Perceptual control and feedback control in the analysis of complex tasks

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Title:
A perceptual control theory approach to task analysis

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Abstract

Despite its extensive and successful use in human factors work, there remain areas for the
development of task analysis methods. Three key issues are: (i) integrating “cognitive” and
“behavioural” approaches to task analysis; (ii) taking account of contextual factors that
influence behaviour; (iii) a grounding in theories of human performance and behaviour. This
paper discusses the theoretical and practical implications of using perceptual control theory
(PCT; Powers, 1973; 1990) as the basis for task analysis. Current PCT-based methods are
described, as well as the development and evaluation of a new method that aims to
integrate PCT concepts into a hierarchical task analysis framework. This method, perceptual
control hierarchical analysis of tasks (PCHAT) was found to provide broadly consistent and
credible results when used by a group of novice analysts in a laboratory-based exercise. Its
application to a real-world dynamic control task is also demonstrated.

1. Introduction

Task analysis is a well-established human factors methodology, and numerous analytical
methods have been developed over the past forty years. However, despite the proliferation
of task analysis methods, there appears to be scope for further development in this area
(Diaper & Stanton, 2004). Some of the key issues are:

i) ‘Behavioural’ versus ‘cognitive’ approaches. Will a parsimonious ‘black-box’ approach to
performance description suffice in a given situation, or is a more detailed but potentially
more speculative ‘information processing’ account required? It could be argued that most
tasks in fact have both behavioural and cognitive components, and so both should be
examined in a task analysis. However, most methods seem to focus on one or the other,
and there remains a need to develop a general purpose method that integrates both
perspectives to the satisfaction of potential users (Shepherd, 2000).

ii) The influence of the socio-technical context. The philosophy of ecological design (ED),
which has arisen in response to the increasing prevalence of socio-technical work systems, is
to incorporate into work design an understanding of those social and physical factors that
impose constraints on human activity (Vicente, 1999). In other words, ED attempts to take
account of both the person and the environment in which he or she works. The importance
of the latter can be illustrated by considering ‘open-loop’ tasks such as playing golf or
operating a chemical plant. In both of these situations, task behaviour can be affected by
environmental factors that are dynamic and external to the operator (weather and visibility
in the case of golf; chemical processes in the case of plant operation). If it is to support
ecological design, task analysis needs to allow the influence of such variables to be captured
in some form.
iii) Theoretical underpinning of analytical methods. With regard to task analysis, a ‘good’ theory, as well as attracting academic credibility, provides a practical framework that allows analysts to make sense of information gathered about a particular task. Furthermore, it facilitates the explanation and prediction of task-related behaviour (O’Hare, Wiggins, Williams, & Wong, 2000; Hobbs & Williamson, 2002). It would therefore be useful to incorporate into task analysis a theory that is able to achieve such aims in a range of settings.

A number of researchers have suggested that using perceptual control theory (PCT; Powers, 1973; 1990) as a basis for task analysis may address these concerns. The perspective taken by PCT is to view behaviour as a means of controlling perception — in other words, rather than reacting to a stimulus (whether this comes directly from the environment or via cognitive processing), a person acts in such a way as to maintain a particular perception. Perceptual control theory describes behaviour in terms of a process (illustrated in Figure 1) in which a person receives and processes perceptual input from the external environment, in much the same way as would happen in a cognitive model. However, within the PCT model, the person then compares the actual perception with the desired perception. The ‘error’ is determined by the extent to which these two perceptions differ; if the error is too great, then behaviour is generated in order to reduce it.

Perceptual control theory effectively provides a psychological account of goal-directed behaviour. As such, it would appear to be particularly suitable for forming the basis of a task analysis, and a number of PCT-based methods have been developed. These include:

- Perceptual Control Analysis of Tasks (PERCOLATE: Marken, 1999) in which task decomposition is presented in a tabular format describing the task’s perceptual control characteristics;
- Perceptual Task Analysis (PTA: Farrell & Chéry, 1998), which is similar to PERCOLATE but also includes cognitive and behavioural characteristics of the task;
- Hierarchical Goal Analysis (HGA: Hendy et al., 2002), which as the name suggests is a variant of Hierarchical Task Analysis in which perceptual goals are used in place of task steps;
- Layered Protocols (Farrell, Hollands, Taylor & Gamble, 1999), which applies PCT to the analysis of interaction between two “agents” (either human or machine).
While there are few published evaluations of these methods, their use is supported by some field studies. Chéry, Vicente & Farrell (1999) used PTA to generate design recommendations for a prototype helicopter flight management system interface. This interface was then evaluated using a cognitive walkthrough, in which operators attempted to perform tasks using the interface during a simulated scenario. The situations presented in the scenario included both normal working conditions and abnormal conditions (in which technical or environmental problems would interfere with normal working). The interface was found to be effective in normal conditions, and was found to be intuitive in use. However the interface was less effective in abnormal conditions that presumably rely on knowledge-based reasoning. This would suggest that PTA does not completely supplant cognitive task analysis and the latter may still be required for a detailed examination of cognitive variables. What PTA may provide in such a circumstance, though, is a means to integrate the insights of the cognitive task analysis into a behavioural context. Hendy et al. (2002) conducted a HGA of a command and control task, and compared its output with that of the Department of Defense’s (1999) Mission, Function and Task Analysis (MFTA), which is more characteristic of a traditional task analysis. Hendy et al. found that HGA provided additional insights that were not included in MFTA. In particular, the representation of information flows up and down the task hierarchy allowed them to identify sources of workload associated with monitoring and supervision, which would have been missed had only the other method been used.

Meanwhile, Eggen, Haakma, & Westerink (1996) compared a standard interface for a Digital Audio Tape recorder with a prototype interface which had been designed using Layered Protocols. They found that on a standardised set of tasks, novice participants using the prototype interface made fewer errors, completed the tasks more quickly and consulted the manual fewer times than did those using the standard interface. Furthermore, participants using the standard interface were observed more often to be unsure what the outcome of their actions were, or what actions they should take.

While the methods described have been seen to have both theoretical and practical value, there is one shortcoming; in order to understand HGA (or indeed, PTA or PERCOLATE), one needs to be familiar with the concept of perceptual control. It is clear from the foregoing description of PCT that it is philosophically somewhat different from cognitive theory and behaviour theory, both of which are more familiar to psychologists. There appears a need to ensure that a PCT approach is accessible to those from a non-cybernetics background. Furthermore, HGA, while it is conceptually similar to HTA, does not include plans; while this is compatible with a purist PCT view that gives more importance to the target perception than to the means by which the perception is achieved, the use of plans might be necessary if there is an ordinal or temporal relationship between certain task steps. One way of developing PCT-based task analysis, therefore, might be to integrate PCT principles into an existing (non-PCT) task analysis method.
3. Perceptual Control Hierarchical Analysis of Tasks (PCHAT)

As its name indicates, the aim of PCHAT is to incorporate perceptual control principles in a hierarchical task analysis format. The use of HTA as an organising framework provides a ‘tried and tested’ method for representing task activity, which includes the rigour of hierarchical representation and plans. As suggested by HGA, the goal hierarchy that characterises HTA is compatible with a perceptual control description of tasks. However, HTA is plan-driven rather than perception-driven, and so there is a need to ensure that the perceptual control element is adequately expressed within this method. In order to achieve this, PCHAT uses soft systems methodology (SSM; Checkland & Scholes, 1990) as a conceptual framework for integrating PCT with HTA. Soft systems methodology, like PCT, takes a systems thinking approach, in which the object of study (whether it is an organisation, an individual, or an event) is treated as a “whole”; that is, the level of explanation is the dynamic interrelationships between objects rather than the objects themselves. The basic process in SSM involves constructing an abstract representation of a real world situation that captures the dynamics of that situation. If the situation is taken to be a group of people, or of people and machines, completing a specific task, then the SSM model could be used to facilitate a task analysis.

The PCHAT process consists of four stages, based loosely on the seven-stage SSM model of Checkland & Scholes (1990). In order to illustrate this process, the authors will examine the task of delivering an anaesthetic to a surgical patient, and consider how PCHAT compares to the hierarchical task analysis that has previously been conducted by the first author (Phipps et al., 2008).

1. Identify the context of the task analysis

The focus of the first stage is on the real world situation that has given rise to the requirement for task analysis. During this stage, the analyst examines the situation and identifies the actual requirement to be met through the task analysis.

2. Define the task

Having identified the problem to be solved by the task analysis, the analyst’s attention then turns to the task itself. Before it can be modelled, the nature of the task needs to be identified. In keeping with the metaphor of task conduct being a “system”, the analyst would define the task initially in terms of its purpose.

Stages 1 and 2 have been described here as if they were specific to PCHAT. In practice, though, the basic principle of identifying the context and scope of the task to be analysed would also be familiar to experienced users of HTA (Shepherd, 1990). In PCHAT, the task
definition effectively constitutes the desired perception associated with the main goal, and hence the goal can also be derived from the task description. Hence, Phipps et al. (2008) describe two superordinate goals in their HTA: “provide pre-operative care” and “provide peri-operative care”, which together are defined as covering all of the anaesthetist’s activities between starting the pre-operative visit and handing over the patient to the recovery nurse following surgery. In PCHAT, the task might be described as “a system involving the anaesthetic team, the surgical team, other hospital staff and the patient, whose purpose is to facilitate safe surgery by providing anaesthesia”. Readers familiar with SSM may recognise this as analogous to the concept of a system’s “root definition” (Checkland & Scholes, 1990).

3. Create a model of the task

During this stage, the analyst creates a model of the task that would achieve the goal. This stage is effectively the task decomposition, and follows closely the procedure used in HTA. As in HTA, the analyst will identify the sub-goals (which are referred to here as ‘activities’) that are taken in pursuit of the main goal. Having identified the relevant activities, the analyst then organises them into a model that represents their execution in pursuit of the task goal. Figure 2 illustrates the model that would be created for the peri-operative anaesthetic task. As can be seen from this figure, the model illustrates the temporal relationship between the activities. Some activities are shown as needing to occur before others (in other words, they are arranged in serial order), while other activities are shown as occurring either concurrently or in any order, by virtue of their being arranged in parallel order. In the latter type of arrangement, text has been appended to the diagram to describe the conditions under which activities are conducted in a particular order. The diagrammatic and textual representation provides the equivalent of the ‘plan’ that is found in HTA; that is, it describes when and under what circumstances each activity will be carried out in pursuit of the task. Also on the diagram is a description of the goal; as suggested earlier, this represents the perception that is associated with successful completion of the task. By default, the activities are preceded by a generic and preliminary activity, “determine requirements”. In the current example, data for this activity would come largely from the anaesthetist’s pre-operative examination of the patient (Phipps et al., 2008).

For each activity that is to be decomposed, the analyst completes a “decomposition template”. This is essentially a tabular representation of the cognitive, behavioural and perceptual control aspects of the activity. The analyst provides information under the following headings:
- **Elements**: aspects of the task or things in the environment that indicate to the person whether or not the activity has been carried out successfully (for example: objects; signals; displays; state of knowledge).

- **Senses**: how these elements are presented to the person. Select any or all of: vision, audition, kinaesthetic, memory recall, olfactory (smell), gustatory (taste).

- **Current state**: list the different situations that could arise in the course of this activity. One of these will be the desired situation (that is, what the situation will be if the activity has been carried out successfully). If the activity is a simple one, there may be only one other state. More complex activities, however, may have a number of alternative states;

- **Goal state**: this is the desired situation from the list provided under ‘current state’;

- **Critical values**: a description of how the actor will know that the goal state has been achieved (using the ‘elements’ described earlier);

- **Cognitive resources**: where specific cognitive resources are used during the activity (for example, specific declarative or procedural knowledge, or a mental model), these are described here;

- **Operations**: the behaviours that will be used to achieve the goal state. Each operation will be of one of the following types: voice; action; sense (that is, listen, read, taste, smell or touch); memory (that is, commit information to memory to use for subsequent activities);

- **Plan**: describes how the operations will be used to reduce the discrepancy between the current state and the goal state.

Figure 3 demonstrates how activity 12 (maintain anaesthesia) would be decomposed. A task diagram for this activity shows two subordinate activities that are interdependent; this characterises a dynamic control relationship. The decomposition template provides further details about the cognitions and behaviours upon which this relationship is based. In effect, the behaviours are described by the elements, critical values, operations and plan. The cognitions are described by the senses and cognitive resources. The perceptual control elements, into which the behaviours and cognitions are integrated, are described by the current state(s) and goal state.

**INSERT FIGURE 3 HERE**

It is insightful to compare Figure 3 to a hierarchical task analysis of the same activity (Table 1). Here, the task appears to be represented largely in terms of the behavioural steps. In
fact, cognition is represented by HTA, albeit implicitly – for example, the plan represents the
decision making that an actor takes with respect to task execution (Annett, 2004). There are
methods by which the cognitive elements of a HTA can be made more explicit (e.g. Phipps et
al., paper submitted). However, PCHAT provides an alternative representation, which is
similar in concept to that provided by the HTA but gives equal prominence to “cognitions”
and “behaviours”.

4. Validate the model

Having created the full task model, the analyst then validates the model. *Internal validation*
involves a qualitative evaluation of the model. The model should provide a hierarchical
representation of the task and this should be to an appropriate level of detail. The diagrams
and plans should provide an accurate description of the sequence of activities. *External
validation* is effectively a comparison of the model against the ‘real world’ situation for
which it was created. This could be carried out by the task analyst depending on his or her
understanding of the situation; alternatively subject matter experts may be needed to
provide assistance. The method of external validation is likely to involve working through
the task model as if one was using it to achieve the task goal in the real world; a “valid”
model in this sense is one that leads to successful execution of the task. If the task model is
found to be suitable then it is presented as the task analysis, to be used for whatever
purpose the analysis was commissioned.

It should perhaps be emphasised at this point that, although PCHAT has been described as a
linear process, it may need to be conducted in an iterative manner. For example, if there are
a number of tasks that could be defined to solve a particular problem, then the analyst
would need to repeat the process from stage two for each task. Alternatively, if a task
model is created that is later considered unsuitable, the analyst would need to go back to
the model construction or task definition stage.
4. Evaluation of PCHAT

In order to provide some initial evidence to support the use of PCHAT, a laboratory-based trial was carried out by the first and third authors. By examining how laypeople perform using PCHAT with a common but potentially complex consumer product, the trial followed a similar approach to that of previous studies evaluating task analysis methods (e.g. Baber & Stanton, 1994).

**Method**

*Design.* The trial used an experimental design. All participants were assigned to a single condition.

*Participants.* Ten postgraduate students at Cranfield University’s School of Engineering were recruited in response to advertisements placed across the university campus; each was paid for their participation. All of the participants were on courses in design, engineering and operations management, and so were considered by the authors to be representative of those who typically use task analysis.

*Materials.* A guide was developed for the participants, which explained the concept and application of PCHAT and provided a worked example (this guide is available on request from the first author). For the experiment, participants were provided access to a Sharp VC-M41HM video cassette recorder connected to a Goodmans 148T television; they were required to familiarise themselves with this equipment before using PCHAT to describe the procedure for setting the video timer.

*Procedure.* Each participant took part in two sessions that followed the same format. In both sessions, he or she conducted a PCHAT analysis of the timer setting procedure under the supervision of the experimenter. An evaluation questionnaire was provided to each participant at the end of each session in order both to capture his or her experience of using PCHAT during the session, and to offer an opportunity for the participant to provide feedback. The sessions were twelve days apart, except for one participant, whose sessions were seven days apart. Hence, each participant analysed the same task, on two separate occasions.

*Results*

*Comparison of participants’ analyses against criteria.* Patrick, Gregov & Halliday (2000) suggested four criteria against which to assess the quality of a hierarchical task analysis:
hierarchical representation; logical decomposition of tasks; logical equivalence of decompositions; use of stopping rules. These are defined in Appendix A. In addition to these criteria, the content of the participants’ decomposition templates (that is, the elements, senses, current state, goal state, critical values, and cognitive resources) was also compared against those provided in an analysis of the same task performed by the first author. The first author scored all of the participants’ analyses, while the second author scored a cross-section of the analyses generated from the first session in order to check consistency between the two raters.

Tables 2a and 2b list the scores obtained by the participants. Table 2a indicates that most of the participants structured the task description in a manner consistent with the style of HTA, as indicated by the frequency of hierarchical representations and use of stopping rules across the sample. Table 2b indicates that in most instances, the decompositions performed by participants were logical steps of the activity or task from which they were derived. A considerable proportion of the decompositions also provided full coverage of the parent activity or task. Of those decompositions that were not logically equivalent, most were due to the omission of required operations rather than the inclusion of extraneous operations. The latter findings are broadly comparable to those of Patrick et al (2000), who also found that of those equivalence errors made, omissions were more common than commissions.

Table 2b also provides the scores obtained when assessing the content of decomposition templates. On the behavioural parts of the template (elements, critical values, operations and plan), participants tended to perform particularly well at identifying task elements – when compared to the author’s analyses, 82 percent were judged to be “correct” in the first session and 90 percent in the second session. The critical values appeared to be less easily identified. The most common error here was to describe prerequisites for activity completion rather than how task completion is indicated to the actor. On the cognitive parts of the template (senses and cognitive resources), participants usually identified the senses correctly. However, the cognitive resources section was less likely to be completely correctly, with only 40 percent in the first session and 45 percent in the second session.

The perceptual control parts of the template generally elicited appropriate responses from participants. Where mistakes were made, these tended to be violations of the “grammar” of the current state and goal state definitions – usually, describing a goal state that cannot be related to the current states.

INSERT TABLES 2a AND 2b HERE
Reliability of participants’ analyses. In order to measure the intra- and inter-rater reliability, an adapted version of Baber & Stanton’s (1996) sensitivity index was used. The procedure used to calculate this “reliability index” is described in Appendix A. Intra-rater reliability was measured for each participant by comparing the analysis performed in the first session with that in the second session. Inter-rater reliability was measured for each session by comparing the participants’ analyses conducted within that session.

The intra-analyst reliability indices are shown in Table 3. The values vary considerably between the different participants; some produced a similar analysis in each session, while others produced quite different analyses. An examination of the analyses provided in each session suggests that some of the difference between analyses could be attributed to a practice effect. In general, participants reported feeling more comfortable in the second session than in the first, and as Table 2b showed, they tended to produce more material in the second session. The mean reliability index is 0.62, which compares favourably with the values obtained for a range of techniques and reported in Stanton & Young (1999); however, it should be emphasised by way of a caveat that Stanton & Young’s figures (which range from 0.12 to 0.92, with HTA achieving 0.23) are based on Pearson coefficients.

As with the intra-analyst indices, the inter-rater values varied somewhat across the group; for brevity, only the values for the second session are shown here (Table 4). Generally, the figures are consistent with what is typically expected of task analysis; as it is a qualitative method, there is usually some variety between different analysts examining the same task because while the process is standardised, analyst interpretation is less so. Nevertheless, it is clearly desirable for there to be some consistency between different analyses, and in this respect the mean inter-analyst reliabilities (0.52 in the first session; 0.54 in the second session) are encouraging. By way of comparison, Stanton & Young (1999) provide transformed Kurtosis values that range from 0.06 to 0.75, with HTA achieving a figure of 0.21.

5. Discussion

In concept, perceptual control theory allows the behavioural and cognitive aspects of a task analysis to be integrated in a coherent manner. Hence, it potentially forms a useful theoretical basis for an analytical method. The current paper introduced one such method, PCHAT. The value of this method is in combining the conceptual strengths of PCT with the practical strengths of hierarchical task analysis, the latter providing a credible framework for organising a description of task-related behaviour.
An evaluation of PCHAT found that participants without extensive task analysis knowledge were able to use the method to analyse a human-machine interaction following some basic training. It is particularly encouraging to find that participants performed as well describing the perceptual control parts of the analysis as they did the cognitive and behavioural parts of the template. However, it should be pointed out that participants’ understanding of PCHAT has been largely inferred from the content of their analyses; no attempt was made to directly assess their knowledge of the principles underlying the method, and neither was a second task used from which knowledge transfer could be examined. Indeed, examination of the analyses, as well as comments from the participants themselves, suggested that more guidance is required for some parts of the analysis, for example the task definition, critical values and cognitive resources. The findings also suggest that PCHAT produced broadly consistent results in the hands of these novice users. While this, again, is an encouraging finding, it should be borne in mind that the experimental task was a compromise between being challenging enough to test the use of PCHAT and being simple enough that the participants could conduct the exercise in a reasonable amount of time. Hence, the scenario is slightly contrived when compared to what might be encountered in a real-world task analysis. Nevertheless, it was sufficiently representative to provide initial evidence supporting the use of PCHAT.

The current paper demonstrates how PCHAT can be used to analyse a dynamic control task, and evaluates its use on a common consumer product by novice analysts. It appears to have potential value as a general-purpose task analysis method. Given the limited scope of this study, though, there is a need to examine the use of this method in a broader range of experimental and real-world task analysis situations.

Note

The work described in this paper is an extension of work presented at the Third International Conference of the Control Systems Group, Manchester, November 2007.
References


Appendix A: Evaluating PCHAT analyses

The criteria derived from Patrick et al.’s (2000) study are as follows:

i. **Hierarchical representation.** Looking at the analysis in general, has the analyst used a hierarchical representation of activities and operations?

ii. **Logical decomposition of tasks.** Where an activity has been decomposed, do the operations describe actual “steps” by which the activity is performed?

iii. **Logical equivalence.** Does following the operations and plan lead to the achievement of the activity from which they are derived? (Note that this criterion depends on criterion ii being met).

iv. **Use of stopping rules.** Has the analyst gone down to an appropriate level of detail but no further?

The calculation of the reliability index is derived from the sensitivity index, which was used to determine how well a human reliability analysis predicts observational data of the same task (Stanton & Baber, 1996). According to the sensitivity index, sensitivity (S) is calculated by:

\[ S = \left[ \frac{a}{b} + \left(1 - \frac{c}{d}\right) \right] / 2 \]  

(1)

Where: a is the frequency of hits (parts of the analysis that predict observed behaviours); b is the frequency of hits plus the frequency of misses (observed behaviours that were not predicted by the analysis); c is the frequency of false alarms (parts of the analysis that did not predict any observed behaviour); and d is the frequency of false alarms plus the frequency of correct rejections (behaviours that were neither observed nor included in the analysis). The calculated S value is on a scale from 0 to 1, where 0 indicates no prediction at all and 1 indicates perfect prediction.

If a second analysis is substituted for the observational data, then the sensitivity index can be adapted to measure how well analysis 1 matches (rather than predicts) analysis 2 as follows:

- **Hits** are those activities and operations that are in both analyses;
- **Misses** are those activities that are in analysis 2 but not analysis 1;
- **False alarms** are those activities that are in analysis 1 but not 2;
- Correct rejections are those activities that are in neither analysis.

- For the purposes of comparing two analyses, the number of correct rejections is assumed to be zero (because the only analyses that exist are those that are in at least one of the two analyses). Therefore:
  - \( d = c + 0 = c \)
  - \( 1 - \left( \frac{c}{d} \right) = 0 \)

- Substituting these values into the sensitivity index gives:
  - \( S = \left( \frac{a}{b} \right) / 2 \)
  - Removing the divisor gives a direct measure of effect divided by effect plus error: \( S = \frac{a}{b} \)

- Including an additional penalty for false alarms gives:

\[
RI = \frac{a}{(b + c)}
\]  

Further details about the background to and use of the reliability index are provided in Phipps (2005).
Tables and figures

Tables
1. A HTA representation of the “maintain anaesthesia” activity
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2b. Mean proportion of logical and equivalent decompositions, and errors in decomposition, per analysis, and mean proportion of “correct” ratings per analysis
3. Intra-analyst reliability indices
4. Inter-analyst reliability indices for the second session

Figures
1. A simplified representation of PCT
2. A PCHAT task diagram for administering an anaesthetic
3. Decomposition of the “maintain anaesthesia” activity
Table 1. A HTA representation of the “maintain anaesthesia” activity (adapted from Phipps et al., 2008)

<table>
<thead>
<tr>
<th>Plan 12: Continuously do 12.1. According to observations from 12.1 do in any order 12.2. As end of operation approaches do 12.3 and 12.4.</th>
</tr>
</thead>
<tbody>
<tr>
<td>12. Maintain anaesthesia</td>
</tr>
<tr>
<td>12.1 Monitor condition</td>
</tr>
<tr>
<td>12.1.1 Monitor patient’s level of responsiveness</td>
</tr>
<tr>
<td>12.1.2 Monitor anaesthetic administration</td>
</tr>
<tr>
<td>12.1.2.1 Monitor inspired inhalation agent concentration</td>
</tr>
<tr>
<td>12.1.2.2 Monitor inspired O\textsubscript{2} concentration</td>
</tr>
<tr>
<td>12.1.3 Monitor oxygen saturation</td>
</tr>
<tr>
<td>12.1.4 Monitor blood pressure</td>
</tr>
<tr>
<td>12.1.5 Monitor heart rate and rhythm</td>
</tr>
<tr>
<td>12.1.6 Monitor respiration and respiratory gas traces</td>
</tr>
<tr>
<td>12.1.7 Monitor surgical activity</td>
</tr>
<tr>
<td>12.1.8 Record observations on observation chart</td>
</tr>
</tbody>
</table>
Table 2a. Frequency of participants obtaining “correct” ratings in each session (n = 10)

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Session 1</th>
<th>Session 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hierarchical representation</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>Use of stopping rules</td>
<td>7</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 2b. Mean proportion of logical and equivalent decompositions, and errors in decomposition, per analysis, and mean proportion of “correct” ratings per analysis (n = 10)

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Session 1</th>
<th>Session 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logical decompositions</td>
<td>0.85</td>
<td>0.99</td>
</tr>
<tr>
<td>Equivalent decompositions*</td>
<td>0.52</td>
<td>0.77</td>
</tr>
<tr>
<td>Omission of required operation</td>
<td>0.30</td>
<td>0.18</td>
</tr>
<tr>
<td>Extraneous operations</td>
<td>0.04</td>
<td>0.09</td>
</tr>
<tr>
<td>Contents of decomposition template:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elements</td>
<td>0.82</td>
<td>0.90</td>
</tr>
<tr>
<td>Senses</td>
<td>0.88</td>
<td>1.00</td>
</tr>
<tr>
<td>Current states</td>
<td>0.60</td>
<td>0.81</td>
</tr>
<tr>
<td>Goal states</td>
<td>0.64</td>
<td>0.92</td>
</tr>
<tr>
<td>Critical values</td>
<td>0.49</td>
<td>0.59</td>
</tr>
<tr>
<td>Cognitive resources</td>
<td>0.40</td>
<td>0.45</td>
</tr>
</tbody>
</table>

* Note: for a decomposition to be equivalent, it must first be logical. However, for the sake of consistency of presentation, the score for this criterion is presented here as if it was an independent score.
**Table 3.** Intra-analyst reliability indices

<table>
<thead>
<tr>
<th>Participant</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>RI</td>
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<td>0.79</td>
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<td>0.76</td>
<td>0.56</td>
<td>0.63</td>
<td>0.72</td>
<td>0.32</td>
<td>0.83</td>
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</tbody>
</table>

**Table 4.** Inter-analyst reliability indices for the second session

<table>
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<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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</tr>
</thead>
<tbody>
<tr>
<td>2</td>
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<tr>
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<tr>
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<td>0.19</td>
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<tr>
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<tr>
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<td>0.38</td>
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<td>0.54</td>
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<tr>
<td>7</td>
<td>0.77</td>
<td>0.74</td>
<td>0.34</td>
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<tr>
<td>8</td>
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<td>0.66</td>
<td>0.23</td>
<td>0.48</td>
<td>0.55</td>
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<tr>
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<tr>
<td>10</td>
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<td>0.73</td>
<td>0.41</td>
<td>0.60</td>
<td>0.74</td>
<td>0.45</td>
<td>0.76</td>
<td>0.58</td>
<td>0.65</td>
</tr>
</tbody>
</table>
Figure 1. A simplified representation of PCT (adapted from Hendy et al., 2002, p.210)
Figure 2. A PCHAT task diagram for administering an anaesthetic

0. Determine requirements

1. Check equipment
2. Prepare drugs
3. Identify patient
4. Attach monitors
5. Commence monitoring
6. Establish IV access
7. Administer anaesthetic
8. Secure airway
9. Attach monitors
10. Commence monitoring
11. Transfer patient to theatre
12. Maintain anaesthesia
13. Discontinue anaesthesia
14. Transfer to recovery

If anaesthetic is to be administered intravenously then do in order 5, 6, 7, 8. If anaesthetic is to be administered by other means then do in order 5, 7, 8, 6.

If induction room is not being used then omit step 11.

Goal: Patient recovers safely from surgery
**Figure 3.** “Maintain anaesthesia” activity

0. Determine requirements

12.1 Monitor condition

According to observations from 12.1 do 12.2

12.2 Adjust anaesthetic concentration

Every five minutes do 12.3

12.3 Record observations

---

**Decomposition template**

**Elements**

- Patient’s response (e.g. Glasgow Coma Scale or Alert-Voice-Pain-Unresponsive)
- Physiological indicators (oxygen saturation, blood pressure, heart rate, respiration)
- Concentration of inhalation agent in inspired and expired air
- Setting on inhalation agent dispenser
- Surgical activity

**Senses**

- Vision, Audition

**Current state**

- Patient fit to complete surgery
- Patient not fit to complete surgery

**Goal state**

- Patient fit to complete surgery

**Critical values**

- Patient is unresponsive
- Oxygen saturation is above 90%
- Blood pressure is within acceptable limits for type of patient
- Heart rate is within acceptable limits for type of patient