

Knowledge engineering and psychology: Towards a closer relationship

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Abstract

Knowledge engineering projects deal with a wide range of domains within organizational and academic contexts. A number of elicitation techniques are used to acquire knowledge from experts. Most of these techniques originated within psychology but have been developed by knowledge engineers to become more structured, efficient and systematic. Until now, nobody has tried to re-apply these modified techniques back into psychology. This paper describes work that addresses this matter. It focuses on the psychological knowledge possessed by all people that enables them to deal with everyday problems and make life decisions. We refer to this as 'personal knowledge'. To take a knowledge engineering approach to personal knowledge, we investigated the use of knowledge elicitation techniques to capture personal knowledge. We describe an empirical study involving ten participants and 80 knowledge acquisition sessions that assessed eight elicitation techniques in this context. The results revealed that each of the techniques showed promise at efficiently capturing and structuring aspects of an individual's personal knowledge. A content analysis of the acquired knowledge led to the construction of a meta-model (a primitive ontology) of personal knowledge and to the design for a new methodology for psychological research. From the perspective of psychology, the paper shows that knowledge engineering methods can be of value to psychologists. From the perspective of knowledge engineering and the wider computer science community, the paper shows that empirical methods used by psychologists can benefit the development and evaluation of ontologies and elicitation techniques.

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1. Introduction

Knowledge engineering is that part of AI concerned with the principles, methods and tools for acquiring knowledge and developing knowledge-based systems (Studer et al., 1998; Schreiber et al., 2000). A primary research area during the 1980s and 1990s addressed the elicitation of knowledge from subject matter experts (Hoffman et al., 1995). Although research in this area has dwindled over the past few years, a number of organizations are benefiting from the practical application of these research findings,

not only for AI but also for the wider field of Knowledge Management (Milton et al., 1999; Hammersley et al., 1999).

A key feature when assessing knowledge elicitation techniques has been the use of empirical studies, particularly controlled experiments (Shadbolt and Burton, 1995). Over recent years, a shift in emphasis in knowledge engineering from acquisition techniques to ontologies and computer languages has taken place. This shift has resulted in a lack of emphasis on experiments and other empirical methods of assessment. One of the aims of the work presented in this paper is to demonstrate that a properly designed empirical study can be of benefit to the development and evaluation of ontologies as well as for elicitation techniques. Another aim, from the perspective of psychology, is to show that techniques used by knowledge

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engineers to acquire and model knowledge can be of benefit for psychological research and perhaps as a therapeutic tool.

1.1. Personal knowledge

Knowledge engineering projects typically involve domains associated with organizational or academic knowledge. In this paper, we explore a different type of knowledge: the psychological knowledge possessed by all people that enables them to deal with everyday problems and make life decisions. This includes the knowledge individuals have of their life history, their behaviours, their moods, their attitudes, their relationships, their abilities, their aspirations, and so on. We refer to such knowledge as ‘personal knowledge’.

The study of personal knowledge is usually the preserve of psychologists, psychotherapists, psychiatrists and counsellors. We aim to show in this paper that a knowledge engineering approach to personal knowledge can provide methods that add to those already used by these professionals. We believe that these methods can help in the development of new psychological theories and be of benefit to ordinary people by increasing their self-understanding. This follows a trend in psychology, and the social sciences, to widen the use of qualitative techniques (Smith et al., 1995).

In exploring these issues, we follow an interdisciplinary approach by treating personal knowledge as if it were a type of expert knowledge. In other words, we take the principles and techniques used by knowledge engineers in domains such as medicine, electronics and geology and apply them to the domain of personal knowledge. Our subject matter experts are ordinary people each of whom possesses the expertise to deal with life situations within complex social environments.

1.2. Knowledge elicitation techniques

It is important to note that many knowledge elicitation techniques originated within psychology. However, work undertaken by the knowledge engineering community over the past 20 years has transformed these techniques so that they have to become more structured, efficient and systematic. One development has been the use of structured methodologies such as CommonKADS (Schreiber et al., 2000) and MOKA (Stokes, 2001). Another has been the use of software support tools such as Protégé (Protégé website) and PCPACK (Epistemics website). Another has been the use of generic knowledgebases such as CYC (CYC Website). In spite of these advances, there has been no attempt to export the adapted techniques back into psychology and assess their merits for psychological purposes. The research presented here aims to rectify this matter.

1.3. Structure

The rest of the paper is organized as follows. Section 2 describes the background and rationale for pursuing a knowledge engineering approach to personal knowledge. Section 3 describes an empirical study that examined the use of knowledge elicitation techniques to acquire personal knowledge. Section 4 presents a meta-model of personal knowledge derived from the empirical results. Section 5 describes a new methodology for psychological research. Section 6 contains a summary and concluding remarks.

2. A knowledge engineering approach to personal knowledge

2.1. Approach

When defining the approach to be used in the study, we first sought to determine the significant differences between the domain of personal knowledge and conventional knowledge engineering domains. We discerned four key differences. First, unlike most knowledge domains, personal knowledge is not based on a core set of theories and practices taught to practitioners at schools and universities. Second, the history of psychology shows that personal knowledge is vastly complex, with numerous perspectives and points of view. Indicative of this is the variety of different psychotherapies and psychological research approaches that are used. Third, the domain of personal knowledge has no obvious experts. Although some may lay claim to be experts, we feel that every person in the world can be considered to be an expert on their own life. Fourth, knowledge engineering domains tend to be problem-focused and often involve structured knowledge, clear-cut goals and decisions. In contrast, an individual’s personal life tends to be less driven by the need to solve clear-cut problems and may involve less structured knowledge, such as knowledge associated with emotions and feelings.

The differences outlined above led us away from a conventional knowledge engineering approach; that is, to acquire and model the knowledge of domain experts to create an intelligent software system. The development of such a system in the context of personal knowledge would be too ambitious and too problematic. Instead, we looked to the use of personal knowledge in psychology. Psychologists capture and analyse personal knowledge for two main reasons: (i) to provide psychotherapeutic help and (ii) to develop theories. Thus, we have two distinct possible aims: to help in the provision of psychotherapeutic help, or to help in the development of new psychological theories. We chose to explore both of these aims, but with an emphasis on the latter.

To address these aims, we asked two questions: (i) How is personal knowledge used to provide psychotherapeutic benefits? (ii) How is personal knowledge treated within psychological research? The following sections briefly address these questions as a background to the study described in Section 3.

2.2. Personal knowledge and psychotherapy

There are many approaches and methods used by psychotherapists, clinical psychologists and counsellors. Indeed, there are over 250 different forms of psychotherapy (Meichenbaum, 1997). Taken as a whole, the literature on psychotherapy is equivocal in the evidence for and against each of the therapies. What can be discerned is that most forms of psychotherapy involve personal knowledge. Indeed, many important and well-known therapies use techniques that involve eliciting, revealing, analysing and challenging personal knowledge. To illustrate this, the following paragraphs give a brief account of the main psychotherapeutic approaches and the some of the techniques that are used.

2.2.1. The psychodynamic approach

The psychodynamic approach has its roots in the psychoanalytic tradition of Freud and his followers. Therapy is based essentially on interview sessions, with analysis and interpretation by the therapist. Hence, this type of therapy has been described as a ‘talking cure’ (Rycroft, 1995). The key aim is to uncover and reveal unconscious memories, wishes, motivations and fears. These are seen as the cause of emotional disturbance but are not able to be explicitly verbalized due to a coping mechanism of internal repression. Therapy involves techniques such as free association, analysis of dreams, association tests and interpretation of meaningless or ambiguous images.

2.2.2. The humanistic approach

The humanistic approach is inspired by the work of Carl Rogers (1951) and places great importance on the support, empathy and unconditional positive regard that the therapist displays to the client. The purpose of most humanistic therapies is to help the client to become what he/she is capable of becoming (Maslow, 1968), rather than diagnose a problem and cure it. The therapist aims to provide opportunities, ideas and experiences within the therapeutic session. The techniques that are used can be seen as ways of being with a client rather than procedures that operate to make things happen in the client (Bohart and Tallman, 1996).

2.2.3. Cognitive-behaviour therapies

Cognitive-behaviour therapies include a family of approaches based on empirical psychological research. The main therapeutic goal is the modification of behaviour and/or cognitions. The two main approaches are behaviour therapy and cognitive therapy. Behaviour therapy is based on the behaviourist movement of experimental psychology, primarily with the work of Pavlov and Skinner. Therapy aims to break maladaptive associations that were learned via conditioning. Techniques such as systematic desensitization and token economies are used (Murdoch and Barker, 1991). Cognitive therapy is based on the idea that

symptoms (e.g. of depression) and negative automatic thoughts about the self (e.g. “I’m worthless”) are locked in a vicious cycle (Beck et al., 1980). Therapy involves a number of techniques such as monitoring daily activities, disrupting negative automatic thoughts, challenging underlying assumptions and preparing for future life changes.

2.2.4. Personal construct psychology

Personal construct psychology (Kelly, 1955) is a constructivist system based on the idea that an individual’s psychological processes are driven by the way in which events are interpreted. Prediction of future events is based on a person’s constructs, i.e. the ways in which entities are construed as being similar or different from each other. Maladaptive thoughts and behaviours are seen to stem from inappropriate constructs. The therapeutic approach encourages the client to develop alternative construct systems. The main therapeutic technique is the role construct repertory test, now referred to as the repertory grid (Fransella and Bannister, 1977). This method involves the construction of a grid consisting of numerical ratings of constructs for a set of elements (e.g. significant people). Evidence indicates that revelation of underlying constructs using this technique has beneficial effects on mood and decision making (Beail, 1985; Smith, 1990). Of particular relevance for our research is the work of Mildred Shaw and Brian Gaines who have used the repertory grid technique for both psychological and knowledge engineering purposes (Shaw, 1980; Gaines and Shaw, 1993; PCP Website). This work is an important precedent for our approach and suggests that the techniques of knowledge engineering may not need substantial modification when applied to personal knowledge. However, in the case of techniques other than the repertory grid, this remains an important research issue requiring empirical examination.

2.2.5. Self-help and self-development approaches

Self-help and self-development approaches do not rely on a therapist to relate directly to the client. Instead, these approaches make use of self-help books, diaries and computer-assisted therapies. Self-help books, in particular, are very popular; for example, surveys have shown that over 30% of American adults having purchased a self-help book (Wood, 1988). These approaches split into those that address a particular problem and those that aim to facilitate more self-understanding and engender personal development. Of the problem-focussed approaches, many studies have shown that self-help therapies are just as effective as those involving a therapist for many types of psychological problems (Bloom, 1992; Gould and Clum, 1993; Marrs, 1995). Knowledge-based systems developed for therapeutic uses have been shown to engage the user and provide a cost-effective means of therapeutic intervention (Binik et al., 1988; Velicer et al., 1993).

2.2.6. *Implications*

Even this brief survey of psychotherapies shows the variety of different methods and approaches that are used. Which of these should we adopt? We decided not to adopt any particular psychotherapeutic approach. Instead, we circumvented the issue, by choosing to involve people with no specific psychological problem. In this way, we could use a holistic approach in the manner of self-help and self-development approaches. Thus, we hypothesized that the simple act of eliciting an individual's personal knowledge and providing him/her with the resulting structured representations (e.g. concept maps) would be beneficial; for example, in realizing new ideas, seeing things from a new perspective, making new connections, etc.

2.3. *Personal knowledge and research psychology*

Rather than aim to help people directly, many research psychologists focus on the development of new theories in areas such as perception, cognition, learning, decision making and social interaction. How do such researchers treat personal knowledge? This depends on the research method being used. The methods generally fall into two main groups: quantitative and qualitative. There has been a long debate in psychology and the social sciences about the relative merits of these two approaches and some have sought to unite the two (Robson, 2002; Todd et al., 2004). However, the vast majority of research still uses one approach or the other.

For the present purposes, there are three reasons for examining the different methods that the quantitative and qualitative approaches adopt: (i) the pragmatic reason of deciding which methods to use in our empirical study; (ii) the longer-term aim of providing new techniques for psychological research; (iii) to promote methods used in the social sciences for use within knowledge engineering and the wider computer science community. For these reasons, we take a brief look at the two approaches.

2.3.1. *The quantitative approach*

The quantitative approach takes its practices from the natural sciences, favouring the testing of hypotheses to examine small aspects of behaviour and experience. The use of controlled experiments, predefined metrics and multivariate statistics is commonplace. Personal knowledge is acquired using observation and self-reporting techniques. Opponents of the quantitative approach argue that the results lack validity due to the artificial nature of the experiments and that various biases are introduced by the experimenter and experimental environment resulting in conclusions of questionable value (Smith et al., 1995).

2.3.2. *The qualitative approach*

The qualitative approach takes its practices from linguistics, sociology and the humanities (Weinberg, 2002). Researchers acknowledge the multi-faceted reality of experience, treating people as complex, self-reflective

entities, inextricably bound to their social and cultural climate. Personal knowledge is primarily acquired using interviews, although other methods are used such as repertory grids (Collett, 1979), concept ranking (Stainton Rogers, 1995) and role play (Yardley-Matwiejczuk, 1997). Although qualitative approaches capture a rich form of knowledge, opponents criticize the flexible, non-rigorous methods, the subjective interpretation of data and the highly contextualized nature of the studies. In addition, they note that studies are very expensive in resources, particularly the time needed from highly skilled psychologists and highly motivated participants (Miles, 1979).

2.3.3. *Implications*

A knowledge engineering approach to personal knowledge has many similarities with the qualitative approach to psychological research. Perhaps it is the case that the principles and techniques used in knowledge engineering may mitigate some of the problems with the qualitative approach. An attractive notion is to use techniques that gather a rich form of structured knowledge from a large number of people. This may provide a crossover between a quantitative and qualitative approach. Use of elicitation techniques that allow the participants to structure and codify their own knowledge may diminish the problems of expensive resources and subjective interpretation of data levelled at the qualitative approach. In addition, the use of an ontology of personal knowledge (sadly lacking in the psychological literature) might be useful when acquiring knowledge and developing new theories.

2.4. *Research questions*

Having surveyed the use of personal knowledge within psychology, we are now in a position to identify the specific questions to be addressed in the empirical study. Can knowledge elicitation techniques be used to capture personal knowledge? What sort of knowledge will be captured? Can the process of eliciting personal knowledge from an individual help that individual to understand more about themselves? Can that increased understanding be of benefit to the individual, psychotherapeutically or in some other way? Which techniques will be best at capturing personal knowledge and at facilitating more understanding? In what ways might knowledge elicitation techniques be used for psychological research and psychotherapy? What would a meta-model of personal knowledge look like and how might it be used? To tackle these research questions, we undertook a large-scale empirical study.

3. **Empirical study**

3.1. *Design considerations*

The empirical study aimed to assess various knowledge elicitation techniques with a number of participants acting as experts. The domain of their expertise is their own

personal knowledge, including knowledge of their behaviours, emotions, aspirations and life story.

We adopted a tried-and-trusted format of knowledge acquisition session in which a knowledge engineer interacts with a single expert. The techniques to be assessed were a mixture of paper-based methods and those that are supported by knowledge acquisition software. For the latter, we chose the PCPACK suite of knowledge tools, which has been used on many knowledge acquisition projects and in domains outside knowledge engineering (Shadbolt and Milton, 1999).

3.2. Selection of elicitation techniques

A variety of techniques have been developed for eliciting, mapping and validating knowledge from subject matter experts. A number of authors have provided reviews and comparisons (e.g. Boose, 1989; Cooke, 1994; Hoffman et al., 1995; Shadbolt and Burton, 1995). For example, Shadbolt and Burton (1995) provide a taxonomy of techniques with two high-level classes: non-contrived (aka natural) techniques and contrived techniques. Non-contrived techniques include interviews (structured, semi-structured and unstructured) and protocol analysis techniques (Belkin et al., 1987). Contrived techniques include mapping techniques, such as concept mapping (Zaff et al., 1993) and repertory grid (Gaines and Shaw, 1993), and goal decomposition techniques, such as laddering (Corbridge et al., 1994) and limited information tasks (Grover, 1983).

For the current study, it was decided that eight techniques would be assessed. Seven of these were selected from a range of elicitation techniques assessed during a pilot study. An eighth technique was added as a control technique to act as a benchmark against which to compare the others.

The decision of which elicitation techniques to select was based on a number of criteria. First, each technique should be capable of acquiring knowledge, preferably structured knowledge. Second, each technique should be able to be fully explained and implemented with a participant in a session lasting approximately 1 hour. Third, there should be at least one technique that can acquire knowledge from the different types of personal knowledge, e.g. knowledge of social entities, attitudes, behaviours, emotions, goals, events and attributes. Fourth, each technique should have performed well during the pilot study (that involved 20 knowledge acquisition sessions in which various techniques were tested and developed). The following paragraphs describe the techniques that were selected based on these criteria.

A *semi-structured interview* technique was selected because it is representative of a questioning technique and can acquire a broad range of knowledge. The semi-structured interview is a standard technique used in many knowledge engineering projects. It makes use of a pre-designed set of questions but allows unplanned supple-

mentary questions to be asked during the session. The design of the interview included 12 questions partitioned into three sections based on the structure of a psychological interview developed by De Waele and Harré (1979).

A repertory grid technique, named the *people grid*, was selected because of its widespread use for acquiring knowledge and its uses in psychology. The people grid technique is based on the construction of a repertory grid in which the elements are aspects of the participant and significant others. The constructs (attributes) are personality traits, which were selected from those described by the participant during the semi-structured interview. The technique involves rating the elements for each of the constructs on a numerical scale. These ratings are subjected to a cluster analysis using special software to produce a focus grid. The final stage involves reviewing and amending this grid.

A second repertory grid technique, named the *events/periods grid*, was selected to capture knowledge of the participant's life history by comparing different events and time periods. Thus, the elements in the grid were events and time periods in the participant's life. The constructs were attributes of these events and time periods. These constructs were elicited using a triadic elicitation method.

A diagram-construction technique, named the *state diagram technique*, was selected because it is a structured, model-based technique that can elicit behaviours, moods and emotions. This technique is based on the construction of a state transition network; a diagram showing states as nodes linked by arrows representing transitions. The participant selects states they regularly experience (e.g. emotions) which are represented as nodes. The transitions are the ways in which the participant moves from state to state (usually actions performed or external events). The technique involves the construction of such a diagram from scratch on a large sheet of paper. The technique concludes with the participant assessing what percentage of time he/she spends in each state.

A combined laddering and concept-mapping technique, named the *aspirations technique*, was selected because it is a structured technique that can capture knowledge of decisions, goals and motivations. This technique has two stages. First, a decision tree is constructed based on a key decision that the participant is considering or has recently made. The nodes on the tree are the possible courses of action, and the sub-nodes are advantages and disadvantages. There then follows a questioning procedure in which the participant is asked repeated "why" questions for the reasons behind the advantages and disadvantages. A second diagram, the 'aspirations diagram' is then constructed using the abstracted answers from the "why" questions as nodes on a concept map. Extra nodes are added to show all aspirations and associated concepts. Links are added to the diagram to represent the relationships between the aspirations and associated concepts.

A process mapping technique, named the *event diagram technique*, was selected because it is a structured, model-based technique that can elicit and capture event-based knowledge. The technique is based on the construction of a set of diagrams similar to the process maps used by knowledge engineers. There are three main types of nodes on the diagrams: events, inputs and outputs. The inputs represent the state of affairs before an event, and the outputs show what the event has caused to change. The technique involves the construction of a hierarchical set of these diagrams using special software.

An *interview review* technique was selected based on the use of diaries for therapeutic means. It makes use of the transcripts from the semi-structured interviews. Each participant is supplied with a transcript of the semi-structured interview in which they took part some months previously. The participant reads and reviews the transcript. Their reactions are captured as the transcript is read by adding symbols and remarks to the text.

The *Keirseley Temperament Sorter* (Keirseley and Bates, 1984) was selected as the control technique since it is a standard personality technique that captures knowledge of an individual's personality and provides information that aims to increase self-awareness. This technique is based on Jungian psychoanalysis and is derived from the Myers–Briggs type indicator, the most widely used technique for personal development in organizations (Quenk, 2000). Answers to a set of 70 questions provide scores on four scales (extrovert–introvert, judgement–perception, thinking–feeling and sensing–intuition). These scores allow the participant to be categorized into one of 16 temperaments that group into four temperament classes. Standardized descriptions of each temperament and class are provided for the participant to read and reflect upon.

3.3. Participants

The number of participants to involve was determined by two opposing factors. First, having enough participants to ensure a good spread of demographics and enough assessment data for quantitative analyses to be applied. Second, having a small enough number to ensure that there was enough time to assess each technique with each participant and enough time for a full analysis of the resulting data. On this basis, it was decided to involve 18 people: eight in the pilot study and ten in the main study. The participants in the pilot study were all post-graduate university students. The participants in the main study were all employees of a large engineering organization. These people were selected using a quasi-random procedure (i.e. random within the constraints imposed by the study) so that they represented a range of ages, educational backgrounds, work areas and job positions. In recruiting the participants, we followed the normal procedures of a psychological study to ensure ethical standards were observed.

3.4. Assessment methods

There are many problems when evaluating knowledge elicitation techniques (Shadbolt et al., 1999). There is the difficulty of involving a large enough sample of experts to give statistical significance. There is the difficulty of assessing and validating the knowledge acquired given the lack of 'gold standards' to compare against. There is the need to discover the range of tasks and domains for which the techniques are useful. There is also the difficulty of isolating what added value a technique gives when each technique may need to work alongside other techniques.

A further difficulty arises from the fact that knowledge is not easy to quantify. Various measures can be used, such as the number of rules, the number of frames and the number of nodes in semantic networks. Since the techniques being assessed here are inherently different in nature, such measures cannot be used. Rather than concoct a knowledge-based measure that may be biased and invalid, it was decided to follow the assessment procedures used in many psychological experiments, and allow the participants to provide subjective judgements of the techniques. Hence, questionnaires and feedback interviews were used. Four measures were designed: (i) a questionnaire containing open-ended questions, (ii) a questionnaire containing rating scale items, (iii) a semi-structured feedback interview and (iv) a ranking technique. These different methods overlap in what opinions they capture, hence provide a way to assess the reliability and validity of the measures.

3.5. Method

All ten participants in the main study were seen separately on eight occasions, over a period of about 8 months, i.e. 80 separate knowledge acquisition sessions took place. Each session lasted about 1 hour. The first session for all of the participants involved the semi-structured interview technique. Excluding the interview review technique, the other six techniques were randomly assigned so that each participant assessed them in a different sequence. At the end of each session, the participant was given a questionnaire to complete. The questionnaire captured the participant's opinions of the session using open-ended questions and rating scales.

Following the seventh session with each participant, the interview review technique was used. The eighth and final session with each participant (the 'feedback session') comprised a review of all the techniques and of the study as a whole. This session used a semi-structured interview format and included a ranking of the techniques using a card sorting technique.

All the sessions were tape-recorded. The first session (the semi-structured interview) and the final session (the feedback session) were transcribed in full. The other sessions were selectively transcribed.

Analysis involved both qualitative and quantitative methods. Qualitative methods were used to analyse the

content of the knowledge captured, the responses to the open-ended questionnaire and the responses made at the feedback session. Quantitative (statistical) methods were used to analyse basic measures of each knowledge model (such as the number of nodes), ratings made on the questionnaire and rankings made at the feedback session.

3.6. Results

This section contains the main results of the empirical study. A full description of the results, and the study as a whole, can be found in Milton (2003).

3.6.1. Assessment of each technique

A brief summary of the results obtained for each of the techniques is as follows.

Semi structured interview: Responses to the interview questions provided a large and rich source of personal knowledge, covering areas such as life events, self-descriptions and opinions of personal knowledge. The content of the responses also provided an efficient means of leading into the other techniques being assessed. A number of participants felt that it was useful to have the opportunity to talk about and examine things that they do not normally talk about. The main problem identified by the participants was a lack of clarity in some questions, which may be overcome by a more structured answering system and advice on what knowledge can be captured.

People grid: A content analysis identified four classes of constructs: (i) ambition and strength, (ii) emotions and niceness, (iii) social skills and (iv) thinking skills. Participants who liked the people grid did so because it was thought-provoking and revealed similarities between people they had not previously realized. A statistical analysis of the results of the questionnaire showed that the people grid technique was rated more highly by women and by younger participants. Generally, participants felt that the main problem with this technique was difficulty in performing the ratings.

Events/periods grid: A content analysis identified eight classes of constructs that were used, the most common being associated with feelings/emotions, moods/states and decisions/outcomes. The technique was found to be the least favoured by the participants as a whole. The main reported reason for this was the failure to reveal anything new to many of the participants. A statistical analysis of the results of the questionnaire showed that the events/periods grid technique was rated more highly by women and by participants without a university degree. The main problems identified by the participants were in the choice of which events/periods to use and the generation of the constructs. Using less important life decisions and using another technique to elicit the constructs may overcome these problems.

State diagrams: Each participant’s diagram contained, on average, eight states and 22 links between states. An example of part of a state diagram is shown on Fig. 1. The

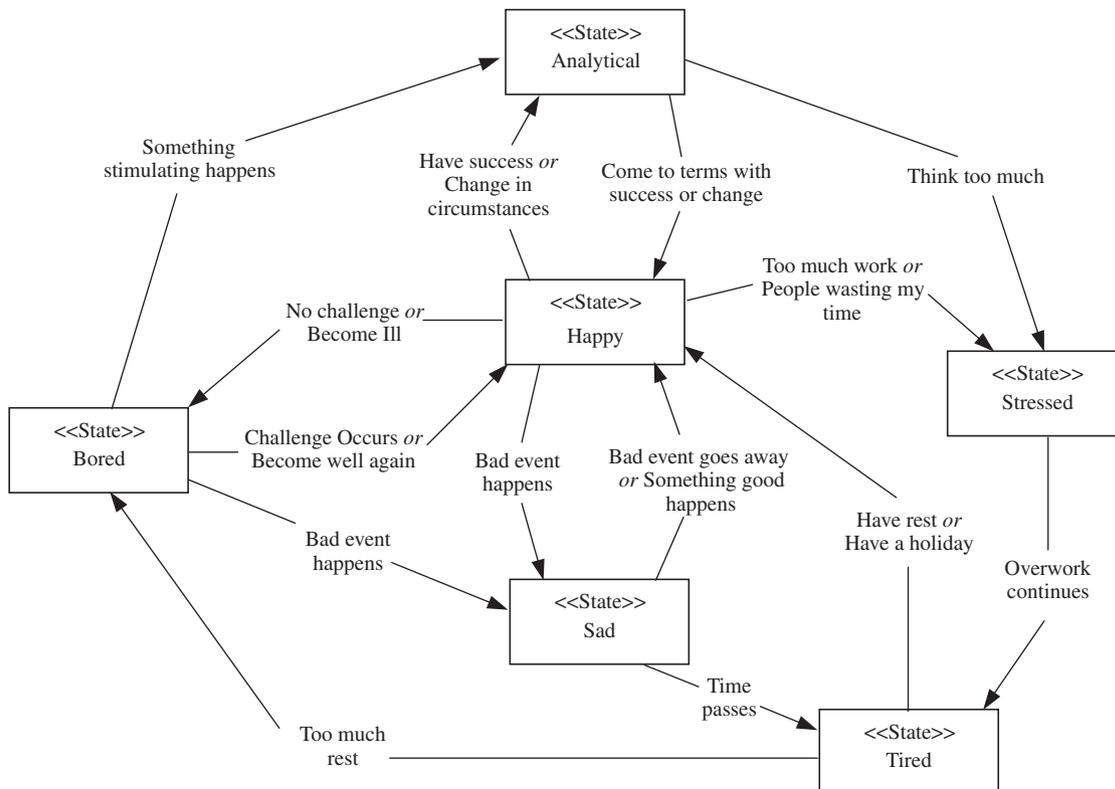


Fig. 1. Part of a typical state diagram constructed with a participant.

most common states used by participants were ‘happy’, ‘stressed’ and ‘worried’. The state diagram technique was found to be the most popular technique by the participants (as shown later). There were indications that this popularity may result from the enlightening nature of this technique. Suggestions for possible improvements included the use of standard lists of states and transitions to select from, improving the presentation, and having more time.

Aspirations technique: Each participant’s decision tree contained, on average, four courses of action, each of which had about three advantages and three disadvantages. Each aspirations diagram contained about 27 nodes and 37 links between the nodes. An example of part of a typical aspirations diagram is shown in Fig. 2. The most common types of nodes on the aspirations diagram were associated with interests, friends/others and job. A statistical analysis of the results of the questionnaire showed that the aspirations technique was rated more highly by men, older participants and university graduates. Suggestions for possible improvements included the need for more than one decision to be mapped, and having more time.

Event diagrams: Each participant produced about four diagrams each containing, on average, six events and nine inputs/outputs. An example of one of these diagrams is shown in Fig. 3. The most common types of events were

associated with starting a job, the break up of a marriage or serious relationship and birth/deaths. The most common types of inputs/outputs were associated with feelings, situation/context and interests. A statistical analysis of the results of the questionnaire showed that the events diagram technique was rated more highly by older participants. A number of participants found that the technique revealed new thoughts such as identifying patterns and connections. Suggestions for possible improvements included the use of standard prompt questions from the software and having more time.

Interview review: Analysis of the comments made by the participants on the interview transcript showed that about 80% of statements were agreed with, and about 8% were surprising to the participant. There was a polarization of opinions with some participants liking this technique and others not. Those who liked the technique did so because reading the transcript revealed how much they had changed in the intervening time and in what ways they had changed. A statistical analysis of the results of the questionnaire showed that the interview review technique was rated more highly by participants with a university degree. The main problems identified by the participants were the need for a longer period in between the interview and the review, and for an improvement to the marking scheme, possibly making use of software.

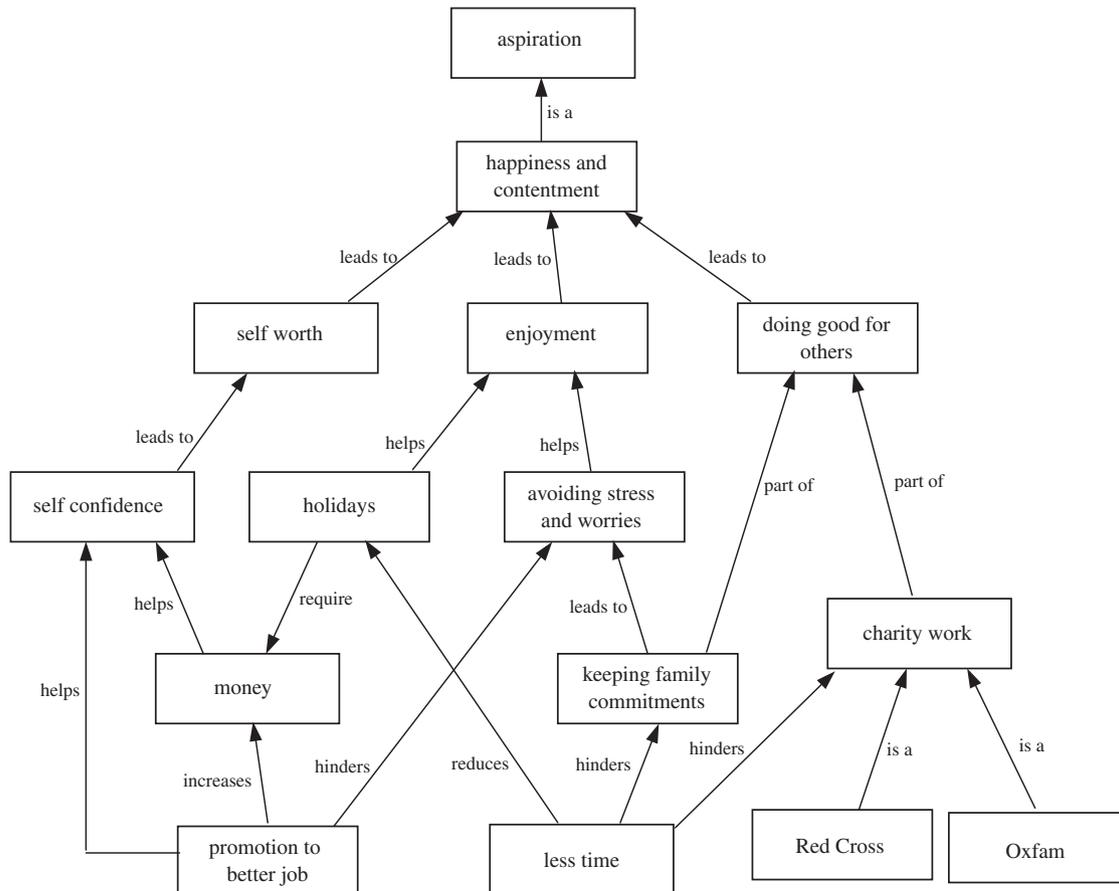


Fig. 2. Part of a typical aspirations diagram constructed with a participant.

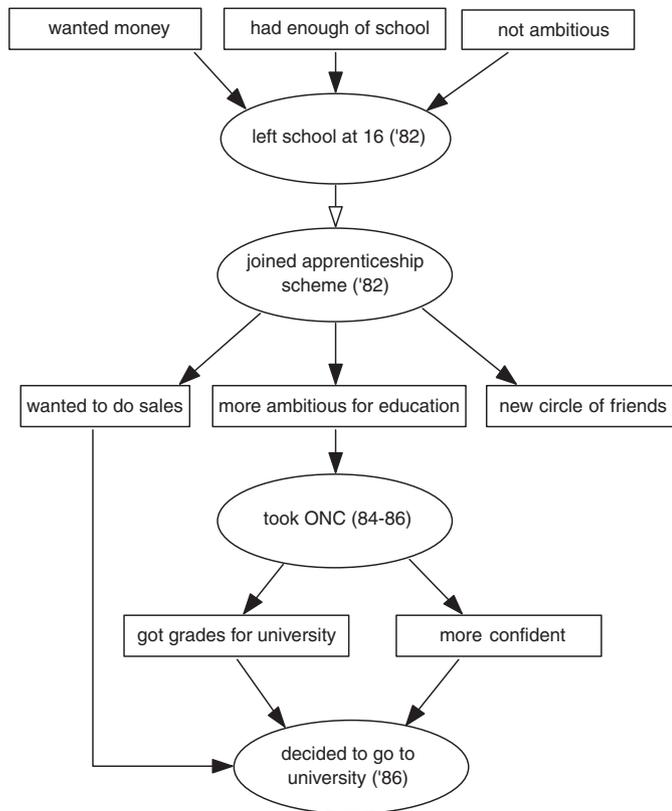


Fig. 3. Typical example of an event diagram constructed with a participant.

Keirsey technique: Most participants felt that the standardized descriptions were surprisingly accurate. However, they felt that the technique was neither thought-provoking nor enlightening. Those who liked the technique did so because it was enjoyable and interesting. A statistical analysis of the questionnaire results showed that the Keirsey technique was rated more highly by younger participants. The main problem identified by the participants was difficulty in answering the questions.

3.6.2. Comparison of the techniques

How do the techniques directly compare to one another? To establish this, two assessment measures were used. Both were based on the opinions of the participants as to the perceived quality of the technique to capture their knowledge and be of psychological benefit. The first measure used the results from a rating-scale questionnaire presented directly after each technique. The key items on the questionnaires were ratings of *interesting*, *thought-provoking*, *enlightening* and *recommendation*. During the analysis, these were combined to provide an overall measure. The second measure was taken from rankings of the techniques made by each participant during the feedback session. The analysis demonstrated a strong correlation in the results of these two measures. This correlation was found to be statistically significant using a Pearson's product-moment test ($r = -0.902$, $N = 8$). Note, this correlation coefficient is negative because high ratings correspond with low

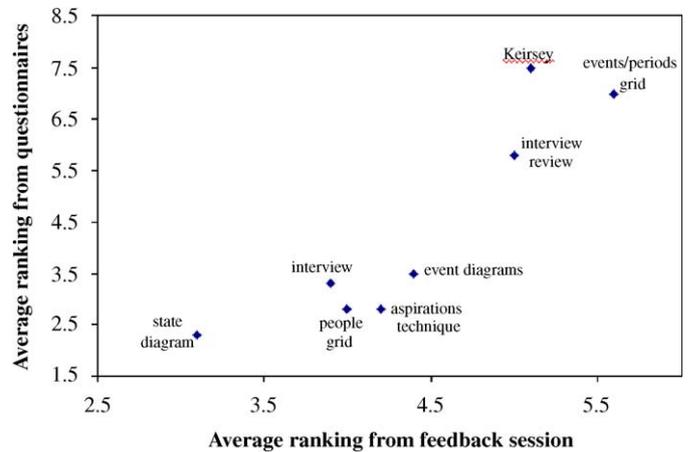


Fig. 4. Graph of the average rankings from the feedback session and the post-session questionnaires.

rankings. An illustration of the strength of this correlation is shown in Fig. 4, which is a scatter diagram of the average rankings from the feedback session plotted against the average rankings of the ratings from the post-session questionnaires. Note, that the axes are both rankings; hence techniques that are closer to the origin (i.e. bottom left) are more preferred.

Further statistical tests (pair-wise comparisons using t -tests) provided a verification of the information presented visually in the graph above, i.e. that there are four 'divisions' of techniques: (1) most favoured technique is the state diagram technique; (2) the second most favoured techniques are the interview, people grid, aspirations technique and event diagrams; (3) in the third division is the interview review; (iv) the least favoured are the events/periods grid and Keirsey technique. These results were further supported by participants' comments on the open-ended questionnaires and during the final feedback sessions.

A statistical analysis of the factors that lead to the participant's rating and ranking of each technique provided no conclusive results. It seems that a combination of factors is involved. There was some indication that those techniques that acquired a substantial, and important, part of a person's knowledge were those techniques that were preferred as a whole. Attempts to assess what percentage of knowledge each technique could acquire proved inconclusive.

3.6.3. Benefits of capturing personal knowledge

Does the process of capturing an individual's personal knowledge increase his/her personal knowledge? Feedback from the participants indicated that some increase in personal knowledge does occur during an elicitation session. The majority of the comments concerning new thoughts were of two types. First, many comments were associated with the thought-provoking nature of the techniques, with phrases such as "made me think about ..." and "made me consider ..." being commonly

used by the participants. Second, many comments were associated with an increase in personal knowledge, with phrases such as “made me realize that ...” and “made me understand ...”. Often a participant would see links or associations between factors (such as people or events) that they had not previously realized.

3.6.4. Benefits of increasing personal knowledge

The results indicated that the techniques have the ability to help people gain more understanding and have new ideas. These can be seen in terms of the person’s past, present and future.

- In terms of the past, this can be (i) a better understanding of how and why life events have occurred and how they impacted on other events or circumstances; (ii) a better understanding of how one has changed and developed over time; (iii) an improved feeling concerning past decisions and actions.
- In terms of the present, this can be (i) a better understanding of the emotional states one gets into and how one might deal with less desired states; (ii) a better understanding of social relationships and how people are affected and behave with different people; (iii) a new, or renewed, perspective on life and re-assessment of what is important.
- In terms of the future, this can be (i) a better understanding of one’s wishes and aspirations; (ii) a better understanding of the factors that help or hinder gaining what one wants; (iii) a new, or renewed, motivation to take certain actions.

During the final session, each participant was asked whether any changes in thinking or behaviour had resulted from each of the previous sessions. Results showed that about one third of the sessions had provoked some changes in thinking or behaviour. These changes included thinking about issues raised during the session, changes in attitudes or understanding, increased understanding about past events, increased motivation for change and modification of behaviours.

3.6.5. Benefits of using knowledge representations

Do the results of capturing and representing personal knowledge in an explicit format (e.g. transcripts, diagrams, grids) help the person? During the final session, each participant was asked for his/her ideas on possible uses for the transcripts, diagrams and grids created during the sessions. Four main uses were identified:

1. Diary uses, such as reviewing the way one had thought and felt when creating the representations, seeing how much one has changed, and capturing one’s life story.
2. Uses in decision making, such as capturing the decision process (for later reflection) and making better decisions by learning from the past.

3. Uses in gaining a perspective on where one is (such as one’s emotional state), how one got there, and how one could proceed.
4. Increased self-understanding, such as providing more self-awareness, altering priorities, and identifying areas for growth.

3.6.6. Summary of empirical study

The results demonstrated that most of the techniques showed promise at being used for psychological purposes. The overwhelming impression from the participants was that the techniques were interesting and were thought-provoking. Although it may have been expected that the semi-structured interview and repertory grid techniques should do well, it was encouraging to see that the three diagram-based techniques, particularly the state diagram technique, all performed favourably. Each of the participants felt that a number of the techniques were enlightening and were capable of helping in various ways. In comparison to the control technique, all but one of the techniques gained better rankings and ratings. When the participants made comparisons to other techniques of a similar nature, the techniques under assessment fared very well. It was particularly encouraging to have two participants who are HR (Human Resource) professionals state that a number of the techniques could provide useful supplements to existing employee development tools. Future work could build upon this by involving professional and practitioner psychologists as assessors of the techniques and the gathered knowledge.

4. Meta-model of personal knowledge

This section describes a meta-model based on a content analysis of the knowledge captured during the empirical study. A meta-model is a structured representation of knowledge for a domain that falls between a taxonomy and an ontology. As the name suggests, it is a model that describes other models. In our case, it is a model that describes three factors: (i) a set of high-level classes of knowledge objects; (ii) a taxonomy for each of the high-level classes and (iii) the relationships between the high-level classes of knowledge objects. It was the case a few years ago, that a meta-model (and indeed a simple taxonomy) could be thought of as an ontology (e.g. [Noy and Hafner, 1997](#)). With a shift in work on ontologies to web languages such as RDF and OWL, ontologies are now generally viewed as computer codifications of knowledge.

4.1. Purpose of the meta-model

There are a number of reasons for creating a meta-model of personal knowledge. First, no comprehensive meta-model of personal knowledge currently exists in the psychological literature. Second, the meta-model can help

miscarriages”), generic events and hypothetical events. Types of events include incidents and actions.

Incident: Knowledge of the types of event that are beyond the control of a person, such as accidents, illnesses, natural disasters, deaths, redundancies and socio-political occurrences (e.g. wars, economic depressions).

Action: Knowledge of the types of events in which a person is a main actor. Actions can be tangible (involving something of the physical world) or intangible (e.g. a cognitive action, such as reflections and realizations).

Event property: Knowledge of the properties of events. These include the valence of the event, such as positive (e.g. I went on holiday) and negative (e.g. I was not allowed to go on holiday) and emotiveness (e.g. it was good, it was dreadful).

State: Knowledge of the temporary characteristics that a person can exist in. Examples include emotions (e.g. happy, sad, and excited), cognitive states (e.g. ambitious, creative), and physical states (e.g. tired, ill).

Transition: Knowledge of the ways in which a person’s state is altered. The three main types of transitions are actions, incidents and the passing of time.

Characteristic: Knowledge of the stable properties of a person. Examples include a person’s traits (e.g. sociability, intelligence, niceness) and physical characteristics.

Behaviour: Knowledge of the actions of a person that are repeated and form patterns. Examples include particular responses to particular situations (e.g. “they did a lot for the church”, “I’m always doing things like that”).

Decision: Knowledge of the choices made by a person when there is more than one course of action available.

Aspiration: Knowledge of the ambitions, goals, motivations, wishes and desires of a person. Examples include “being happy”, “doing good” and “looking after my family”.

Resource: Knowledge of the economic, physical and cognitive capabilities possessed by, or available to, a person. Examples include money, possessions, tools and techniques.

Ability: Knowledge of the physical and cognitive aptitudes and resources possessed by a person. Examples include the capability of the person to perform certain actions in certain ways.

Belief: Knowledge of the ways in which a person thinks about various aspects of their life. Examples include thoughts, ideas, opinions, attitudes (likes and dislikes), priorities, perspectives, expectations and second-order beliefs (i.e. beliefs about beliefs).

Interest: Knowledge of the domains and subjects with which a person is involved. Interests can be at work (e.g. occupation, subject areas, expertise) and outside work (e.g. pastimes, hobbies, arts, crafts, voluntary work, religion).

Place: Knowledge of the locations in which a person resides or visits for work or social occasions. Places are an important factor in defining time periods.

Job/Role: Knowledge of the occupations and/or positions held by a person. Jobs/roles exist both within work

and outside work in various organizations and social situations.

Relationship: Knowledge of the interactions of a person with significant others, such as family, friends and work colleagues. Relationships include having beliefs concerning one another and inter-personal actions.

4.4. Testing the meta-model

As a test of the completeness of the meta-model, it was compared to the elements that constitute various psychological theories and models.

4.4.1. Decision making and behavioural models

Table 1 shows a comparison of the classes in the meta-model and those used in decision making and behavioural theories. The theories included in the table are subjective expected utility theory (Wright, 1984), conflict theory of decision making (Janis and Mann, 1977), theory of planned behaviour (Ajzen and Madden, 1986), health belief model (Becker, 1979) and transtheoretical model of change (Prochaska and DiClemente, 1992).

4.4.2. Attitude, attribution and schema models

Table 2 shows a comparison of the classes in the meta-model and those used in some influential theories and models of social psychology. The theories and models included in the table are the three-component model of attitudes (Rosenberg and Hovland, 1960), an influential theory of attributions called correspondent inference theory (Jones and Davis, 1965) and the main schema developed for use in social cognition (Fiske and Taylor, 1991).

4.4.3. Psychological models comprising many elements

As a final comparison, the meta-model was tested against two approaches that contain a substantial number of elements (see Table 3). The first of these is the intentional action formulation used in descriptive psychology (Ossorio, 1981). This is a parametric analysis of behaviour intended to identify and discriminate between behaviours along ten dimensions. The second approach is the Biographical Inventory of the autobiographical research method (De Waele and Harré, 1979), which is a very large questionnaire used to capture knowledge of many aspects of a person’s life.

4.4.4. Validity of the meta-model

As shown in Tables 1–3, a high degree of congruence was found between the meta-model and the elements from many psychological theories and models. This indicates that the meta-model has a certain validity and completeness in modelling the high-level classes of personal knowledge that we all possess and use in our everyday life.

Table 1
Comparison of decision-making theories with classes from the meta-model

Theory	Elements used in the theory	Classes from the meta-model
Subjective expected utility theory	Actions Events Assessment of the probability Expected utility	Actions Incidents Beliefs Beliefs
Conflict theory of decision making	Actions Coping patterns Pros/cons	Actions Behaviours Beliefs
Theory of planned behaviour	Beliefs Attitudes Intentions Behaviour	Beliefs Beliefs Aspirations Behaviours
Health belief model	Actions Assessments	Actions Beliefs
Transtheoretical model of change	Stages of behavioural change Processes of change	Behaviours, actions and decisions Actions

Table 2
Comparison of attitude and attribution theories/models with the meta-model classes

Theory/model	Elements used in the theory/model	Classes from the meta-model
Three-component model of attitudes	Stimuli Attitudes Affect Cognition Behaviour	Events and relationships Beliefs States, actions and behaviours Actions and behaviours Actions and behaviours
Correspondent inference theory	Dispositions Intention Knowledge Ability Action	Characteristics Aspirations Beliefs and abilities Abilities Actions
Schema from social cognition	Person schema Self-schema Role schema Event schema Causal schema	People People Jobs/roles Events Beliefs

5. The personal knowledge methodology

The empirical study and meta-model led us to design an architecture for a web-enabled system that provides a new methodology for psychological research. We call this the personal knowledge methodology.

The personal knowledge methodology has two aims. The primary aim is as a research method to gather structured personal knowledge for analysis and theory construction. A second aim, indicated by the results of our study, is as an intervention method providing direct psychological benefit to its users. At the core of the methodology are knowledge engineering techniques that involve the acquisition, representation, presentation, modelling and analysis of personal knowledge. These activities are underpinned by an ontology of personal knowledge. The methodology is an evolving system that captures knowledge from a large

number of people then uses this to improve the techniques being used. The basic architecture is shown in Fig. 6.

The user interacts with an interface that includes a suite of web-enabled elicitation techniques, similar to those assessed during the empirical study presented earlier. This interface is supported by a generic ontology that allows knowledge re-use and acts as a common language for communication between users. As knowledge is acquired from the user, it adds into a domain ontology of personal knowledge.

The domain ontology, and other information gathered from the user (such as their use and ratings of particular techniques) are analysed either by psychologists directly or by web services that automatically analyse the knowledge.

The results of the analysis phase contribute to the development of new or revised theories. The increased theoretical understanding is used to update the body of

applicable theories that drive the methodology. The body of applicable theories is a resource for the design and re-design of the interface tools and ontology. This final stage in the cycle enables a tight loop of theorizing, intervention

and evaluation, such that new ideas and techniques can be quickly tested and assessed. The final element of the methodology requires that the body of applicable theories constantly draws from and updates the body of possible theories that involve personal knowledge.

This methodology is a qualitative approach to psychological knowledge, but seeks to mitigate many of the problems associated with qualitative methods in a number of ways:

- By involving large numbers of people.
- By acquiring structured knowledge.
- By applying rigorous theory-driven methods.
- By using semi-automated analysis methods.
- By adopting a tight loop of theorizing and assessment.

The methodology can achieve all this by combining the methods and principles of knowledge engineering with the latest advances in ontological engineering. It is envisaged that the methodology could be implemented using emerging semantic web technologies and services (such as RDF/OWL) and the forthcoming web-enabled version of PCPACK.

6. Summary and conclusions

6.1. Summary

The paper has presented work that examined a knowledge engineering approach to personal knowledge. To this end, we undertook an empirical study that involved 18 participants acting as experts of their personal knowledge. 80 knowledge acquisition sessions took place in the main study to assess eight knowledge elicitation techniques: a semi-structured interview, an interview review, a repertory grid using people as elements, a repertory grid using events/periods as elements, a state diagram technique, an

Table 3
Comparison of classes in the meta-model with two substantial psychological methods

Theory/approach	Elements used in the theory/approach	Classes from the meta-model
Intentional action formulation	Behaviour	Behaviours
	intentional action	Actions
	Identity	People
	Want	Aspirations
	Know	Beliefs and states
	Know how	Ability and states
	Performance	Actions and behaviours
	Achievement	Actions and resources
	Individual difference	Characteristics
	Significance	Event properties
Concepts from the autobiographical research	The time course	Life history
	Significant others	People
	Wishes	Aspirations
	Attitudes	Beliefs
	Artefacts	Resources
	Socio-economic factors	Incidents and resources
	Norms	Beliefs
	Expectations	Beliefs
	Roles	Jobs/roles
	Institutions	Places
	Interpretations	Beliefs
	Occupations	Jobs/roles
	Interests	Interests
	Leisure activities	Interests
	Goals	Aspirations
	Aspirations	Aspirations
	Conflicts	Beliefs

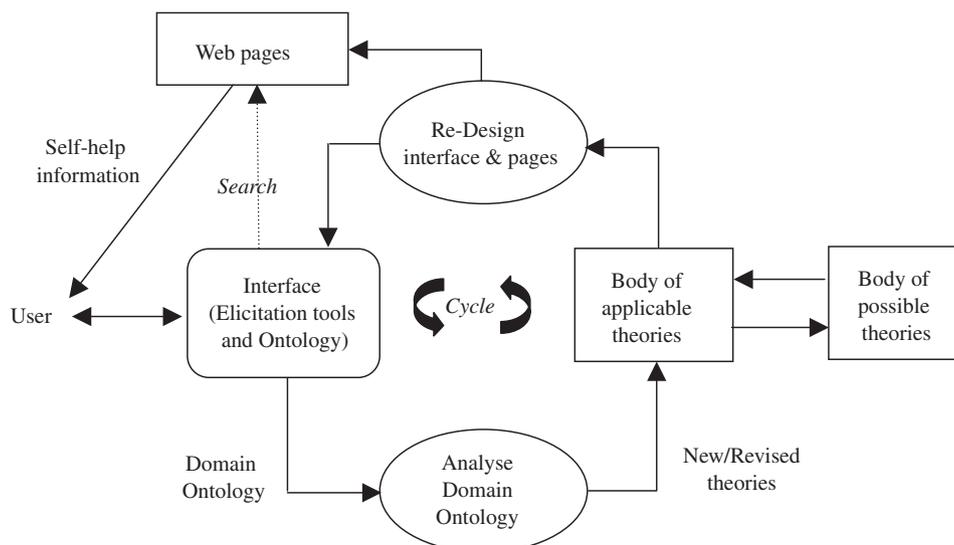


Fig. 6. Basic architecture of the personal knowledge methodology.

aspirations mapping technique, a life-event mapping technique, and a personality technique. The latter was included as a control technique with which to assess the other techniques for their psychotherapeutic value. The participants assessed each of the techniques and provided feedback of their opinions using a number of assessment methods. The study produced the following key findings:

- A range of elicitation techniques taken from knowledge engineering proved useful in capturing personal knowledge. Most of the techniques also prompted the participants to see new things about themselves. Most of the techniques were considered to be better than the control technique, a well-known personality testing technique. The more unusual elicitation techniques, based on the construction of network diagrams, were highly rated.
- A technique based on the construction of a state diagram was clearly the most favoured by the participants. Such a technique has its roots in AI and computer science but has not previously been used in psychological research or practice. We believe that such a technique would prove a valuable addition to the methods used by psychologists.
- While most people responded well to the state diagram technique, other techniques (notably the interview review) were liked by some participants but not by others. Although there was some indication that this may be due to demographics (such as gender, age and personality type), more research is required to examine this.
- The use of multiple assessment methods (rating-scales questionnaires, open-ended questionnaires, feedback interview and ranking) proved successful in gaining opinions from the participants. Consistency was found between the different measures, suggesting both reliability and validity. It is unusual to employ such measures when assessing knowledge elicitation techniques, but this proved valuable in this context and may do so more generally.
- A meta-model was developed based on a content analysis of the knowledge elicited from the participants. This meta-model showed consistency with a number of leading psychological approaches, indicating a degree of completeness and discrimination.

The empirical study and meta-model led to the design of an architecture for a web-enabled system that provides a new methodology for psychological research. By incorporating the latest principles and technologies of knowledge engineering, this methodology could provide a tool for psychologists that might overcome some of the problems with existing techniques, from a theoretical and practical perspective.

7. Conclusions

We conclude from our study that knowledge engineering has much to offer the world of psychology. We also conclude that the empirical methods used by psychologists and other social scientists have much to offer to the world of knowledge engineering. We believe that the name of this journal, that includes the words *human* and *computer* separated by a mere hyphen, should not only mean that both be considered when they meet directly (e.g. work on human factors) but also in more distant fields. We suggest that there should be more of the *human* involved in *computer* research (e.g. in the development of ontologies) and that there should be more of the *computer* involved in *human* research (e.g. in the development of psychological theories).

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