A Virtual Information-action Workspace

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ABSTRACT

Rapid technological development is a hallmark of modern life. Innovation has come in the form of more information at higher rates, of different forms, at shorter delays and from a wider range of resources. Those working with these innovations have had to adjust as best they can to many of the new demands. The emerging problem is one of information management. Now the forces of a competitive environment are forcing us to do something about it. The development of virtual information-action workspaces offers one opportunity to do things differently. The goal is to organize our information so that we can act on it effectively. That requires an understanding of the information each and everyone of us needs to do our job, the desirable form, level of abstraction and organization of that information, and the action modes that are needed to respond to it. Diverse analytic and design tools to accomplish these goals are available within the behavioural sciences. The development of a virtual information-action workspace requires a coordinated effort to apply those tools in a systematic manner. The virtual information-action workspace offers a solution to a problem that will only become more severe unless we resolve it.

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Executive Summary

Rapid technological development is a hallmark of modern life. Innovation has come in the form of more information at higher rates, of different forms, at shorter delays and from a wider range of resources. Those working with these innovations have had to adjust as best they can to many of the new demands. The emerging problem is one of information management. Now the forces of a competitive environment are forcing us to do something about it. The development of virtual information-action workspaces offers one opportunity to do things differently. The goal is to organize our information so that we can act on it effectively. That requires an understanding of the information each and everyone of us needs to do our job, the desirable form, level of abstraction and organization of that information, and the action modes that are needed to respond to it. Diverse analytic and design tools to accomplish these goals are available within the behavioural sciences. The development of a virtual information-action workspace requires a coordinated effort to apply those tools in a systematic manner. The virtual information-action workspace offers a solution to a problem that will only become more severe unless we resolve it.

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Contents

1. Introduction

Information management has emerged as a significant contemporary challenge to efficient and effective work. It has often been said that we cannot have too much information but information has now become a demanding taskmaster. Paradoxically, we appear to have both too little and too much information. It can seem that so much time is spent gathering and disseminating information that there is little time to focus on the productive aspects of work.

This modern challenge of information management has emerged from the remarkable technological advances in communication systems and digital computation. These technological developments have changed the nature of work. Where once we may have waited hours, days, or even months for a crucial report, it is often now possible to access information in seconds. Where once communications from others arrived at our desks once or twice a day in the form of carefully crafted letters and reports, they now appear at any moment in fragmented, hastily typed messages. Not all of those changes are improvements. For example, those who work in areas of moderate to high complexity often complain of being burdened with excess information.

It is not clear that complaints of more information are accurate but there can be no doubt that there are more sources of information and more fragments of it, which imposes on us a heavy burden to select, integrate, summarise, and assimilate. Typical of the problems are those facing the pilot of a modern commercial aircraft, whose job is more one of information management than of perception and action. The modern cockpit is referred to as a *glass* cockpit because computer screens have replaced the once-dominant suite of instruments. However, pilots are not the only ones who have to deal with this. Increasingly, workspaces are going *glass* and these problems, first documented in the case of the modern commercial pilot (Weiner, 1989), have become widespread.

The new information modes impose both benefits and costs. While many will debate whether the costs outweigh the benefits, the problems of information management are not the result of technology itself but rather of the manner in which we interface with that technology. However, technology has exacerbated the problem by offering the opportunity to provide more information more rapidly at greater temporal and spatial scales and at more levels of abstraction. Nevertheless, we have not yet taken full advantage of the opportunities made available by technology to offer this information in fully usable forms.

A common response to a complex and diverse information space is to use a search engine to identify useful sources of information. However, search engines are not an ideal solution. They typically miss relevant documents, they identify irrelevant documents and they impose on the searcher a considerable amount of selection, analysis and integration. In addition, information retrieval is only a part of the problem. Processing it and then acting on it are also onerous demands.

The solution offered here to the challenge of information management is development of a virtual information-action workspace that will offer access to information in forms that facilitate our effective interaction with it by matching our natural and powerful information-handling capabilities to the diverse demands of our work domain. This space will be one that catalogues or tags information in terms of useful conceptual distinctions and presents it in forms directly compatible with our needs for knowing, understanding, prioritizing, and deciding. It will provide means of testing the likely effects of decisions before they are implemented and will also provide directly compatible means of implementing decisions by facilitating our actions on physical resources or our interactions with other people. It will rely on forms of automation to sort, summarize and integrate information but will leave real-time judgement and decision to human agents and will make evident to those human agents the key processing that has been undertaken on information.

In that it deals with both information and action, it is termed an *information-action workspace*. It is termed *virtual* to distinguish it from a natural information-action workspace, which also has some of the same properties. A natural object is embodied and, in that sense, the information it presents is intrinsically bound to its physical nature. In contrast, the properties represented in a virtual space are not intrinsically bound to the nature of the represented object. A virtual representation may be assigned only a partial set of the properties of the real object or may be assigned properties not found with the real object.

2. The Nature of Information

The term *information* is used here in the sense employed by the psychologist James Gibson (1979; Reed, 1996). Information carries meaning and is derived from patterns or relationships. Most specifically, information supports physical or manipulative activity and cognitive activity such as deciding, judging, and selecting. As Gregory Bateson (1979) has observed, information is a difference that makes a difference. This usage should be distinguished from the scientifically more common statistical conceptualization of information as forwarded from the perspectives of cybernetic, thermodynamic, and communication theory[1].

In Gibson's terms, information is, and always has been, central to the manner in which humans and all other sentient creatures interact within their environment. The problems of finding, isolating, interpreting, summarizing, navigating through and acting on information are not new, but technological innovations have increased the challenges and, in some cases have increased them beyond normal human capabilities.

[1] The anthropologists, Gregory Bateson, Margaret Mead and their daughter, M.Catherine Bateson were key participants in the cybernetic revolution. The manner in which information came to be regarded as the statistical concept, and their concern with that view, are described by Hayles (1999).

Like all sentient creatures, we have evolved within a natural information-action workspace. Information is both spatially and temporally distributed and is available at different levels of abstraction and via different perceptual modalities. We have evolved as exploratory beings that actively search for information to guide functional action. Furthermore, we have a variety of action systems that can be used in the service of that functional action and as we use them we generate further information. Our physical environment can be characterized as a natural information-action workspace or, after Gibson, an ecological information-action workspace. A virtual information-action workspace might be designed in a similar manner (Rasmussen, Pejtersen & Goodstein, 1994; Vicente, 1999).

3. Revolutionary Design

A considerable amount of design work, much of it characterized as user-centered design, is being directed at development of effective interfaces for information management. Flach and Dominguez (1995) prefer the term *use-centered design* to emphasize that this is not just about the user but also about the interaction of the user with the technology. The notion of user- or use-centered design has been with us for some time but there is now a need for a radical re-evaluation of the interface design process. Although excellent work has been undertaken on isolated aspects of this problem, the development of a virtual information-action workspace will require a new design philosophy, here characterized as *revolutionary* (in contrast to *evolutionary)* design. Revolutionary design seeks to identify needs and solutions independently of current work practice or currently available artifacts (Vicente, 1999). In contrast, evolutionary design works on weaknesses of current practice and artifacts.

At best, technology has shaped interfaces to conform to the constraints on human perception-cognition-action via an evolutionary design strategy. At worst, new information and action modes have been provided with little thought to human constraints. New technological perception-action modes are being developed and existing ones enhanced at a rate that could barely be imagined not many years ago. In the face of such rapid changes, evolutionary design will continue to be too slow, with many issues becoming irrelevant before they are resolved and new issues becoming critical before old ones are resolved.

If we are to take full advantage of the opportunities presented by the new information-action technologies, we must exploit a revolutionary design approach. The strategy is to:

- Identify the information and the conceptual distinctions that will support effective work
- Create perceptual and response forms that link information directly[2] to action, and

[2] Following Gibson (1979), to be direct means to be without computation or inference. For example, an aircraft pilot will normally calculate range from fuel quantity and rate of fuel usage. Dinadis and Vicente (1999) have proposed an interface feature in which potential range and required range are presented together. The

- Develop a comprehensive and seamless virtual space that enables a comprehensive appraisal of work situations and an integrated response to those situations.

This strategy conforms to the philosophy of revolutionary design because it identifies fundamental needs independently of current practice or artifacts, and then develops solutions also independently of current practice or artifacts[3].

4. Application Areas

The notion of a virtual information-action workspace is relevant to a huge range of application areas. The following list represents a preliminary identification of work areas that would benefit from a well-designed virtual information-action workspace:

- Commercial
  - Law
  - Commerce
  - Management
  - Finance
- Production
  - Process Control
  - Manufacturing
- Human Services
  - Medicine
  - Transportation
  - Employment
  - Social Welfare
  - Libraries
- Defence
  - System Procurement
  - Command and Control
  - Intelligence
  - Logistics

These are work areas characterized by the need for use of large amounts of information from a large number of sources and at different levels of abstraction.

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computation is undertaken behind the interface, leaving the pilot with a perceptual comparison (also see Hutchins, 1995) to support a decision to proceed to the destination.

[3] An emphasis on principles of revolutionary design and an interest in representation of properties not found in the real world can remain consistent with the desire to exercise our natural and powerful capabilities for perception, cognition and action that have been selected via evolution. The key is to implement new technological opportunities and the new patterns of use they engender in ways that exercise our natural capabilities.

5. The Nature of a Virtual Information-action Workspace

The Command Decision Center of a US Naval Battle Group serves as the focal point at which information about air, surface, and subsurface activity of allied and hostile craft is assembled, integrated, and interpreted. Typically, this information is processed by one highly skilled individual, the Tactical Operations Officer, who establishes what might be termed a *mental picture* of these activities. The task is one of assimilating information from a variety of sources, of assembling a spatial and temporal context, and of assessing the status of threats and also the status of defences that might counter those threats. During the time that the Tactical Operations Officer has successfully established the mental picture of these events he is said to be *in the bubble* (Roberts & Rousseau, 1989).

A virtual information-action workspace is essentially a computer interface that presents information and provides possibilities for action in a manner analogous to this mental bubble. The information is organised at different levels of abstraction and detail and is summarised in forms that can be directly associated with functional action. The action modes are designed to be compatible with the functional requirements. It is an object space in much the same sense that a tradesman's workshop is an object space. Tools and resources are visible and within reach.

It is possible in a virtual workshop to objectify abstract concepts and relationships. Notions such as threat, vulnerability, functional utility and purpose can be revealed pictorially. It is not that these do not exist in a tradesman's workshop but that they need to be recognised on the basis of the appearance of the physical objects that populate the space. The tradesman's hard-earned expertise is in part the ability to recognise those functional, abstract properties. However, many of our information workspaces are too complex and too dynamic for individuals to build the essential level of expertise[4]. Thus, a virtual space for a complex, information-rich workplace might offer explicit representations of functionally relevant concepts and relationships.

The distinction between intentional and physical systems is crucial for the development of a virtual information-action workspace. An *intentional* system is one in which the goals and values of the human participants dominate. A public library is the archetype of the intentional

[4] An expert carpenter knows from extensive experience what plane is needed to dress a special piece of timber, and knows (implicitly) the subtle pressures and movements that result in fine workmanship. In contrast, a lifetime of experience is insufficient for a national treasurer to build the implicit knowledge needed to appraise the interactive effects of all variables that might influence the outcome of a decision to adjust interest rates. A virtual information space for a national treasurer might display relevant variables, provide ready access to data and projections, and support direct manipulation of variables as a means of modelling outcomes for a variety of scenarios.

system. That library must stock books that appeal to the clientele. Ideally, the book stock will be catalogued in terms consistent with the dominant conceptual distinctions found in the client population. In contrast, a *physical* system is one in which the physical constraints dominate. The archetype of a physical system is the process control plant. Information at the process control interface must guide operators to effective control of the physical processes that lie behind that interface. No system is purely intentional or purely physical, and in general, systems for which a virtual information-action workspace might be designed vary considerably in their balance of intentional and physical constraints.

The ideal virtual information-action workspace for a complex socio-technical system may take a generic form but will be tailored to individual needs. The same hardware might be appropriate for all members of an organisation at all levels and in all disciplines and, for a wide range of individuals, the virtual information-action workspace may even access the same information base. Nevertheless, people at different working levels will need to access that information at different levels of abstraction and detail and their resulting actions will be of a different form. Thus the representation and organisation of information may differ at different working levels and the response modes may differ. The resulting workspace will, however, take account of organisational structures and practices by aligning the demands of information management with doctrine and with staff capabilities. Selection and training of personnel will remain as important issues that can impact the effectiveness of the technological solution.

In addition, we need to recognise that we live in a dynamic work environment. Solution forms ideal for today's environment may not be ideal in a year or a decade. New modes of work and new work requirements will almost certainly develop. That will likely require adjustments in the virtual information-action workspace. Adjustments will need to take account of new classifications of information, changes in conceptual structures relevant to work activity, and new ways of implementing action. It is likely that a large and dynamic organisation will benefit considerably from ongoing development of its virtual information-action workspace.

6. Development of a Virtual Information-action Workspace

The arguments presented so far capture elements of what most workers/researchers in human-computer interface design already know. The challenge is to develop a strategy to cope with the information and action requirements of large-scale, multi-faceted and dynamic work environments. This challenge can be met by a revolutionary design strategy. It requires the systematic use of tools that, in the main, are already known and used on more isolated and constrained design problems. Thus, the answer to the challenge of designing virtual

information-action systems lies not in the development of new tools but in their assembly into an integrated program designed to resolve the diverse issues in a systematic manner. In the coordination of the various tools, it is essential to recognise that different types of information-action systems will require somewhat different approaches. Possibly the most crucial distinction that will influence the types of analytic tools to be brought to bear on the problem is that between intentional and physical systems.

There are several distinct phases to the development of the virtual information-action workspace:

- *Identification of distinctive features*. For intentional domains it is necessary to identify the conceptual structures that will be of use. Tools from the behavioural sciences such as repertory grid analysis and factor analysis can be useful here. For physical domains, document analysis can be used to identify the functional structure of the system. Intentional and functional structures can be represented in an Abstraction-Decomposition hierarchy as used in Work Domain Analysis (Rasmussen et al, 1994; Vicente, 1999) and as shown in figures 1 and 2.

- *Identification of the forms of cognitive activity and outcomes*. Many different techniques of Cognitive Analysis are available. The choice of a particular analytic tool depends to a considerable extent on the nature of the system and the desired scope of the solution. Cognitive Work Analysis offers a suite of tools that can be useful here (Vicente, 1999; Figure 3). Activity Analysis maps the patterns of information flow and decision processes in recurring classes of situations such as those identified as General Functions in figure 1. Figure 4 shows one sequence of analysis. This sequence may, however, be adjusted in accordance with the specific demands of the design problem and the experience and capabilities of the analysts (Figure 5).

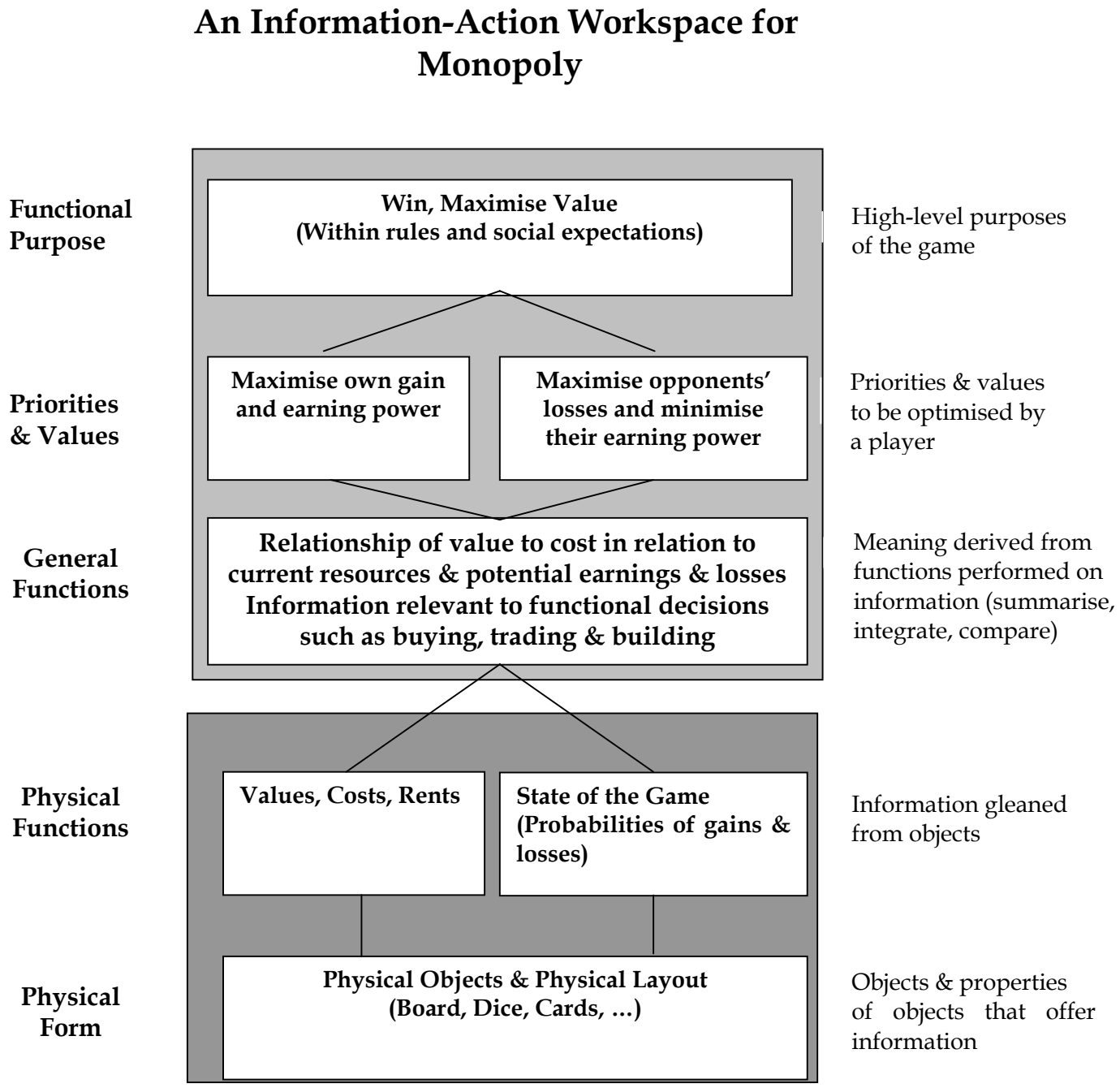

Figure 1. An abstraction hierarchy for the board game, Monopoly, as an information-action work domain. There is a transition from higher to lower levels of intentional to physical properties. Also shown are some of the means-end links. Links to the higher level show why a property is implemented and links to lower levels show how it is implemented.

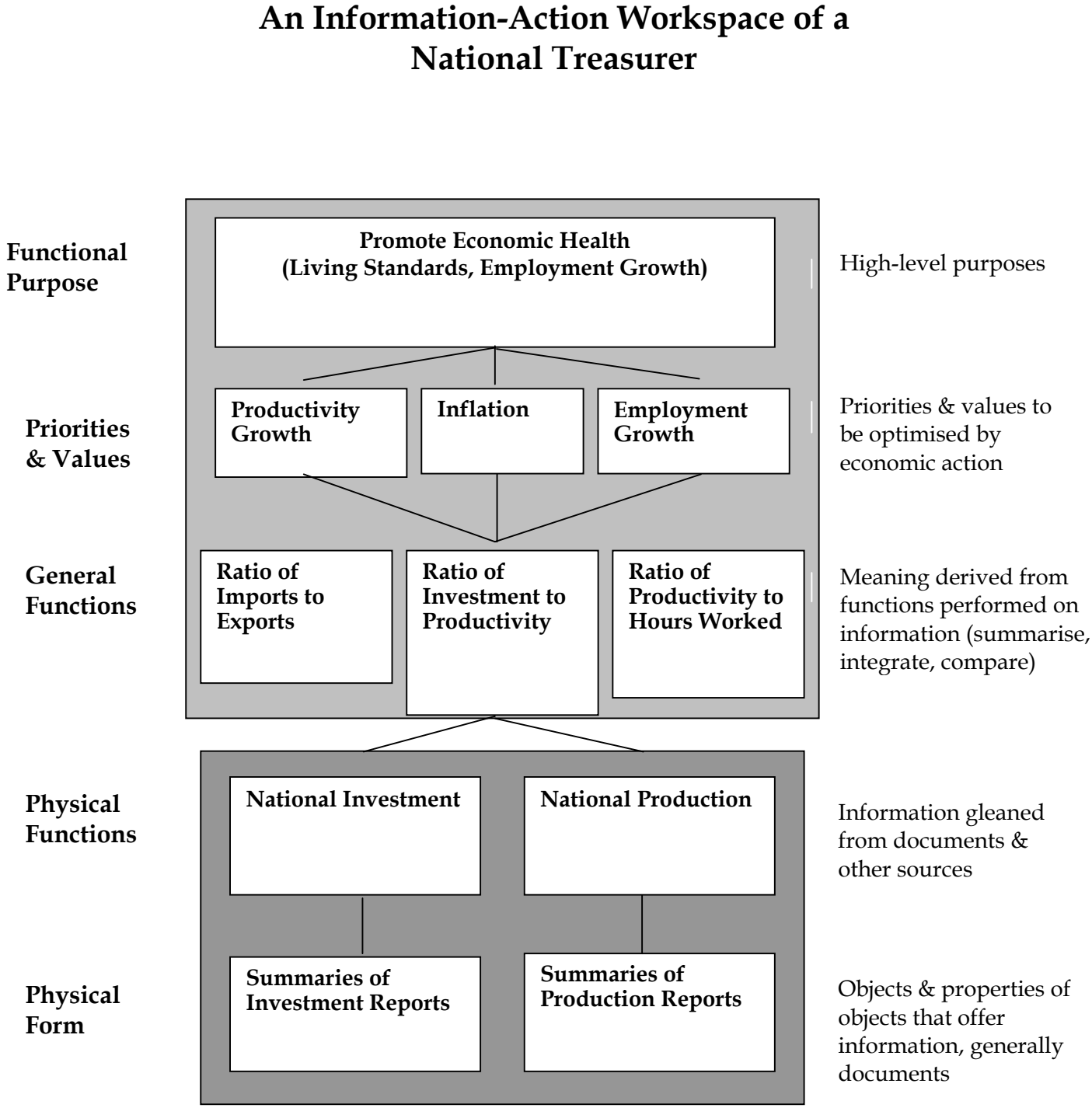

Figure 2. The abstraction hierarchy of an information-action work domain. Shown here, as a means of illustration, is a fragment of an imagined work domain for a national treasurer.

- *Identification of perception and action forms for information and response elements*. Considerable work has been undertaken on the evaluation of forms for perception within the disciplines of Human Factors, human-centered design, and scientific visualization. Development and evaluation of forms for action has not been as intensive. There is still scope for innovation in the development of useful forms for both perception and action but the need in the area of action is particularly acute. Capabilities for action will include modelling tools to enable evaluation of possible actions on outcomes. Modelling is, in itself, a substantive technical challenge. In particular, the problems of identifying influential factors and of developing the appropriate algorithms should not be underestimated. One goal in the development of the virtual information-action workspace is to make robust modelling tools available and useable for those who are not necessarily experts in modelling but it is critical that the underlying models are valid and that their range is appropriate for the problems to be modelled.
- *Development of an integrated and comprehensive information-action workspace*. A guide to the way this might be done is found in the relatively few examples of virtual information-action workspaces. Two significant developments are an interface for the engineer's station in a C130 aircraft designed by Dinadis and Vicente (1999) and an interface for a public library designed by Pejtersen (1992). Each of these interfaces employs an innovative layout of perceptual forms to support navigation through the information space. They incorporate elements at different levels of abstraction and detail in response to specific needs.

The goals in the development of a virtual information-action workspace are to offer ready access for each worker to the information required, to enable effective judgements related to issues at hand, and to promote effective action in relation to those issues.

7. Conclusion

Rapid technological development is a hallmark of modern life. Innovation has come in the form of more information at higher rates, in different forms, at shorter delays and from a wider range of resources. Those working with these innovations have had to adjust as best they can to many of the new demands. The emerging problem is of one information management. Now there is an opportunity to do things differently and the pressures of our competitive environment are forcing us to find a solution.

The goal is to organize and present information so that we can act on it effectively. That requires an understanding of the information each and every one of us needs to do our job, its desirable form, its level of abstraction and organization, and the action modes that are needed to respond to it. Diverse tools to accomplish these goals are available within the behavioural

sciences. The development of a virtual information-action workspace requires a coordinated effort to apply those tools in a systematic manner. The virtual information-action workspace offers a solution to a problem that will only become more severe unless we resolve it. A solution is, in fact, essential if we are to exploit fully the potential of technological developments in communication and computation.

Phase of Analysis	**Properties of the Information-Action Workspace**	**Tools**	
		Knowledge Acquisition	**Knowledge Representation**
Work Domain	Physical & Purposive Constraints	Document Analysis Reviews by Subject Matter Experts	Abstraction-Decomposition Matrix
Activities	What needs to be done in the Work Domain (Work Functions & Control Tasks)	Cognitive Walk-Through, Study of Work Practices	Decision Ladder
Strategies	Strategies for Management & Control (Planning, Adapting)	Critical Decision Methods, Interaction Analysis, Verbal Protocol Analysis	Information Flow Map
Social-Organisational	Collaborating Actors & Organisational Structure	Communications Analysis, Interaction Analysis	Integrate information from tools above
Concepts & Competencies	Human Capabilities & Limitations (SRK, Conceptual Distinctions)	Repertory Grid Analysis & Review of Decision Ladder	Concept Map & Skills-Rules-Knowledge Frame

Figure 3. A set of tools used for knowledge acquisition and knowledge representation in each phase of a Cognitive Work Analysis employed to identify the design-relevant properties of an information-action workspace. The tools shown here illustrate how it is possible to proceed with a Cognitive Work Analysis. However, the diversity of tools that might be listed here is too great for a figure such as this to capture all possibilities. Different tools could be substituted with good effect, depending on the demands of the project and the expertise of the analysts (Seamster, Redding & Kaempf, 1997; Lintern, in press).

Appendix A: Work Domain Analysis

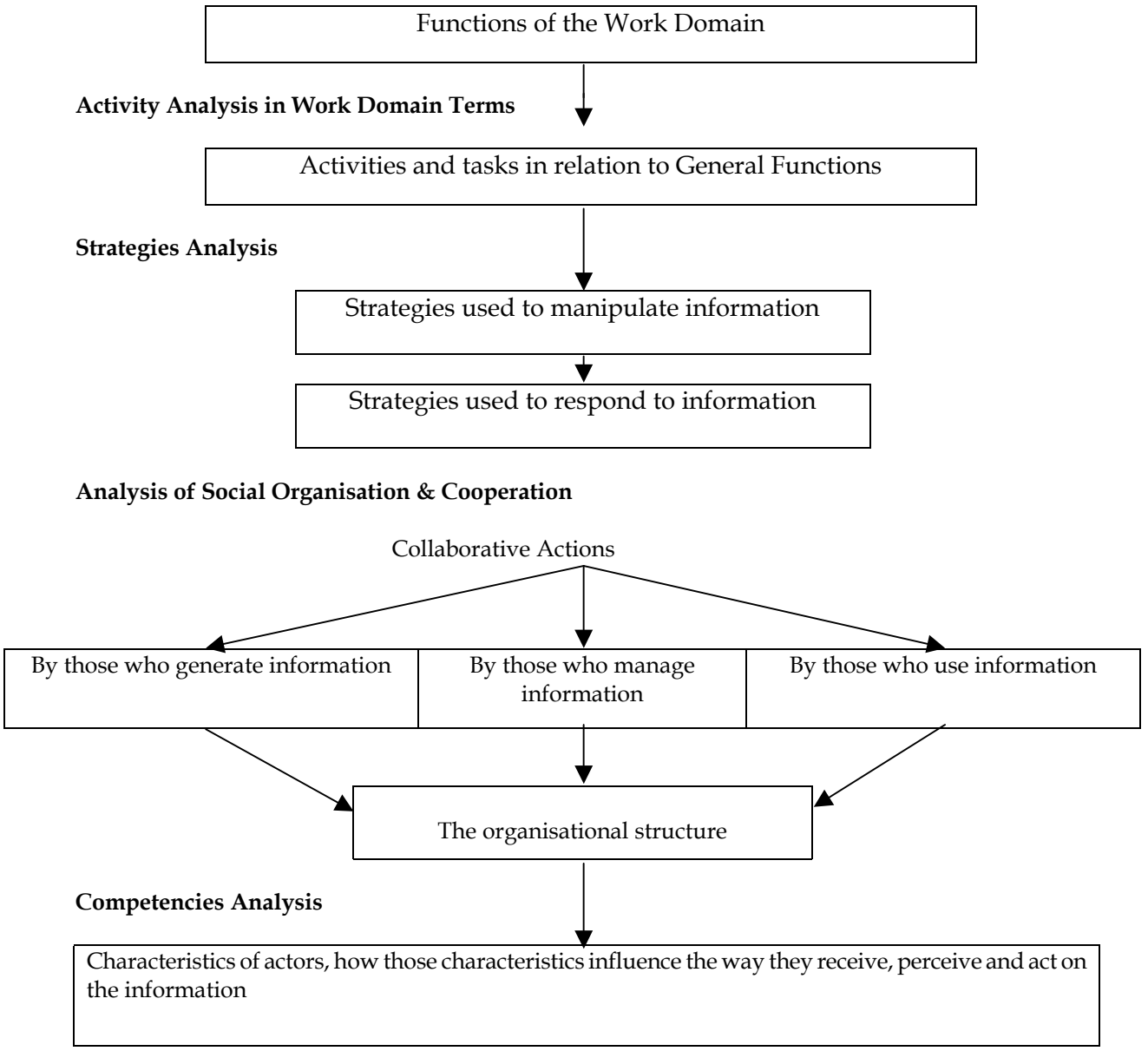

Figure 4. Cognitive Work Analysis has five distinct stages (Vicente, 1999). To identify the diverse constructs for design of a complex information-action workspace, the overall analysis might start with Work Domain Analysis as identified in figures 1 & 2 followed sequentially by an Activity Analysis, a Strategies Analysis, an Analysis of Social Organisation & Cooperation, and an analysis of Worker Competencies.

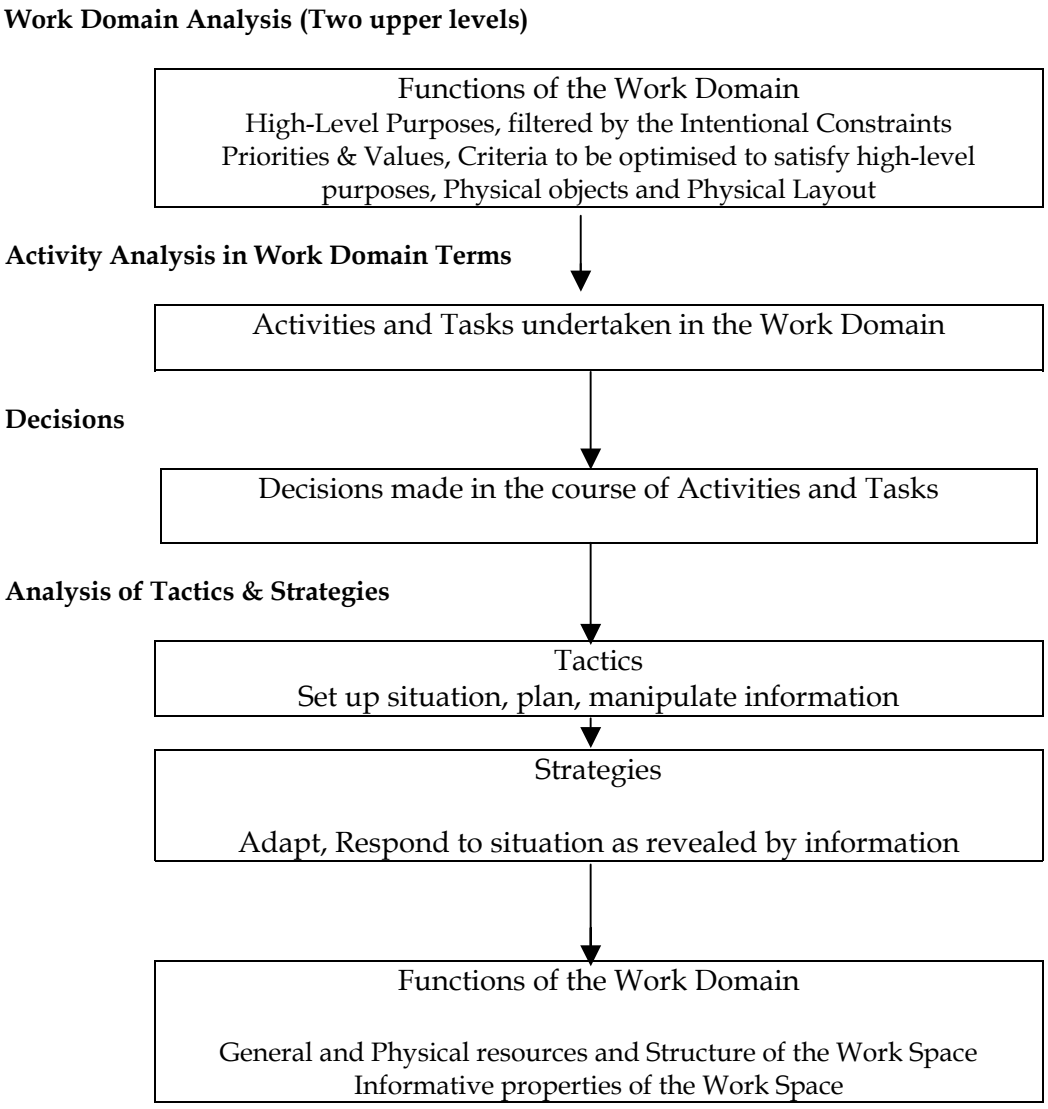

Figure 5. The sequence outlined in Figure 4 is useful for the design of a system that will result in a new form of work practice but it is not always desirable in Cognitive Work Analysis to follow that sequence. For the work domain of the board game Monopoly, analysis of the third and fourth levels was delayed until tasks, activities, decisions, tactics and strategies had been identified. In general, the sequence and detail of the analytic stages may be adjusted to the demands of the design problem. Furthermore, Cognitive Work Analysis typically requires considerable iteration within and between stages.

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19. ABSTRACT

Rapid technological development is a hallmark of modern life. Innovation has come in the form of more information at higher rates, of different forms, at shorter delays and from a wider range of resources. Those working with these innovations have had to adjust as best they can to many of the new demands. The emerging problem is one of information management. Now the forces of a competitive environment are forcing us to do something about it. The development of virtual information-action workspaces offers one opportunity to do things differently. The goal is to organize our information so that we can act on it effectively. That requires an understanding of the information each and everyone of us needs to do our job, the desirable form, level of abstraction and organization of that information, and the action modes that are needed to respond to it. Diverse analytic and design tools to accomplish these goals are available within the behavioural sciences. The development of a virtual information-action workspace requires a coordinated effort to apply those tools in a systematic manner. The virtual information-action workspace offers a solution to a problem that will only become more severe unless we resolve it.