrator project part funded by the HFI DTC, and developed by TruSim in conjunction with subject matter expert input from the Royal Centre for Defence Medicine, to train users in life saving decision making skills in the urgent treatment of battlefield casualties with 'Zone 1' neck fragment wounds in an army field hospital context (Stone, 2006). Another HFI DTC project is a part-task trainer for the M134 Dillon Minigum trainer. Both the Trauma Trainer and the Minigun Trainer have been ported onto Crytek's Cry Engine (the game engine behind the first person shooter game 'Far Cry').

5.11 Conclusions

Serious games, by virtue of the opportunity to leverage COTS technology, present exciting and cost effective opportunities for training, and as a result the application of serious games for military training purposes has been steadily gaining momentum over recent years. Well designed serious games can exploit not only the properties of games and the properties of digital games, but also of simulation, to create exciting, immersive experiential learning opportunities for decision making.

Despite the importance of decision making and decision making training to the military, and the possibilities for immersive experiential training possible with well designed serious games, there are currently no serious games designed specifically to provide training in the decision making skills which underpin the six decision event types identified by Orasanu (1993), or which seek to reduce decision making biases. This would suggest that this area would benefit from the development of a serious decision making skills game as a concept demonstrator, with stakeholder involvement from the UK military.

Whilst a number of studies have demonstrated the efficacy of serious games for accelerating learning, and developing high level cognitive skills, there is still a paucity of empirically based studies that have moved beyond Kirkpatrick's first stage to assess the acquisition of skills and knowledge, and to assess the transfer of training to the live operational environment. This would suggest that the evaluation of serious games is also an area which needs to be developed.

6 Properties of a Decision Making Serious Game

Having identified that there is a need for a serious decision making skills game concept demonstrator, the next stage is to establish which existing commercial off the shelf games would be most suitable for re-purposing as a serious decision making training game. Suitable off the shelf games would be those which support Orasanu's (1993) decision making types, represent the features of naturalistic decision making (Orasanu and Connolly, 1992), provide opportunities for the use of biases, and provide the opportunity for after action review.

Based on the success of current serious games, it would appear that the most appropriate game genres to exploit would be first person shooter games and real time strategy games. An initial evaluation of the genres to support the features of a naturalistic decision making environment (Orasanu and Connolly, 1993) and the six different decision event types identified by Orasanu (1993) has been carried out. A summary of the findings is shown in Table 6-1 and Table 6-2, with the black dot representing when a property or type is replicated in the game genre.

Table 6-1 - Properties of the naturalistic decision making environment represented by first person shooter and real time strategy games

Properties of the naturalistic environment	First person shooter	Real time strategy
Ill structured problems	●	●
Uncertain dynamic environments	●	●
Shifting, ill-defined, or competing goals	●	●
Action/feedback loops	●	●
Time stress	●	●
High Stakes	●	●
Multiple players	●	●
Organisational goals and norms	●	●

Table 6-2 - Orasanu's (1993) decision event types represented by first person shooter and real time strategy games

Decision event types	**First person shooter**	**Real time strategy**
Go, No-go decisions	•	
Recognition primed decisions	•	
Option selection decisions	•	•
Scheduling decisions		•
Procedural management		•
Creative problem solving		•

Both game genres appear to offer potential for re-purposing for serious games in terms of representing a naturalistic decision making environment. Interestingly, first person shooter games appear to better capture go, no-go decisions and recognition primed decisions. Real time strategy games would appear to better capture scheduling decisions, procedural management and creative problem solving. With both game genres capturing option selection decisions.

Valve's Half-Life game engine, Crytek's Cry Engine and Epic Games Unreal game engine have all been repurposed for serious game applications, and would, therefore, be candidates for more detailed evaluation. A number of game engines supporting real time strategy games have also already been identified as possible candidates for repurposing for a decision making game. These include *Age of Empires*, *Rome Total War*, *Axis and Allies*, *Rise of Nations*, *Commandos* and *Command and Conquer*. A review of these games for re-purposing as serious games can be found at Annex A to this report. In addition, *Subsafe*, appears to offer potential as a trainer for recognition primed decisions.

The next stage of the study is to map these first person shooter games, real time strategy games, and *Subsafe* onto the properties of naturalistic decision making (Orasanu and Connolly, 1993), Orasanu's (1993) decision event types, and the properties of simulation, using experienced game players as subject matter experts. An interview or focus group methodology is proposed which would ensure that the subject matter experts are fully briefed, for example, on the properties of naturalistic decision making and the decision types, and should enable the capture of capture rich data and examples from the subject matter experts.

It will then be necessary to engage military trainers as subject matter experts to develop the context for the game, before writing up formal requirements (for example, along the line of the approach set out in ANNEX B).

7 Conclusions and Recommendations

7.1 Conclusions

- Despite the differences between the classical decision making and naturalistic decision making approaches both are highly relevant to military decision making. The CDM approach is most appropriate during planning stages of operations, where time and information exist, or need to be resourced, to adopt rational, analytical approaches. The NDM approach, in contrast, better reflects decision making in dynamic, uncertain, high stakes environments typical of military decision making.

- Decision making is not a single entity, but according to Orasanu (1993) there are six decision making event types or strategies which vary according to the structure of the decision making task, how well the problem is defined, and whether options exist or need to be created, and include: go, no-go, recognition primed, option selection, scheduling, procedural management and creative problem solving decisions.

- Decision making may improve through training or structuring decision making. It has been argued (eg by Means et al, 1993 and Orasanu, 1993) that it is not possible to provide generic decision making training. However, a number of trainable decision making skills have been identified including situation awareness, metacognition and resource management, in addition to specific skills which can be trained according to the different decision event types.

- Decision making biases, caused as a result of the use of heuristics can undermine the reliability of decision making. Accordingly, any decision making training needs to include the opportunity for biased as well as non biased decision making, for example to train students to attend to negative information.

- Serious games have developed in recent years as a result of leveraging commercial off the shelf (COTS) gaming technology. Well developed serious games which leverage the properties of games (such as rules, challenge, competition), the properties of digital games (such as feedback in real time or above real time, information manipulation, and the automation of complex systems), and the properties of simulation (such as after action review) present exciting opportunities for creating immersive experiential learning environments. It is argued that serious games are capable of motivating students, enabling them to become active learners in a safe benign environment, but one which encourages them to take risks and explore the solution space, with the benefit of immediate feedback, and subsequent review of performance.

- It is suggested, e.g. by Prensky (2001) that serious games are by their nature a set of fast paced decision making events, with the player taking the role of the decision maker. It is, therefore, logical that a robust application of serious games would be to use them to train decision making. However, there are currently no serious games designed specifically to train decision making skills to enhance performance of the six decision making strategies identified by Orasanu (1993).

- In considering decision making training it is essential that a systematic approach to determining training needs is undertaken, to help ensure that decision making training using a serious game transfers to the operational environment. It is also important to bear in mind that decision making games do not by themselves necessarily train, instead they need to be integrated with good instructional techniques. Instructors need to guide the instruction and ensure that training objectives are met (Belanich et al, 2004).

- Whilst there have been a number studies which have demonstrated that serious games accelerate learning and support the development of higher level cognitive skills (deFreitas and Jarvis, 2005), there is still a paucity of empirical evidence demonstrating the learning benefits of serious games and demonstrating behavioural change in the operational environment.

7.2 Recommendations

- It is recommended that a serious game to train decision making skills to enhance the performance of the six decision making strategies identified by Orasanu (1993) be developed. An initial evaluation of the suitability of different commercial games for re-purposing as serious games to train Orasanu's (1993) decision event types has been undertaken. It is recommended that this is now developed into a more extensive study using proficient computer games players as subject matter experts, to identify which games reflect the properties of naturalistic environments (Orasanu and Connolly, 1993), which games incorporate the six different decision making event types (Orasanu, 1993), which games support the presentation of negative information, and which games exploit the properties of simulation such as after action review.

- New serious games need to be evaluated to assess their efficacy in terms of providing opportunities for learning and behavioural change. Every opportunity should be taken to evaluate serious games. For example, *Subsafe,* the spatial orientation trainer for the Trafalgar class submarine, being developed by the HFI DTC, is shortly to be evaluated according to Kirkpatrick's (1998) first and second levels. The design of a series of experimental trials is currently in progress, with data collection scheduled to commence in August 2007. A transfer of training trial (Kirkpatrick's third stage) would be a logical extension to the evaluation of the game.

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ANNEX A Real Time Strategy Games

A.1 Real time strategy games amenable to being re-purposed for a serious decision making training game

Prepared by Kevin Bessell, Aerosystems International

Title	URL	Notes	Multiplayer Capability / Scope for User Modification
Age of Empires	www.microsoft.com/games/empires	Age of Empires is a popular RTS franchise that has so far undergone three iterations, with expansion packs also available. Medieval theme.	The original Age of Empires features multiplayer via the Internet or a local network, and includes a scenario generator for creating custom scenarios.
	www.microsoft.com/games/pc/age2gold.aspx		Age of Empires 2 features mulitplayer via the Internet, and may also facilitate play via a local network, but this could not be determined from the Website. It includes a map editor for generating custom scenarios.
	www.ageofempires3.com		Age of Empires 3 features muliplayer games via a dedicated online site, but this Website makes no mention of offline multiplayer via a local network, or custom scenario generation.
	http://aoe3.heavengames.com/modding/tutorials/basis/introduction/index.shtml		It appears to be possible to modify the Age of Empires games beyond the simple scenario generation offered 'out of the box'. The link given here discusses the modding process for Age of Empires 3, and also includes links to modding tutorials and resources for the other two games, as well as many other RTS games.
Rome: Total War	www.totalwar.com	Rome: Total War is the third installment in the Total War series (as per Age of Empires, previous versions are also available). Historical Roman setting.	Multiplayer via Internet or local network. Unable to ascertain scenario generation capabilities from sites looked at, but modding appears to be an option (see next couple of links below).

Title	**URL**	**Notes**	**Multiplayer Capability / Scope for User Modification**
	http://rtw.heavengames.com/		This site contains some information and tutorials regarding modification of Rome: Total War, along with forums and downloadable mods made by other players.
	http://www.twcenter.net/		Another fan site with more modding info and downloadable modding toolsets.
Axis & Allies: RTS	www.timegate.com/aa/	RTS set during World War II, inspired by a previous board game. Could be possible to perform experimental comparisons between the board game and the software?	Online multiplayer and a random map generator.
	http://axisallies.strategyplanet.gamespy.com/		Site containing limited information on modding, mostly downloadable maps made by other players and some utilities for extracting game data files.
	www.triplethreatclan.com		Site including downloadable utilities for creating mods.
Rise of Nations	www.microsoft.com/games/riseofnations/	Another RTS series with several different versions or expansions available. Initially a historical theme, but the latest version (Rise of Legends) has a fantastical theme.	First version supports multiplayer for up to 8 players via Internet or local network. Rise of Legends supports online multiplayer, but uncertain about local network multiplayer. This site includes a downloadable scenario editor and an exporter to enable new 3D models to be added into the game.
	http://ron.heavengames.com/		Site containing modding tutorials and utilities.
Commandos	www.eidosinteractive.co.uk/gss/commandos3/	RTS series with 4 different versions, set during World War II. Involves command of a squad of troops, as opposed to the usual larger forces seen in most RTS games.	Latest version (Commandos 3) features multiplayer for up to 8 players online or via local network. Earlier versions also support online or local network multiplayer, but this appears to be cooperative i.e. teaming up for missions as opposed to fighting against each other. No mention of scenario editing capability.
	http://chq.gamemod.net/index.php_page=modding_mods		Site containing mods and a decent number of modding tools and tutorials for the entire Commandos series.

Title	URL	Notes	Multiplayer Capability / Scope for User Modification
Command & Conquer	www.ea.com/official/cc/firstdecade/us/index.jsp	One of the longest running RTS series with a fictional military (as opposed to historical) theme. Many different versions and expansions.	Most versions seem to offer some kind of multiplayer functionality, with the latest (Generals) claiming head-to-head online or up to 8 player cooperative. One version (Red Alert) features a terrain editor for creating new maps, and both Generals releases (original and Zero Hour) include a World Builder utility for creating custom maps. Uncertain as to whether other versions include scenario or terrain generation.
	www.cncden.com		Site dedicated to many of the various versions of C&C, with downloadable mods and maps, and forums and tutorials relating to aspects of modding, including the Generals World Builder.
	www.cncgeneralsworld.com		Another mod related site, this time specifically for the Generals versions.

ANNEX B How to Write a Requirement

Prepared by Mel Lowe, Systems Engineering and Assessment Ltd

B.1 Introduction

B.1.1 Purpose of the document

This document outlines a generic approach to requirements capture and generation. This document is intended to guide human factors (HF) engineers through writing user requirements for a decision-making synthetic environment (SE) or strategy game.

B.2 Development of requirements

B.2.1 Definitions

A requirement is 'a *formal statement of:*

(1) An attribute to be possessed by the product or a function to be performed by the product.

(2) The performance standard for the attribute or function.

(3) *The measuring process to be used in verifying that the standard has been met*'. [Ref.1]

In engineering, a requirement is a singular documented need of what a particular product or service should be or do. In essence, a requirement is a concise statement of what the customer wants.

B.2.2 Types of requirements

There are various ways of breaking down and classifying requirements that change from project to project; but essentially there are two principal types of requirement:

- **Functional requirements** – statements about the specific behaviours of a system.
- **Non-Functional requirements or constraints** – statements about the quality or acceptable performance of a system. Typical non-functional requirements are quality, reliability, scalability, and cost. Human factors and operability requirements usually fall into this category.

B.2.3 Organisation and structure of requirements

Design requirements usually originate from the customer's high-level statement of requirements or key user requirements (KUR). SMART acquisition and most systems engineering processes start by breaking down these high level statements into functional and non functional 'user requirements'. These are used and interpreted by engineers who then define the 'systems requirements', which define the system that will meet the user requirements. This document describes the system architecture and tools to be used to make the system or product. Design (often software) requirements or design specification documents are then written in response to the system requirements. These documents describe the underlying behaviour (or functions) and the 'look and feel' of the software (HCI).

B.2.4 How to write a requirement

A requirement needs to be a clear, precise statement of what is desired. It must also be possible to meet the requirement, therefore, they should be achievable and realistic. Since requirements are sometimes contractual it should also be possible to verify the requirement.

Requirements can be mandatory or desirable. Requirements engineers typically use specific language to indicate the level of compliance that is required to be met. Table B-1 outlines the type of language used in requirements that commands the presence of some feature, function, or deliverable. They are listed below in decreasing order of strength. This guidance is taken from the International Council on Systems Engineering (INCOSE) Handbook [Ref 2].

Table B-1- Requirements language

Shall	Requirement specifications are demands upon the designer or implementer and the resulting product and the imperative form of the verb, '*shall*', shall be used in identifying the requirement. '*Shall*' is used to indicate the requirement is mandatory.
Will	A statement containing '*will*' identifies a future happening. It is used to convey an item of information, explicitly not to be interpreted as a requirement.
Must or must not	'*Shall'* is preferable to '*must*'. If both are used in a specification, there is an implication of difference in degree of responsibility upon the implementer.
Other forms	Indefinite forms of the verb such as '*to be'* , '*is to be*', '*should*' and '*should be*' are not encouraged in the writing of requirements. This is because they make the requirement sound weak

B.2.5 Composition of a requirement

A requirement generally consists of the following:

- A unique ID.
- Title/name.
- Requirement statement.
- Acceptance/verification method.
- Documentation or parent requirement.

B.2.5.1 Unique ID

All requirements will have a unique identification number. The numbering system is usually related to the requirement tree and will show some traceability back to the higher-level requirement.

B.2.5.2 Title/name

Requirements are usually grouped by type of requirement and by function.

B.2.5.3 Requirement statement

This statement sets out what functions or properties are necessary in order to build the customer's desired system.

B.2.5.4 Acceptance/verification method

There should be a statement about how the requirement will be verified and accepted. The standard methods of measuring requirements include:

- Live trials.
- Standards compliance checklist.
- Modelling and simulation analysis.

B.2.5.5 Optional

Documentation/Source

Would include supporting evidence of a process that is being carried out., for example evidence that human factors and operability issues and risks are being managed would be evidenced through management plans, risk registers and trade off studies.

Parent Requirement

The original or source requirement, which would enable the requirement to be traced back to the key user requirements.

B.3 Overview of requirements development

B.3.1 Approach

Figure B-1 illustrates a generic approach to developing requirements. The approach consists of requirements capture, generation, testing, and revision.

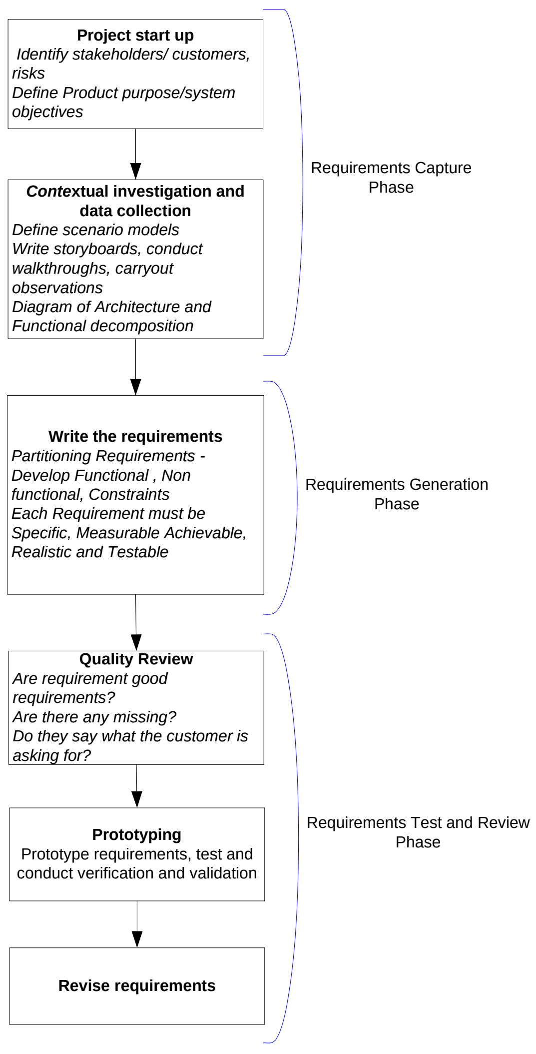


Figure B-1 - Outline of Approach

B.3.2 Requirements Capture

B.3.2.1 Project Orientation

At the start of a project, the main focus of requirements capture activities is to understand what is required and what the risks might be. Table B-2 summarises the key outputs from the project orientation phase.

Table B-2: Key Outputs

1. Purpose statement
2. Overview Description of Product
3. List of Customers and Stakeholders

The first step is to define the purpose of the system to be designed and give a brief overview of the design and the high level training objectives.

In the case of a decision-making SE, the purpose of the SE may be described as:

- ‘*To develop a training tool that enables strategic decision making skills to be taught to trainees’, or*
- *‘To design a tool to aid recognition primed decision making in military conflict situations’”.*

The next step is to identify all customers and stakeholders and to interpret their underlying requirements.

B.3.2.2 Contextual investigation and data collection

Once the project goals and customers are identified the next stage of requirements capture is to investigate the context of use and understand the users, and their tasks and goals. Standard HF techniques from participative design or contextual inquiry can be useful at this stage. As part of this collaborative design activity, potential scenarios should be explored with subject matter experts (SMEs). The exercise of understanding the potential trainee’s tasks and job responsibilities helps to draw out the functionality that will be required.

Table B-3 summarises the key outputs from the requirement capture phase.

Table B-3 - Key Outputs

4. Training objectives and training task description (or Task Analysis)
5. Potential Scenarios
6. Architectural structure or Functional decomposition

Once the user/trainee data, training objectives and potential scenarios haves been defined it possible to start to decompose the system into discrete functions.

One way to breakdown the system into its component parts is to draw the system. Figure B-2 is an example of a draft system diagram that was created for an urban SE.

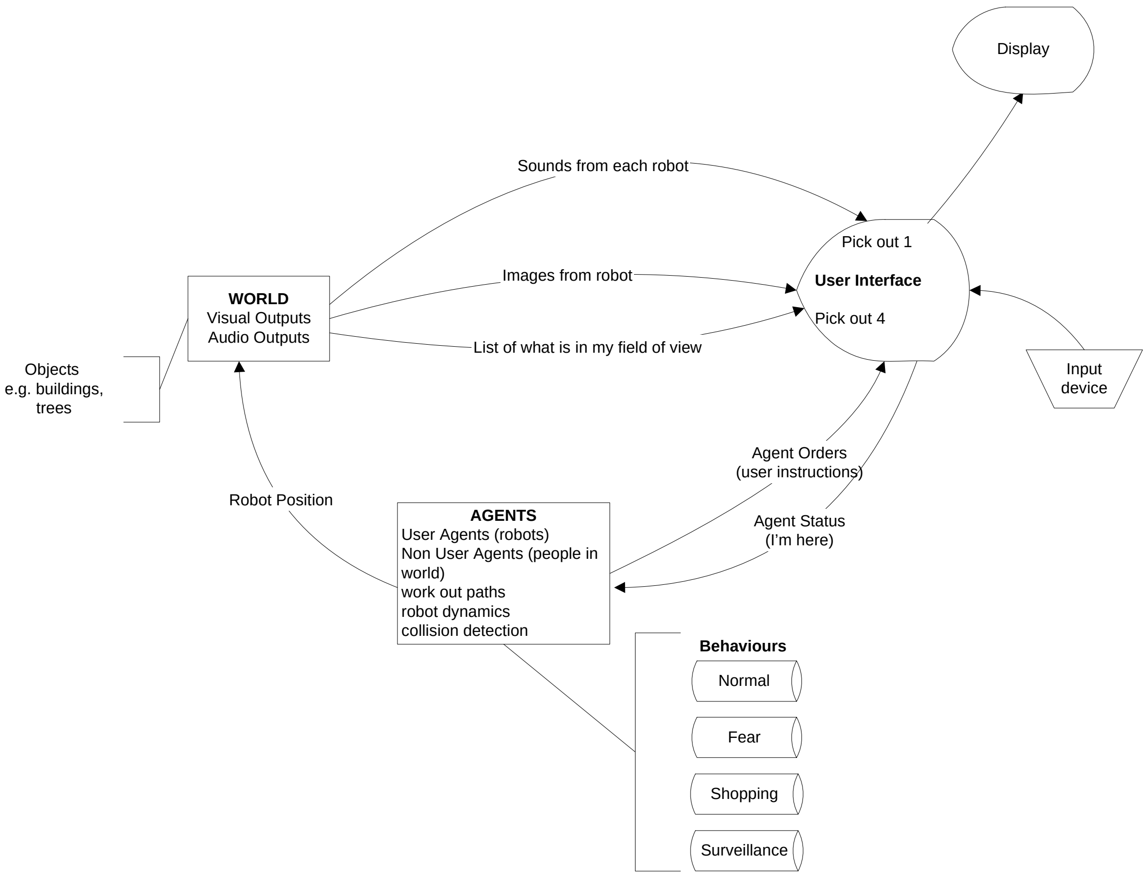


Figure B-2 - SE Components

B.3.3 Requirements Generation

B.3.3.1 Write the Requirements

The requirements will fall out of the requirements capture exercise. For completeness, it can be useful to draw a requirements tree based on the functions identified in the capture and consolidation exercise. Figure B-3 illustrates an example of a generic requirements tree.

In general each requirement should relate to one function. Each requirement should be specific, measurable, achievable, realistic, and testable.

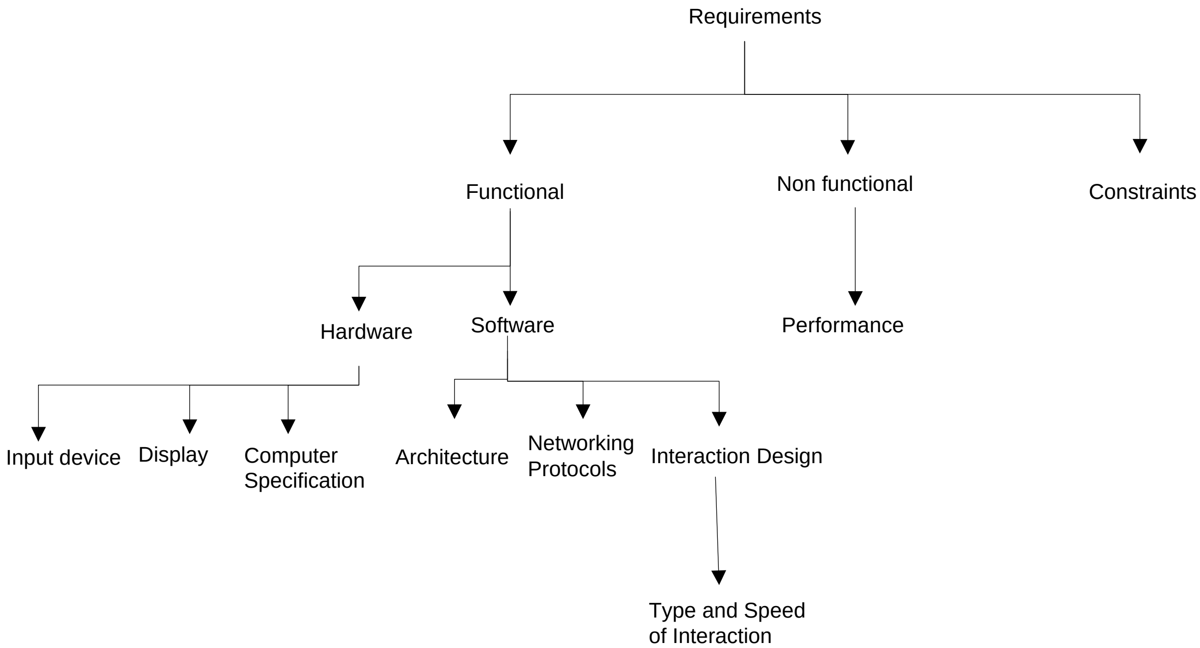


Figure B-3 - Requirements tree

The key outputs of this phase are outlined in Table B-4.

Table B-4 - Key Outputs

7. A set of Requirements

Functional Requirements

Hardware Requirements

These are requirements relating to the hardware and equipment, and would include:

Computer Specification

- Processor, video card, sound card, and memory specification.
- The number of workstations, for example how many people are required to play at any time, include players, enemy players, and administrators.

Input devices

- Equipment required to interact with the SE, for example keyboard, mice, joysticks, and specialised devices such as an interactive gun.
- Other requirements such as force feedback, or touch screen.

Display Screen technology

- Type of screen.
- Whether a number of different display devices may be required.

Software Requirements

Software Architecture/ Functional Components

Networking Functionality/ Protocols

Human Computer Interaction

- Training objectives/strategies.
- Actors and behaviours: specify whether there are non player characters, other people in the simulation/SE, and how interactive should they be.
- Introduction Screens/ Back story or mission brief/scenario.
- Interaction design: speed of interaction/ feedback ie real time, turn based, or asymmetric/decoupled interaction.
- Experimental measures.

Non Functional Requirements

Performance

- Graphics: 3D, 2D parametric, 2D.
- Sounds: Dolby 5.1, sourced from internet libraries or realistic specially recorded sound.
- Other requirements such as screen reader technology/voice recognition/ voice over IP.

Constraints

Anything which is not included in either of the requirements categories.

B.3.3.2 Quality Review

This is usually best carried out as a workshop activity, with a range of technical experts. For a decision-making SE it would be important to invite software integrators and developers as this stage.

B.3.4 Requirements Test and Review

The key outputs at this stage are summarised in Table B-5.

Table B-5: Key Outputs

8. First Prototype
9. Tested Prototype
10. Reviewed and agreed requirements

B.3.4.1 Prototyping

It is necessary to do some prototyping to ensure certain aspects of the design are possible. For example, with a decision-making SE, it may be important to ensure that the game does teach strategy. This can be achieved by making a paper prototype of the game strategies and testing it with SMEs.

B.3.4.2 Review

Requirements generation is an iterative process. It is important that redundant or bad requirements are eliminated. Bad requirements are vague or attempt to specify the implementation of the requirement rather than leaving that to the developer.

B.4 References

B.4.1 References

1. Definition of Requirement, http://strategis.ic.gc.ca/epic/internet/instco-levc.nsf/en/h_qw00037e.html

2. INCOSE-TP-2003-016-02 (June 2004).

B.4.2 Applicable Standards

The following HF standards may be applicable. The main standard for military projects is def Stan 00 25.

1 DEF STAN 00-25 'Human Factors for Designers of Equipment'.

2 European Community Directive 90/270/EEC (Display Screen Equipment).

3 Health and Safety Executive: Work with Display Screen Equipment - Regulations and Guidance, 1993.

4 ISO 9241/BS EN 7179/29241: Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs)

5 NES 599 Policy Requirements for Alarms and Warning Systems.

6 NES 748 Requirements for Safety Signs and Colours.

7 ISO 13407, Human-Centred Design Processes for Interactive Systems, 1999.

8 MIL-STD-1472F, Human Factors Design Criteria for Military Systems, Equipment and Facilities (*US Standard*).

9 MIL-HDBK-46855, Human Engineering Requirements for Military Systems, Equipment Facilities. (*US Standard*)

10 MIL-HDBK-759C, Handbook for Human Engineering Design Guidelines (*US Standard*).

11 MIL-HDBK-763, Human Engineering Procedures Guide (*US Standard*).

12 STGP 10, STG 2002 ISSUE 3. HFI Management Guide and STGP 11, STG 2002 ISSUE 3. HFI Technical Guide.

13 BR8420 The Royal Navy Systems Approach to Training Quality Standard.

14 JSP 502 Tri Service Guide to Training Needs Analysis.

B. Appendix 1 Requirements analysis methods

The main aim of requirements is to manage the costs of software development by reducing the project risk associated with overspend and failure to deliver acceptable software. Methods used to achieve this fall into two categories, formal methods and informal methods. Formal methods provide a systematic approach to capturing and managing requirements. Informal methods tend to favour starting on the code as soon as possible. They are characteristically very iterative design projects.

1. Informal method – Extreme Programming (XP)

Reference/source

http://www.extremeprogramming.org

Underlying Philosophy/attitude

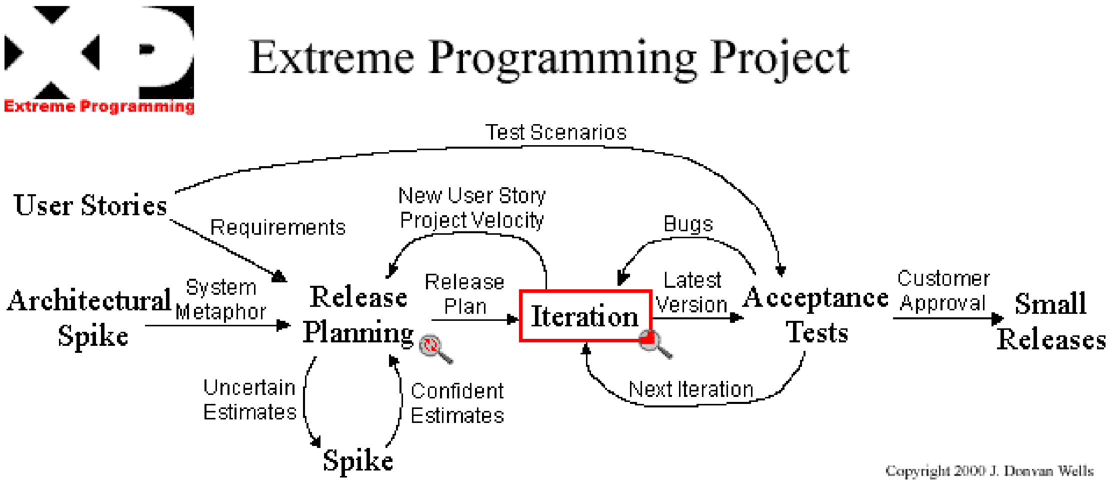
Extreme programming is a formal and deliberate procedure for producing computer software. It stresses the importance of pleasing the end user with the final result, and end users are empowered by constant involvement with the programming project as the software is developed. This contrasts with other approach in which the customer specifies a set of requirements at the beginning of the process and the project is judged to have been completed once the contractor can make the case that those requirements have been met. The key phrase within Extreme Programming (XP) is 'test early, test often'. At its core it is a scheme for the iterative testing of prototypes leading to the completed product. Communication, simplicity, feedback, and courage are the four values sought out by XP programmers.

Description of method

Extreme programming (XP) is primarily about iterative testing. Small chunks of code are created at any one time and then are immediately subject to testing. Testing is automated with test programs that are themselves constructed at the same time as the core code. In this way no programming is done without it being rigorously tested as soon as it has been completed. It is a rule that code without a test is not released. Once a block of code has been completed, it is demonstrated to the customer for feedback. The customer may at this point realise their requirement specifications have changed. In one sense XP is about encouraging programmers to make solid progress on small chunks of a project.

Another feature of XP is that code is created by pairs of programmers, sitting at the same machine. Because XP values rigour over speed it is argued that this paired work produces better quality code first time. Also one programmer can think about the current task tactically (actually working at the keyboard) whilst the other in the pair thinks about it strategically. A finally aspect of XP is that clean and reusable code (suitable for 'refactoring') is produced.

Overall process diagram



Application

Extreme programming is used in software development.

2. Formal method - Unified Modelling Language (UML)

Reference/source

I. Jacobson, G. Booch, and J. Rumbaugh (1999), *The Unified Software Development Process.* Boston, MA: Addison-Wesley.

OMG Unified Modeling Language Specification (2003), version 1.5, formal/03-03-01.

Underlying Philosophy/attitude

The Unified Modelling Language is an industry standard for specifying, visualizing, constructing, and documenting all the artifacts of a software intensive system. Its underlying philosophy stems from the software design modeling approaches as defined within the Unified Software Development Process (Jacobson, Booch and Rumbaugh, 1999).

Central to the modeling approach of UML is to appropriately communicate the high-level functions of the software intensive system and the system's scope and fitness for purpose. This is achieved with the use-case model, which visualises functional and non-functional requirements of a software intensive system, with an emphasis on the relationship of 'actors' (humans interacting with the system) to essential processes in the software intensive system.

Description of method

UML has been derived from object-oriented design methods (Booch modelling, OMT and Objectory methods) and it is related to object-oriented software development processes.

Overall process diagram

Views software from four viewpoints:

- **The Use-case viewpoint**: This viewpoint identifies the relationship of actors to essential processes in a software intensive system. A typical diagram for this viewpoint is the use-case diagram.

- **The Structural viewpoint**: This viewpoint facilitates the representation of the static structure of a software intensive system. Typical diagrammatic notations include: class diagram, object diagram, component diagram, and deployment diagram.

- **The Behavioural viewpoint**: This viewpoint supports the modelling of dynamic elements and processes within a software intensive system. Typical diagrammatic notations include: sequence diagram, activity diagram, collaboration diagram, and state-chart diagram.

- **The Deployment viewpoint**: This viewpoint allows developers to model the management and organisation of components of a software intensive system. Typical diagrammatic notations include: packages, subsystems, and model diagrams.

Application

Used by industry and academia for software and business modelling. There exist several case studies and academic papers, especially within IEEE computer society publications (http://ieeexplore.ieee.org/).

B. Appendix 2 Verification and acceptance methods

1. Live Trials

In large defence projects there are usually several types of live trials. It is usually possible to test the requirements periodically when these trials are taking place.

2. Standards Compliance Checklist

The applicable standards and parts of specified standards are decomposed into a checklist that is applied to the design at specific project stages and key design reviews.

3. Modelling and Simulation Analysis

These are methods and tools that can be used to predict human behaviour prior to design and are then used to verify and validate the operability/user trials results. There are several modelling techniques that can be used.

- Computer based analysis tools
    - Discrete event simulation tools such as Micro Saint, or IPME to demonstrate predicted workload tools such as Micro Saint
    - Manning and complementing simulation tools such as Crew 2, Maritime Exodus,
    - Bespoke software Tools
- Synthetic Environments

These are particularly useful when tools must be networked with other tools or real systems or high fidelity prototypes.

- End of Document -