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FACULTY OF ENGINEERING, SCIENCE AND MATHEMATICS

School of Electronics and Computer Science

PEDAGOGICAL FEEDBACK IN THE MOTOR SKILL DOMAIN FOR COMPUTER-BASED SPORT TRAINING

By

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ABSTRACT

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SCHOOL OF ELECTRONICS AND COMPUTER SCIENCE

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With the rapid development of Computer-based Sport Training (CBST), feedback plays an important role in both coaching and learning. A good CBST system includes not only good training strategies but also effective feedback design. Feedback in the motor skill domain via CBST may be synthetically designed to allow athletes to practice in a more effective way, and enhance their skill acquisition. Little research has been undertaken on the integration of pedagogic theory and instructional design with the design of feedback in CBST. To bridge this gap, this thesis's purpose was to explore the design of pedagogically-informed feedback in the motor skill domain via CBST, in order to support athletes' achievement of their intended training outcomes.

This thesis presents a framework of pedagogical feedback in the motor skill domain. It draws a picture of how principles from learning transactions, competency, cybernetics, and behaviourism, can work together to build sound pedagogical feedback for the implementation of a CBST system. The key principle of the framework is to generate feedback based on the athletes' achievement of their intended training outcome. The training outcome is conceptualised as comprising two components: a statement of capability, and a statement of the subject matter to which the capability applies. The pedagogical feedback system measures athletes' performance and compares it against the intended training outcomes. The system then identifies any performance gap and generates feedback to reinforce better performance.

Four counterbalanced experiments asked student rowers to explore the differences between the pedagogical feedback system and their current feedback system (Sean-Analysis). Pedagogical feedback was at least as good as Sean-Analysis with respect to the level of satisfaction of the athlete. In addition, pedagogical feedback seemed able to generate feedback that was consistent with the athlete's intended training outcome, support the athlete's positioning within their level of achieved performance, and support the athlete's self-assessment. Overall, it can be concluded that the pedagogical feedback based on the proposed framework appears to be a good model for generating feedback in CBST.

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Declaration of Authorship

I, Yulita Hanum P Iskandar, declare that the thesis entitled 'Pedagogical Feedback in the Motor Skill Domain for Computer-based Sport Training' and the work presented in the thesis are both my own, and have been generated by me as the result of my own original research. I confirm that:

- this work was done wholly or mainly while in candidature for a research degree at this University;
- where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
- where I have consulted the published work of others, this is always clearly attributed;
- where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
- I have acknowledged all main sources of help;
- where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
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Definitions and Abbreviations Used

CBST	Computer-based Sport Training
CAA	Computer-assisted assessment
Sean	Session Management
PedaFeed	Pedagogical Feedback
IP	Intended Performance
MANOVA	Multivariate analysis

Intended learning outcome, learning outcome, intended training outcome, training outcome, intended performance, competence, and competency are terms used throughout this thesis to mean similar things. In relevant sections, they are more exactly defined and disambiguated as necessary.

Symbols

n	number of participant
H_0	null hypothesis
H_A	alternative hypothesis
μ	mean
p	probability

Chapter 1

Introduction

1.1 Research Overview

E-learning should be pedagogically driven rather than technology driven. Pedagogy connects with learning outcomes. Learning outcomes define what is to be taught and therefore what is to be assessed. Thus, a pedagogical foundation provides a prerequisite for successful e-learning implementations.

Motor skills, although not usually a major part of educational objectives in Higher Education, are components of a distinct type of learning outcome and are essential to learning and teaching of human performance. Cognitive objectives typically involve declarative, procedural, or conditional knowledge. Performance objectives involve precise, smooth, continuous, and accurately timed performances, characteristically associated with surgical training, pilot training, and sport training.

Computer-assisted assessment (CAA) in the motor skill domain has become an essential tool for evaluating the technical proficiency of athletes' performance. In traditional sports training, the coach directs and improves the performance of athletes by giving information and feedback on techniques, tactics, and physiological demands. The volume of data generated means it is often not possible for a coach to track all the variables and respond to all the information. Furthermore, the environment of some training (large fields, out of doors, scattered athletes) makes the coaches' exact observation of performance difficult. To overcome these drawbacks, computer-based technology (e.g. virtual reality, motion training systems, and ergometer machines) is used to record athletes' performance (Beetz, Kirchlechner, & Lames, 2005; Guang-zhong, 2008; Liebermann et al., 2002). Thus, Computer-based Sport Training (CBST) serves as both a stimulus towards and a method for the study of the choices that athletes make during athlete-controlled training opportunities.

The development of CBST has made it possible to improve the feedback that athletes receive during training. Feedback to athletes has been identified as a key component in motor skill learning. Feedback in CBST typically incorporates sensors and devices embedded into the sports equipment, and uses sensors attached to the athlete, to acquire information about learning processes and the achievement of intended performance outcomes. Feedback contributes to learning by allowing athletes to verify their movements, evaluate their progress, and determine the causes of their errors. It also motivates them to remain involved in their training, provided they perceive the feedback as helpful.

Most research has focused on feedback's role in the cognitive domain (Mory, 2004; Shute, 2008), while less research has focused on designing and implementing feedback in the motor skill domain. Currently, issues of feedback in the motor skill domain via CBST concern: (1) feedback content, such as speed, accuracy, movement, time, and reaction time (Baudouin & Hawkins, 2004; Rowlands, James, & Thiel, 2009); (2) providing athletes with access to their feedback via an appropriate user interface (Cyboran, 1995); and (3) feedback modality, such as visual, audio, tactile, and haptic (Zitzewitz et al., 2008).

Feedback in both the cognitive domain and in motor skill environments is designed to shape the perception, cognition, or action of the learner. However, the design of feedback in the motor skill domain using CBST is typically led by technology and fails to consider pedagogical issues properly (P Iskandar, Gilbert, & Wills, 2009). Feedback in CBST is not usually informed by the goals, actions, processes, outcomes, and contexts of a learning and teaching situation.

Thus, the aim of this research is to explore the design of effective feedback from a technical and pedagogical perspective for the implementation of CBST. The pedagogical design for effective feedback can support athletes in their achievement of the underlying intended training outcomes, assist athletes in identifying the gaps in their performance, and help athletes to determine performance expectations, identify what they have already learned and what they need to learn next, and judge their personal learning progress.

1.2 Research Statement

The question that this research has sought to address is:

'How can effective feedback be designed for athletes when using CBST?'

The research hypothesis formulated is:

'Properly structured pedagogically designed feedback in the motor skill domain will allow the generation of effective feedback in CBST.'

1.3 Addressing the Research Question

In order to answer the research question, the following processes are addressed:

- Analyse the key components of pedagogical feedback in the motor skill domain that support athletes' expected quality of training.
- Design feedback in CBST that is pedagogically informed.
- Implement and test the design of pedagogical feedback in CBST for rowing.
- Validate the effectiveness of pedagogical feedback in the motor skill domain in successfully ensuring a pedagogic focus on coaching and training activities.

1.4 Thesis Overview

This thesis is divided into ten chapters. Following Chapter 1, this thesis has been organised as follows.

Chapter 2 reviews the concept of pedagogy in supporting the design of pedagogically-informed feedback. Pedagogic theories and instructional design are discussed in support of the learning and teaching activities.

Chapter 3 reviews the context of this research, which is CBST. The chapter focuses on how computers are being used in sports training.

Chapter 4 reviews the concept of feedback and analyses current feedback design. The chapter ends with the limitations of feedback design in CBST.

Chapter 5 introduces pedagogical feedback. The main components are presented followed by discussion of the main contribution of this thesis, a framework for pedagogical feedback in CBST.

Chapter 6 describes the detailed design and development of pedagogical feedback in CBST. The design comprises data, processes for generating feedback, and interfaces to the system. The chapter discusses the implementation of a system for pedagogical feedback in CBST.

Chapter 7 presents the experimental protocol. Four experiments were conducted to validate the effectiveness of pedagogical feedback in CBST.

Chapter 8 presents the statistical results for each experiment in Chapter 7.

Chapter 9 presents the discussion for the experimental results presented in Chapter 8, reviewing their interpretation and significant findings.

Chapter 10 concludes the thesis and presents the significant contributions that have arisen from this research. The chapter ends with recommendations for future work arising from this thesis.

Chapter 2

Pedagogy

2.1 Introduction

This chapter reviews pedagogy as the main component in the design of effective feedback. Pedagogical principles are theories that govern the good practice of teaching and learning. Pedagogy can be defined as the ‘art and science of teaching’ (de Boer & Collis, 2002) or as the ‘design and development of teaching and learning’ (JISC, 2009). To support the design of effective feedback based on a pedagogical approach, learning theories are first discussed followed by instructional design.

2.2 Learning Theories

Learning theories provide the conceptual underpinnings for pedagogy. Learning theory specifies the link between what is learned and the conditions under which learning occurs (Driscoll, 1994). Mayer (1999) has shown three views of learning: learning as response strengthening, learning as knowledge acquisition, and learning as knowledge construction.

Learning as response strengthening is also known as behaviourism theory. Behaviourism theory focuses on behavioural changes as a result of learning. Learners’ behaviour is changed particularly through the reinforcement of certain connections through feedback (Mayes & Freitas, 2004). From a behaviourist perspective, to change behaviour one must determine what behaviour is to be changed and what the change is (Driscoll, 1994). Thus behaviourism theory focuses on the behaviour with the goal being to strengthen the learners' behaviour which is controlled either by positive or negative reinforcement.

On the other hand, learning as knowledge acquisition or cognitive theory assumes that the learners' mental processes are the major factors in learning (Gredler, 2001). Cognitive theory emphasises the ways in which the learners' processing and application of information change their thoughts and internal mental structures. Thus, this theory looks at learners to determine their predisposition to learning.

Constructivist theory view learning as knowledge construction and considered knowledge is individually constructed by learners, based on their interpretations of experiences in the world (Jonassen, 1999). The most prevalent form of constructivist theory is co-constructivism (Kanuka & Anderson, 1999) or socio-constructivism (Squires & Preece, 1999). Co-constructivism can be viewed as "what we know arises in a relationship between the knower and the known" (Speed, 1991), while socio-constructivism can be seen as "personal constructs being developed in a social context" (Cumming, 2007). Thus, both co-constructivism and socio-constructivism emphasize that dialogue is an essential part of learning. Learners learn and develop themselves through a social and collaborative process using language. Constructivist theory therefore focuses on self-regulated learning as learners determine their learning activities via their personal experiences.

Meta-theories, such as cybernetics and general system theory, attempt to look for patterns and phenomena in the natural world (Hug, 1997). They provide a view from outside the educational system and look for similarities and differences that affect all systems. Learning is a closed system that allows for some branching and remediation. Thus cybernetic theory emphasizes the interaction between learner and learning in which the learners participate in the learning activities and learning attempts to acquire, evaluate, modify, translate, use, generate, transmit, and export information to achieve their purposes.

Learning theories are useful for understanding why an instructional design works by explicitly addressing which features of the learning environment promote intentional learning and how they may be developed.

2.3 Instructional Design

Instructional design presents a framework that can support the design and development of teaching and learning activities. The principles of instructional design that are grounded in learning theories offer systematic planning of instruction (Gagné & Briggs, 1974). The instructions are planned into an accessible, functional and usable toolkit to support teaching and learning activities in the achievement of learning objectives.

The field of educational psychology has long been sensitive to the desirability of establishing learning objectives for instruction (Krathwohl, 2002). These learning objectives are variously called behavioural objectives, instructional objectives, performance objectives, or intended learning outcomes. Intended learning outcomes guide the learner and guide the teacher. The rationale is that learners will use learning outcomes to identify the skills and knowledge they must master, while teachers will use learning outcomes to create a learning environment that supports the learning activities to the achievement of the intended learning outcomes (Kemp, Morrison, & Ross, 1998). The key of instructional design process therefore is to design instruction that facilitates teaching and learning activities towards the intended learning outcomes.

The instructional design process includes the core elements of analysis, design, development, implementation, and evaluation to ensure congruence among learning outcomes, strategies, evaluation, and the effectiveness of instruction. A wide variety of instructional design processes have been created (e.g. Gilbert & Gale, 2008; P. L. Smith & Ragan, 1999; van Merriënboer, Clark, & de Croock, 2002).

Although a variety of instructional design model have been designed, all models usually begin with the specification of intended learning outcomes. This shows that learning outcome is the key aspect that is applicable to teaching and learning situations.

2.3.1 Learning Outcomes

Instructional designers and other educators usually identify behaviourism as the source of the practice of writing explicit learning outcomes. Learning outcome conceptions of instructional design include the analysis, representation, and re-sequencing of content and tasks, in order to make their transmission more predictable and reliable.

For a computer to produce a machine processable representation, it should have a model of the teaching and learning situation. This can be done based on learning outcomes that are rooted in behaviourism theory. We can see how this is done in Chapter 6.

Behaviourism and cognitivism both support the practice of analysing a task and breaking it down into manageable chunks, establishing learning outcomes, and measuring performance based on those learning outcomes (Jonassen, 1999; Mergel, 1998). Cognitive science has broadened the concept of task analysis to include an analysis of the content itself. Such an analysis aims at determining the relationship between, and relative importance of, individual concepts within a body of subject matter.

The most widely investigated kind of content structure is the learning structure, or learning hierarchy, which shows the learning pre-requisite relations among the components of a subject matter (Gagné, 1985; Reigeluth, Merrill, & Bunderson, 1994). The learning structure describes what must be known (what the learner must be able to do) before something else can be learned. The learning pre-requisite relation is identified by the following sentence: “A learner must know (be able to do) ‘X’ in order to learn (be able to do) ‘Y’.”

Advocates of the constructivist model of instructional design take issue with the pre-definition of learning outcomes. Their position is that learning outcomes can only partially represent what we know, and therefore expressing them as the content of instruction might act to constrain what the learner will seek to learn. In constructivist learning environments, the learner is often a participant in determining learning outcomes and directions for learning, which can be a somewhat fluid process.

The cybernetics model encourages the setting of design learning outcomes, and it provides a way to know when the learning outcomes have been met (Gagné & Briggs, 1974). Based on the cybernetics model, the design process relies on constant systemic feedback. Such an instructional system acts somewhat like a thermostat, monitoring its own effectiveness and making revisions as needed to optimise learning outcomes (Pratt, 1978).

To summarise, learning outcomes must be designed and developed in smaller manageable chunks. The smaller chunks are assembled and aggregated in sequences providing a systematic and structured way of labelling and organising teaching and learning activities.

2.3.2 Classification of Learning Outcomes

Bloom and colleagues (1956) have identified three domains relevant to learning outcomes. These are the cognitive domain, affective domain, and motor skill (psychomotor) domain.

The cognitive domain deals with recall or recognition and the development of understanding and intellectual abilities. Bloom and colleagues (1956) developed a taxonomy that follows a sequence from recall through comprehension of the knowledge, its application in particular situations, to the higher order mental skills of analysis, synthesis and evaluation, all of which are involved in the problem-solving process. Their work has provided a common language for educators and has become the standard for identifying and classifying learning outcomes and activities.

The affective domain is concerned with attitudes, values, and emotions. Krathwohl, Bloom, and Masia (1964) developed a taxonomy that follows a sequence from attending to the specific phenomena, then responding to them, then learning to value them, then organizing one’s value in relation to each other, and finally creating a generalised personal value system to guide one’s life.

The motor skill domain is concerned with the general area of muscle development and coordination (Gagné, 1985; Knirk & Gustafson, 1986). Several taxonomies of learning outcomes exist in the literature (Dave, 1970; Harrow, 1972; Simpson, 1966) for the motor skill domain. Three of these are presented in Figure 2-1. In general, these various taxonomies describe a progression from simple observation to mastery of physical skills.

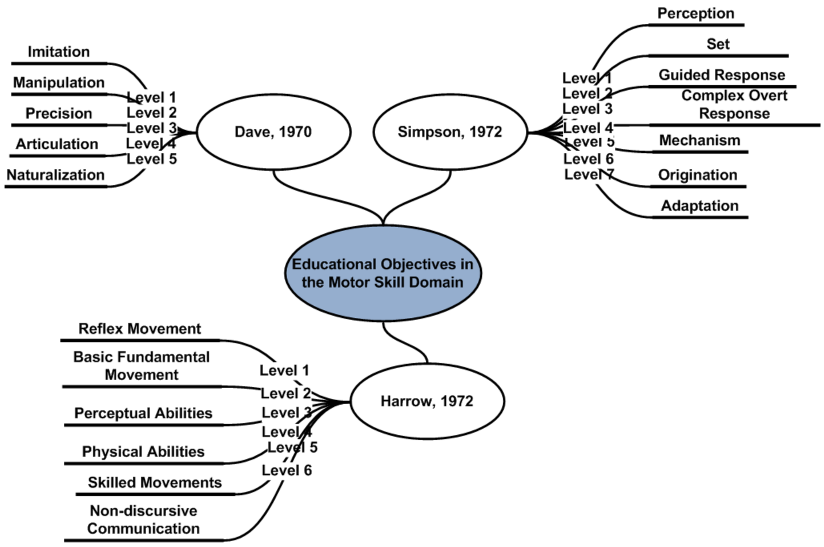

Figure 2-1: Categorization of learning outcomes in the motor skill domain

Although no taxonomy is universally accepted for this domain, Dave's taxonomy, based on the degree of coordination that is applicable to many motor skill applications (Kemp, et al., 1998), is adopted in this thesis.

2.3.3 Representation of Learning Outcomes

Representation of learning outcomes in a matrix provides a basis for developing instructional strategies (Kemp, et al., 1998). The learning outcomes are classified into two dimensions: subject matter content and performance. Content refers to what the students are expected to know and to be able to do and performance describe how well the students are expected to know or to be able to do in relation to the content (Näsström & Henriksson, 2008). Four types of subject matter content ('fact', 'concept', 'procedure' and 'principle') are distinguished as are three levels of performance ('finding', operationally equivalent to Bloom's 'synthesis'; 'using', equivalent to 'evaluation', 'analysis', 'application', and 'comprehension'; and 'remembering', equivalent to 'recall') (Anderson, Krathwohl, & Bloom, 2001; Merrill, 1994).

The matrix allows instructional designers to classify and align learning outcomes with learning and assessment activities by allowing them to identify the type of content and how the learner is expected to use the information. Use of this systematic classification process ensures accuracy in the instructional approach.

2.4 Instructional Design in the Motor Skill Domain

The analysis and training of motor skills seems to be somewhat divorced from the mainstream of educational research and development (Ferris & Aziz, 2005; Kovacs, 1997; Romiszowski, 1984). Bloom and his research team (1964) did not complete detailed work in the motor skill domain as they claimed lack of experience in teaching these skills.

Motor skills can be conceptualised as components of procedures, involving choices between alternative movements, sequences of movements, and iterations of sequences. This procedure, which has been called the 'executive subroutine' (Fitts & Posner, 1967), has the character of a rule by which the learner knows 'what comes after what' (Gagné, 1985). Motor skills can usually be divided into a series of steps or separate skills that constitute the total performance, either occurring simultaneously or in a temporal order. Learning to integrate skills that were previously learned separately has been recognised by researchers as a highly significant aspect of the total learning required. The detail in a task analysis determines the specific muscle coordination required in a physical activity and then states the appropriate training requirements as learning outcomes.

Mastery learning and a personalised system for instruction were instructional design models that seemed to have a direct value and easy application for teaching motor skills (Metzler, 1968). Mastery learning (Bloom, 1968) is based on the premise that learners must acquire skills in incremental, sequential progression, with pre-requisite skills being learned (mastered) prior to attempting more difficult and complex tasks. In such an approach, time is allowed to vary. That is, teachers do not hold the amount of content stable, but allow individual learners their own needed time to acquire skills. Keller developed his Personalized System for Instruction (Metzler, 1968) at the same time. It is based on mastery learning principles in that learners progress through a syllabus only after acquiring pre-requisite skills.

Thus, learning outcomes in the motor skill domain should be based on the premise that learners must acquire skills in an incremental, sequential progression, with prerequisite skills being learned (mastered) prior to attempting more difficult and complex tasks. A more detailed analysis of such learning outcomes is provided in Section 6.2.1.

2.5 Summary

The design and development of teaching and learning activities should be based on a pedagogical approach. Teaching and learning activities occur within a particular context, and are designed to achieve intended learning outcomes through a series of tools and resources. E-learning provides a starting point of how pedagogy can be mapped to teaching and learning activities using technology-enhanced tools. Thus pedagogical design of e-learning could be seen more as providing basic supporting structures that offer affordances and foster the eligible teaching and learning activities that prescribe learning outcomes. This chapter has shown that learning outcomes can be represented in smaller manageable chunks. The smaller chunks are assembled and aggregated into sequences that provides a systematic and structured way of labelling and organising teaching and learning activities.

The following chapter will present Computer-based Sport Training as a tool to support teaching and learning activities within training environments.

Chapter 3

Computer-based Sport Training

3.1 Introduction

The previous chapter has shown that design and development of teaching and learning activities should be based on the intended learning outcomes. Training activities deal with learning outcomes in the motor skill domain. The training encompasses the skills that require the use and coordination of skeletal muscles, whose outcomes are reflected in the rapidity, accuracy, force, or smoothness of bodily movement. Implementation of computer-based training therefore should be based on a pedagogical approach that connects with the attainment of learning outcomes. Thus, this chapter reviews computer-based sport training as the main context of this research.

3.2 Sport Training

Skills lie at the heart of athletes' performances. Athletes develop their skill through the regular practice of training. Training involves continual practice of the motion and is typically composed of repetitions of movements (Gredler, 2001).

The coach helps the athletes to enhance their skill by determining the intended outcomes for training during the period of instruction (Rink, 1985). The coach determines the instructional materials and the procedures to be used in the coaching activities to attain particular learning outcomes. The procedures usually incorporate conditions for demonstrating the skill, providing practice with feedback, and providing athletes with guidance for a given type of learning outcome. Behaviourists recognised this and called these examples rules and practice with feedback.

Planned, coordinated, and progressive coaching is needed for the athlete to develop successfully towards the intended outcomes (Siedentop, 1996). Systematic coaching activities derive from the behaviourist perspective and focus particularly on task analysis. A behaviourist approach to learning provides simple and clear coaching activities. Task analysis involves a breakdown of complex skills by detailing each muscle, nerve, and tendon involved in a given motion to generate an accurate technique and tactic analysis that is congruent with the learning outcomes (Irwin, Hanton, & Kerwin, 2005). Such analysis generates precise and effective instruction that allows the coach to facilitate the coaching activities pertaining to the athletes' achievement on the intended learning outcomes, and thus allows the athletes to progressively develop their skill in an effective and efficient way (Irwin, et al., 2005).

Thus systematic planning in sport training allows the congruity between techniques and tactics to be taught (represented in learning outcomes) and supports the assessment of learning outcomes and the instructional or coaching activities used to foster their achievement.

3.3 Computer-based Sport Training

Computer-based sport training (CBST) such as video analysis, virtual reality, and ergometers provides innovative support to coaches and athletes towards the achievement of intended learning outcomes.

Video analysis of athlete action is one of the tools for analysing performance, resulting in statistics on tactics, computer-aided coaching, and performance improvements (Haojie, Shouxun, Yongdong, & Kun, 2007). Performances are recorded on video tape and then edited to create a series of clips for subsequent screening (Wilson, 2008). However, coaches and athletes perceive the delay between performance and video analysis as detrimental to the effectiveness of this performance analysis (Kirby, 2009).

Virtual Reality (VR)-based training systems (Betzler, Monk, Wallace, Otto, & Shan, 2008) are oriented towards learning a sequence of discrete reactive tasks. Training occurs simply by immersing the user in a virtual environment with various scenarios, which would otherwise be difficult to experience in the real world. The given task is usually to perform a sequence of actions, in reaction to events. Importance is attached to whether the trainee has selected the right type of action, rather than how it has been done kinaesthetically (Baek, Lee, & Kim, 2003).

An ergometer (Begon, Mourasse, & Lacouture, 2009) is used to analyse the relationship between technique and performance. The system provides data for real-time feedback that enhances the results from learning/relearning of a motor task (Sturm, Yousaf, & Eriksson, 2010). Biomechanical analysis in rowing involves the consideration of the kinematics and kinetics of the *boat-rower* system. The Concept II rowing ergometer (Hawkins, 2000) integrates appropriate hardware and software to quantify and graphically display information about the rower’s joint kinematics and pulling force. The on-water rowing instrumentation system (Ritchie, 2008) has been designed to provide kinematic and kinetic information that has an influence on boat speed.

These examples support coaching activities by providing a learn-by-doing computerised environment in which athletes pursue learning outcomes by practising target skills and using instructional materials to help them achieve their learning outcomes (Schank, Berman, & Macpherson, 1999).

Rowing requires an orderly, co-ordinated, and powerful sequence of actions from every major muscle group in the body (P. Page & Hawkins, 2003). CBST supports coaching activities by providing accurate training prescriptions for the rowers (Guang-zhong, 2008). The CBST provides real-time, quantitative performance data to improve rowing performance. Speed of response is one indicator of skill automaticity, which is of great significance as a prerequisite for rowing performance. CBST can react to the speed of the rowers’ response.

This section has shown that CBST has had a profound impact on sport and is well suited to athletic training. The success of such systems however depends on how the athletes' performance that is to be improved is assessed, and how quickly comprehensible results can be made available to coaches and athletes.

3.4 Assessing Athlete's Performance

Assessment is an integral part of teaching and learning activities to measure intended learning outcomes formally (Conole & Warburton, 2005). Assessment can be categorized into summative assessment and formative assessment.

Summative assessment is a judgement at the end of a performance and is mostly connected to grading (Kalz et al., 2008). Formative assessment is given during the training as a kind of feedback (Kalz, et al., 2008). Feedback is usually a significant part of the formative assessment as athletes need to be informed of the results of their achievements (Vasilyeva, De Bra, Pechenizkiy, & Puuronen, 2008). The feedback can be used to assist athletes by identifying good quality work, and helping them to develop criteria which enable them to distinguish good from not so good task performance (Boud, 2000). Thus, formative assessment that provides feedback supports athletes to reach high-order skills (Sadler, 1989). Instruction through CBST can readily incorporate provision for athletes to respond and for feedback appropriate to that response.

Formative assessment in CBST can provide richer data about athletes' performances and make assessment tasks more authentic, and can thus carry very rich pedagogical implications (Conole & Warburton, 2005). Such assessment should focus upon the verification of an athlete's achievement of an intended learning outcome (Gilbert, Gale, Warburton, & Wills, 2009). Assessment feedback in CBST should be timely, specific, and relevant information provided to each athlete in respect of his or her performance. Addressing the performance gap between learning outcomes and athletes' achieved performance allows the athletes to foster the development of their skill acquisition.

The standard of an athlete's performance usually refers to grading or scores such as precision and speed. The standard of achievement tends to be highly correlated with performance rather than with intended learning outcomes. Such standards fail to provide the identification of missing techniques and tactics that are essential in the skill development of the athletes.

3.5 Summary

Systematic planning of sport training derives from behaviourism theory. Sport training should be planned based upon the learning outcomes to ensure congruity between the techniques and tactics to be taught and the assessment and instructional or coaching activities. This chapter has shown how CBST has been used to help the athletes in developing their skill towards the achievement of learning outcomes. Assessment in CBST that focuses upon the verification of an athlete's achievement of intended learning outcomes should be timely, specific and relevant to the athletes' performance. Assessment that provides feedback supports athletes to reach high-order skills.

The following chapter will discuss feedback and its design in CBST applications.

Chapter 4

Feedback

4.1 Introduction

Feedback is generally regarded as an important ingredient for skill acquisition; it is also depicted as a significant factor in motivating learning (Bangert-Drowns, Kulik, & Morgan, 1991; Narciss & Huth, 2006). Skill acquisition is characterized as an active, cumulative process, during which a target movement is expected to improve as a function of practice. Only when the athlete is able to reproduce a desired pattern systematically, and in a satisfactory way, can the motor skill be considered as finally acquired. This chapter presents an overview of feedback followed by the requirements of feedback. Finally current feedback design in CBST is presented.

4.2 Feedback

Feedback relates to information that allows the comparison between an actual outcome and a desired outcome. Feedback is one of the events of instruction described by Gagné (1985) in instructional strategy and usually follows some type of practice task.

Different learning theories attribute different functions to feedback. Behaviourism considers that feedback reinforces behaviour, cognitivism considers feedback as information necessary for the correction of incorrect responses (Kulhavy & Stock, 1989), while cybernetics views feedback as a method of controlling a system by reinserting the results of its past performance (Roos & Hamilton, 2005). In behavioural learning contexts the focus is therefore on feedback characteristics such as frequency and delay, and on the complexity of the feedback contents.

Once athletes have exhibited the new learned performance, they perceive that they have achieved the anticipated goal. This informational feedback is what many learning theories consider essential to the process called *reinforcement*. According to this conception, reinforcement works in human learning because the expectancy established at the beginning of learning is now confirmed during the feedback phase (Gagné, 1970). The process of reinforcement is anticipation for the confirmation of the reward. The importance of expectancy to the act of learning is again re-emphasized by the reinforcement process.

As in the case of other learning outcomes, the expectancy that initiated the learning of a skill needs to be confirmed. Skill acquisition can be conceptualised as a cybernetic system with feedback loops serving to remediate learning (Roos & Hamilton, 2005). Cybernetics focuses on how the athletes process the information, react to the information, and change to accomplish the task better. There is some evidence to indicate that the immediacy of reinforcement is important in facilitating motor skills (Gagné, 1970; Romiszowski, 1999). Besides immediacy, the accuracy, specificity and contingency of feedback have been found to have a positive affect on the learning of motor skills (Schmidt, Lange, & Young, 1990).

4.2.1 Feedback in motor skill instruction

Adams (1971) proposed a theory of motor learning based on experimental evidence. His ‘closed-looped theory’ describes the feedback loop where sensory information from a movement is compared with an intended movement or goal. A schematic representation of Adam’s theory is illustrated in Figure 4-1 below.

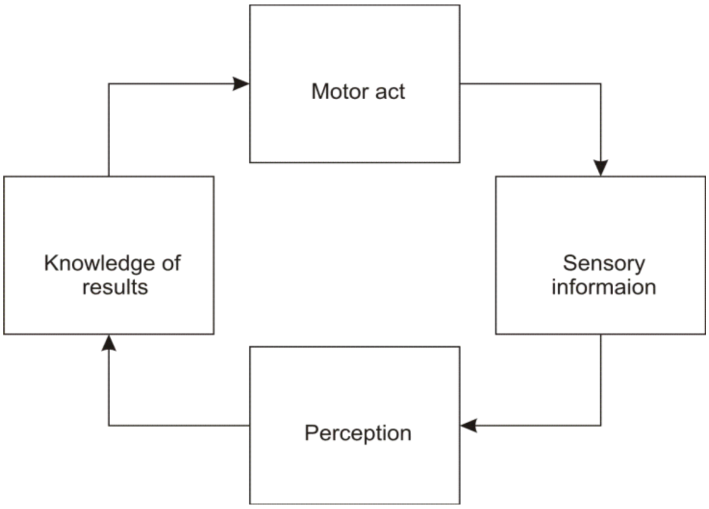

Figure 4-1: The closed-loop theory

For sensory input to become useful feedback, termed 'knowledge of results,' it must be perceived correctly by the learner. This perception is often left to self-assessment rather than to experienced observer feedback. Adams emphasized that knowledge of results (feedback) is required to learn, correct, and improve the performance of the motor action.

Knowledge of the results of a practical trial and knowledge of how the results were achieved represent two ways in which the coach may seek to correct the performance of a task. Providing knowledge of how the results were achieved is more effective. In the case of skills involving a high level of strategic planning and decision-making, the appropriate feedback not only may but should take the form of knowledge of how the results were achieved. Knowledge of results only supplies information about the correctness of a response. The knowledge of how the results were achieved on the other hand may comment on or correct certain aspects of executing the process of the task and give the direction and extent of an error.

4.3 Requirements of Feedback

This section discusses the proposed requirements for feedback. Such requirements are derived from a review of the research literature on both assessment and feedback in the cognitive domain, the motor skill domain, and in sports training. The requirements of feedback information involve:

1. Progress towards an intended learning outcome

Black and Wiliam (1998) emphasized that good feedback lies at the heart of pedagogy. Chapter 2 has shown that pedagogy connects with the learning outcomes. Feedback is used by the learners to compare their performance with the intended learning outcomes (Glahn, Specht, & Koper, 2006; Ramaprasad, 1983). Learners are always involved in monitoring and regulating their own performance in terms of their intended outcomes and in terms of the strategies they use (Nicol & Macfarlane-Dick, 2004) to help them acquire something desirable and avoid something undesirable (Hoska, 1993). Thus, feedback should provide learners with information about their progress towards an intended learning outcome (or set of goals) rather than providing feedback on discrete responses (i.e. responses to individual tasks) (Butler & Winne, 1995; Shute, 2008).

Research has shown that for learners to remain motivated and engaged depends on the expectation that their learning outcomes can be met (Fisher & Ford, 1998; Weinberg & Gould, 2007). If learning outcomes are set so high that they are unattainable, learners are likely to experience failure and become discouraged. When learning outcomes are set so low that their attainment is certain, success loses its power to promote further effort. Thus, learning outcomes must be personally meaningful and easily generated, and the learner must receive performance feedback about whether the learning outcomes are being attained (Cassidy, Jones, & Potrac, 2004; Sadler, 1989).

2. Display of the performance

Feedback can be conceptualized as information about the performance (Butler & Winne, 1995; Hattie & Timperley, 2007; Sadler, 1989). The performance should be closely coupled with feedback for learning to occur. This implies informing the learner of the degree of correctness or incorrectness of the performance (Kulhavy & Stock, 1989; Newell, Quinn, Sparrow, & Walter, 1983). Information presented through feedback might include not only movement correctness, but precision, timeliness, learning guidance, motivational messages, lesson sequence advisement, critical comparisons, and learning focus (Papanikolaou & Grigoriadou, 2005). This means, for knowledge and skills that call for discrete answers, telling the learners whether their movements are correct (Romiszowski, 1999). If incorrect, feedback should assist learners in detecting and correcting their errors (Bangert-Drowns, et al., 1991). Obviously, not all material to be learned consists of right and wrong answers. Motor skills, for example, may be performed correctly, but inexpertly or clumsily (Gagné, 1985). Thus, feedback should be aimed at showing learners how to improve their current skill (Baca, Dabnichki, Heller, & Kornfeind, 2009).

3. Suitability for the individual learner

Learners differ in terms of their learning outcomes, profile, knowledge, and learning paths (Berlanga et al., 2009). This diversity requires feedback to be provided on an individual basis that allows learners to develop their skill and knowledge.

Adaptive feedback (i.e. different learners receive different information) and adaptable feedback (i.e. learners have the possibility of choosing the feedback that suits their needs or preferences) have been introduced (Economides, 2006; Narciss & Huth, 2004). These types of feedback attempt to compensate for the weakness of generic feedback in 'communicating' with learners and to provide personalized feedback, allowing variation of information presented to the learners according to their individual characteristics (Winstein & Schmidt, 1990). Empirical studies, nvestigating whether the type and the amount of feedback are related to the learners' individual differences, draw implications from the degree of success or failure experienced by learners (Wulf & Shea, 2002). In addition, prior knowledge (i.e. the amount of domain knowledge that learners already possess prior to the learning phase) is recognised as a factor influencing feedback effectiveness (Hannafin, Hannafin, & Dalton, 1993), and elaborate feedback may not be as effective for learners with high prior knowledge (Schmidt, et al., 1990; Shute, 2008).

4.4 Current Feedback in CBST

Sport pedagogy can be defined as teaching and learning practices within physical education as exercise and rehabilitation, games, and sports (Borms, 2008). Researchers and educators in sport pedagogy have established guidelines for using feedback in real time training, but they have yet to be evaluated in a CBST context. Currently, feedback design in the motor skill domain via CBST can be categorized as follows.

1. Delivery of the feedback contents such as speed, accuracy, and movement

The Concept II rowing ergometer is frequently used to provide an indication of training progress and potential rowing performance (Nevill, Beech, Holder, & Wyon, 2010). The ergometer is provided with a performance monitor that displays stroke rate and average power per stoke (P. Page & Hawkins, 2003). Such measurement is used as a major indicator of rowing ability for the athlete.

A dry-land rowing tool such as videography and an indoor rowing ‘tank’ have also been used for the training of the athletes (Kinoshita, Miyashita, Kobayashi, & Hino, 2008). Such systems provide quantitative information about the rower’s kinetics and kinematics while the athlete rows on an ergometer.

2. Providing athletes with access to their feedback through an appropriate user interface

MacFarlane, Edmond, & Walmsley (1997) developed a portable data-acquisition system to measure stroke-by-stroke power output and the force developed at the feet during simulated rowing. The interface to the system includes the force, velocity, and heart rate signals of the rower to describe the rowing performance.

Baca & Kornfeind (2006) developed a feedback system for use on land that monitors the factors affecting an athlete’s rowing technique. The interface to the system displays the ground reaction and pulling forces of the rower.

3. Modality of feedback

A virtual reality system has been used to generate visual feedback for the rower (Ruffaldi et al., 2009). Such a system simulates a realistic boat in the water. The system displays different values related to the performance of the rower in their movement. The speed of the boat is the core parameter in the content of the visual feedback training system. Greene (2009) proposes visual information feedback of stroke rate on a digital display mounted ergometer for the rower.

A tactile feedback system was developed to train the timing of the limbs involved in rowing (M. Page & Vande Moere, 2007). The tactile feedback system could provide the feedback during every pull and recovery of the rower. Motion sensors were used to register the movement patterns of an expert, which can be replayed on the tactile guidance system of the rower.

An instrumented foot-stretcher has been developed to generate the propulsive forces of the rower (Krumm et al., 2010). The foot-stretcher forces were integrated within a rowing simulator. Such forces are displayed online to facilitate feedback about rowing performance.

Overall, current feedback design in CBST is led by technology and does not explicitly address the pedagogical issues on the achievement of intended learning outcomes. The feedback generated does not allow athletes to create meaningful relations between their achieved performance and their required performance in a particular context.

The thesis therefore proposes feedback based on a pedagogical approach that supports athletes by providing feedback about their skill development, and suggests possible ways of filling performance gaps.

4.5 Summary

Feedback is an important ingredient to enhance athletes' skill acquisition. Currently, feedback design in the motor skill domain via CBST can be categorized as: (1) feedback content, such as speed, accuracy, movement, time, and reaction time, (2) providing athletes with access to their feedback via an appropriate user interface, and (3) feedback modality, such as visual, audio, tactile, and haptic. The current feedback is led by technology and does not explicitly address the pedagogical issues on the achievement of intended training outcomes. To overcome the limitations of current feedback design in CBST, this research suggests the design of feedback that is based on a pedagogical approach.

The following chapter will discuss the pedagogically designed feedback for the implementation of CBST.

Chapter 5

Pedagogical Feedback in the Motor Skill Domain for CBST

5.1 Introduction

The previous chapter has identified the main limitations of feedback design in CBST. To address these limitations, this chapter presents the proposed framework for feedback in the implementation of CBST, based on a pedagogical approach. First, the key components of feedback in the motor skill domain are discussed followed by the framework.

5.2 Components of Feedback in the Motor Skill Domain

The key principle of pedagogically designed feedback is that it is based on how well athletes achieve their intended training outcomes. Intended training outcomes were used to refer to the intended learning outcomes as appropriate in the motor skill domain. The training outcome can be described as how well athletes are able to perform in relation to the techniques and tactics of the training activities. To provide feedback the system first measures an athlete's performance and compares it with the intended training outcomes. It then identifies the performance gap and generates appropriate feedback.

The components of pedagogically designed feedback include: behaviourism, learning transactions, competency, and cybernetics. The components of pedagogical design for effective feedback in the motor skill domain are illustrated in Figure 5-1. These components were chosen as they repeatedly arose in research as the keys to effective teaching and learning activities.

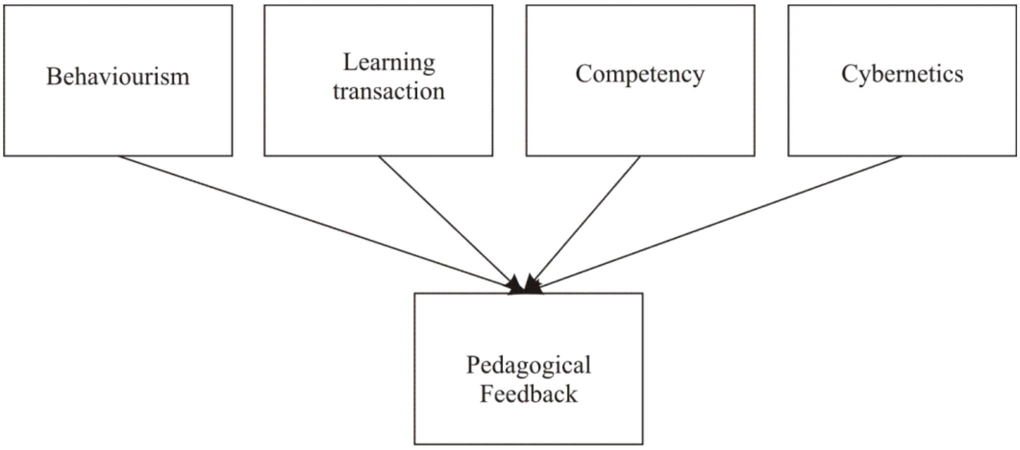

Figure 5-1: Components of the development of pedagogically designed feedback

5.2.1 Behaviourism

Three major components of behaviourism adopted in this thesis are: (1) feedback, (2) performance, and (3) breakdown of skill into smaller manageable units (Mayes & Freitas, 2004). Breakdown of skill is undertaken by competency modelling and is discussed in Section 5.2.3.

Feedback should derive from the task analysis. The aim of task analysis is to identify techniques and tactics that athletes should perform. Task analysis is a step-by-step description of the performance that the task represents, and results in the identification of (1) the routine that must be learned in order for the athlete to carry out the task, and (2) the links between the individual task procedures, each of which must be recalled from previous learning or newly learned (Gagné & Driscoll, 1988). Task analysis is undertaken for performance support tools since it elicits knowledge for design purposes, provides a reference for evaluation, and ensures the efficiency and accuracy of the resulting system.

A skill is a series or chain of movements, with each link and individual Response-Stimulus (R-S) unit acting as a stimulus for the next link. The term ‘contingency is used to refer to the ‘if-then’ relation, which connects behaviour with its consequences. In a *contingency*, a response is an *operant*, and its effect upon the *environment* is a reinforcement. The connection between them is the contingency. Chains of motor responses become the components of motor skills, often as partial skills. These are combined into organised motor performances, which continued practice invest with smoothness and precise timing. Each link in the chain to be acquired must have been previously learned as an R-S association.

Reinforcement must be suitably arranged so that it is made contingent upon the performance of the behaviour to be learned. This means that feedback must be arranged so that some reinforcing activity closely follows the occurrence of the desired behaviour. Feedback therefore determines whether the athlete has acquired all the links of the chains in all the specific R-S units. Since every link is the response for the succeeding link, the absence of one link means that the skill cannot be performed. The feedback also determines whether the athletes have learned all the components to enhance their performance.

5.2.2 Learning Transaction

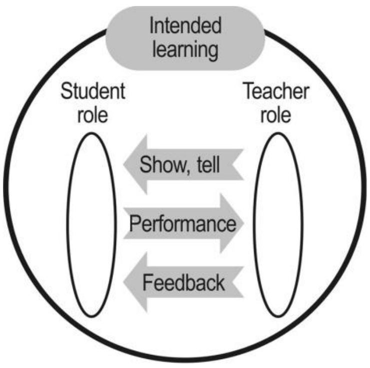

Figure 5-2: Learning transaction diagram

The learning transaction is a model (Figure 5-2) of ‘what goes on’ at the coach-athlete interface (Gilbert & Gale, 2008), providing an overview of what is needed to analyse and implement pedagogical design. It is a simplified version of the ‘learning conversation’ (Laurillard, 2001), based on active learning tasks, intended learning outcomes, reflection, and adaptation. Interaction between the athlete and the coach is central to skills acquisition. A key of the learning transaction is that it is a dynamic and dependent dialogue; each iteration occurs as a sequence of coach-athlete interactions involving description, performance, and interpretation of their impact in the world of action.

The learning transaction involves three major components: subject matter delivery, interaction enactment, and feedback. A transaction provides for partitioning, portraying, amplifying, sequencing, and routing subject matter, the athlete's enactment of the desired skills, and feedback on their performance. It is suggested that information about the components of the learning transactions will form the basis of the pedagogically-informed metadata, which would be relevant to any description of content or process in the design of feedback in the motor skill domain.

During a training session effective instruction is crucial to the pursuit of optimal sporting performance, since the more effective the instruction the more the coach's role will benefit the performance of the athlete. Such instruction requires the application of skills that range from the planning and organisation of the intended learning outcomes, to the presentation of instructional and feedback information. Hence, the primary role of coach and athlete is to stimulate the performance of training activities that will progressively result in the attainment of the learning outcomes. The coach defines the intended learning, provides the contexts and resources to perform the tasks, supports the athlete during task performance, and provides feedback about the results. This may involve providing instruction about optimal movement patterns or feedback on errors relating to the intended learning outcomes.

It is anticipated that pedagogical feedback in this context can be straightforwardly designed and engineered, given an appropriate specification of the intended learning outcomes that need to be learned in a CBST.

5.2.3 Competency

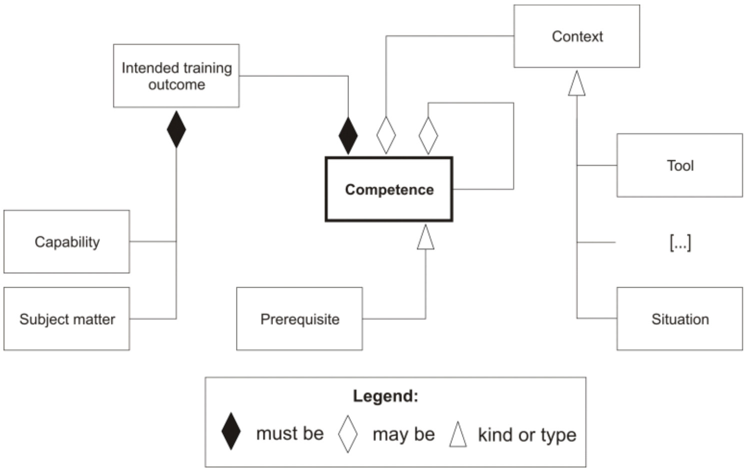

Figure 5-3: Competence conceptual model

A development of current ideas surrounding competencies suggests a conceptual model of intended training outcomes augmented by contextual factors, as illustrated in Figure 5-3. Such augmented intended training outcomes are competency in this thesis. While an intended training outcome may be reasonably constrained by an agreed ontology of capability terms (e.g. Dave's taxonomy) and an agreed subject matter topics list, context is in principle limitless and dependent upon particulars (if not peculiarities) of the target students, teachers, locations, times, tools, required mastery levels, available services, etc (Gilbert, 2009).

A competence may be defined as any form of knowledge, skill, attitude, ability or intended training outcome that can be described within the context of training (Sampson, Karampiperis, & Fytros, 2007). This model focuses on the representation of competency as a rich data structure that allows the machine-processable representation of intended training outcomes.

Competency analysis is often referred to as pre-requisites analysis, and can be used to diagnose failures in learning by identifying the pre-requisites that learners failed to master. A competency structure depicts these pre-requisites in an ordered hierarchical relationship. The lowest skills on the structure will be learned before the higher-ranking ones, up to the highest level objective. The lower-level skills are pre-requisite to the higher level skills. The structure represents what is expected to be a general pattern to be followed by the student: making sure that relevant lower-order skills are mastered before the learning of the related higher-order skill.

A competency model supports the storing, organising, and sharing of athletes' performance data in order to seek and interpret evidence for where the athletes are in their learning, where they want to go, and how they can get there (Sitthisak, Gilbert, & Davis, 2008).

5.2.4 Cybernetics

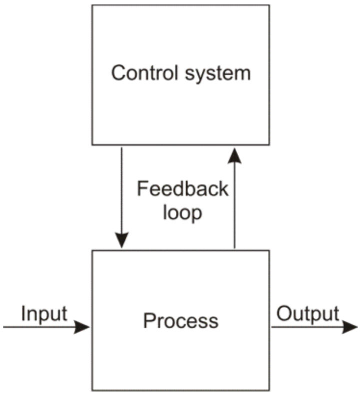

Figure 5-4: Basic cybernetic model

Cybernetics provides a model (Figure 5-4) where discrepancies in performance capabilities can be identified and corrective action taken (Pratt, 1978). If there are discrepancies, the behaviour of the controlled system is changed according to differences between actual output and the required standard. Ultimately, feedback governs the changes in communication, which changes behaviour, which changes the communication, and so on in a loop that enables a system to maintain a desired state. Cybernetics may provide a different and interesting explanation for why a particular approach seems to work while another does not.

In accordance with such engineering models, closed loop systems were designed to keep equilibrium about a reference value, which in turn would allow the work of a main actuator (Scott, Shurville, Maclean, & Cong, 2007). Deviations from the steady-state reference are coded as errors, which would then drive the system to compensate or correct. In movement science, this meant that feedback information about movement was generally expected to allow systematic corrections in the performance. However, feedback will be relevant to the human learner if, and only if, the individual knows the performance goal and perceives the need to carry out corrections relative to some expected outcome. Under such assumptions, the coach should strive to provide an environment that is conducive to effective training by augmenting the feedback that athletes receive. Feedback should thus enable athletes to modify their movements and produce optimum performance.

From a cybernetic point of view, the analysis of pedagogic feedback in the motor skill domain has four major components

- measurement of the current competency of the athlete,
- statement of the required standard of competency,
- comparison of the current competency to the required competency, and
- corrective feedback and information.

5.3 Framework for Pedagogical Feedback

Figure 5-5 shows the proposed framework for pedagogical feedback. The framework illustrates how the principles of learning transactions, competences, cybernetics, and behaviourism, might work together to build sound pedagogical feedback for the implementation of a CBST system. Key to the framework is the description of competence and the identification of the performance changes needed to achieve it. Such pedagogically designed feedback will allow adaptive training experiences that are tailored to the different needs and characteristics of each athlete, especially in terms of their current competence. The pedagogically designed feedback fulfils the requirements of feedback as discussed in Section 4.3.

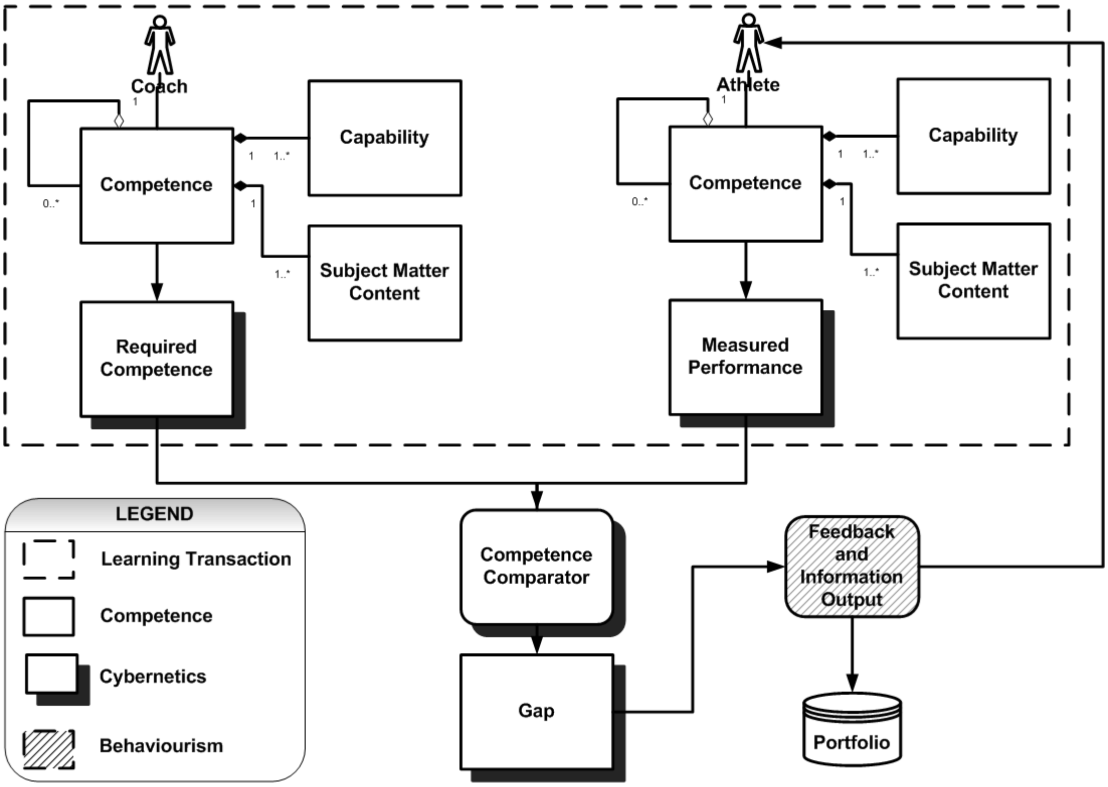

Figure 5-5: Framework for pedagogical feedback in the motor skill domain

The framework can be seen as a lifecycle that aims at the continuous enhancement and development of an athlete's competence. Additionally, it might assist in increasing consciousness of, and focus on, personal competence development. The lifecycle can be seen from four perspectives as follows.

1. Learning transaction

The framework suggests that the coach creates the tree or network of required competences, but this could equally be provided by a coaching or professional organisation or association or by a skilled athlete. The athlete performs the training activities and acquires competence on that particular training.

2. Competence

Competence models are used to inform the design of appropriate training activities to close the gap between the required competences of a given curriculum and the ones already possessed by an individual athlete. In this thesis competence is conceptualised as comprising two components: a statement of capability, and a statement of the subject matter to which the capability applies.

3. Cybernetics

Given an athlete with an acquired competence, which can be interpreted in terms of a network of competences with particular proficiency levels, the competence comparator measures the performance of the athlete and compares it with the required competence. The result is a gap analysis, which yields the required feedback and information output.

4. Behaviourism

The feedback generated is based on the results of the assessment that reflect the attainment of the intended training outcome. During learning personalised training activities are continuously monitored and the data collected used for feedback generation. For an athlete this implies that they should be advised on the learning possibilities that match their current competence level and that work toward their desired competence level (learning goals), taking into account their restrictions and preferences.

A portfolio serves several roles in competence development. This thesis considers a portfolio as a dynamic collection of authentic and diverse evidence that represents which competences a person has developed over time. It provides (a) profiles of competences, and (b) opportunities for athletes to document their competences in different contexts. Athletes provide evidence through a self-reflection process, in which they assign their performances to competences, and reflect on how they acquired such competences. From the pedagogical point of view, this process helps athletes better understand themselves (knowledge of self) and become better self-directed learners.

5.4 Summary

This chapter has given a brief description of the main components of pedagogical feedback in the motor skill domain. Pedagogical feedback lies in the learning theory and instructional design that comprises learning transaction, competency, cybernetics, and behaviourism. The framework of pedagogical feedback has shown how the components work together to provide feedback to the athlete.

Having analysed the pedagogical feedback, the following chapter presents a more detailed proposal for providing pedagogically informed feedback.

Chapter 6

Pedagogical Feedback: Design and Implementation

6.1 Introduction

This chapter presents the detailed design of pedagogical feedback in terms of the data, the processes, and the system interfaces. Finally the implementation of a pedagogical feedback system is presented.

6.2 Design

This section presents the design of a pedagogical feedback system. The design involves three components: data, process, and interface.

6.2.1 Data

The design of the data is obtained by considering the competence model shown in Figure 5-3. This competence model occurs in the framework for pedagogical feedback where the coach identifies the required competence and the athlete performs the training activities based on their competence.

To develop a conceptual model of training outcomes in the motor skill domain, a learning task must be broken down by analysis into specific measurable tasks. In teaching any new behaviour a closer approximation to the goal should not be reinforced until the previous one has been firmly established. If too large a gap between previously learned skills and currently expected skills is presented to the learner, their behaviour may fail and training may have to resume at the point where the learner has repeatedly demonstrated success.

An example of a rowing procedure task analysis is depicted in Figure 6-1. Rowing is a periodic movement that begins with the catch, then the drive phase, the finish, the recovery phase, and back to the catch (R. M. Smith & Loschner, 2002). The catch procedure is composed of parallel sub-procedures of gripping handles, positioning elbows extended, and positioning shins vertical. Positioning elbows extended will result in positioning arms extended.

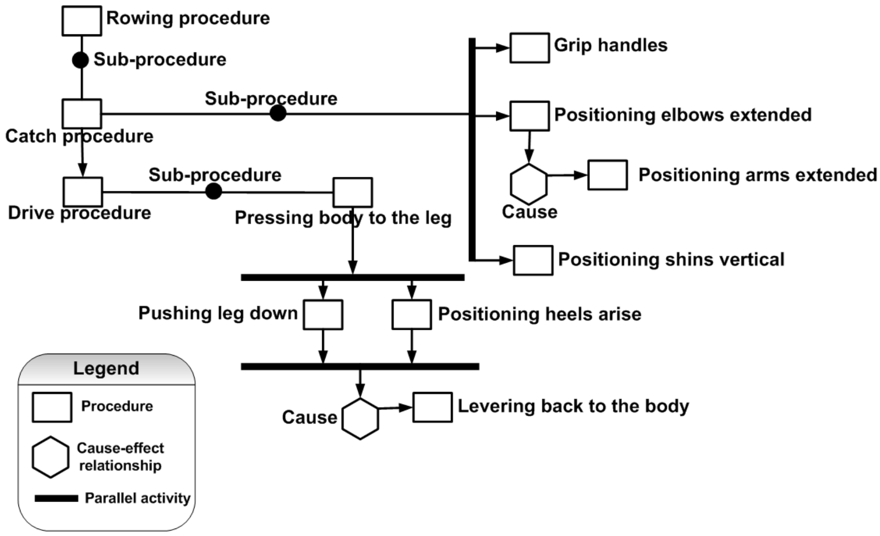

Figure 6-1: Task analysis of rowing procedure

We adopt Dave's taxonomy to represent the capability ontology (Table 6-1). Dave's taxonomy classified action components that describe different motor skill processing modes, and can be characterised with specific action verbs. (Kennedy, Hyland, & Ryan, 2007).

Table 6-1: Dave's taxonomy

Level	Capability	Capability Verb	Description
1	Imitation	Copy	Observing and patterning behaviour after someone else. Performance may be of low quality.
2	Manipulation	Perform	Performing certain actions by following instructions and practising.

Level	Capability	Capability Verb	Description
3	Precision	Demonstrate	Performing a skill or movement sequence independently and emphasising accuracy, proportion, and exactness.
4	Articulation	Articulate	Combining more than one skill in sequence with harmony and consistency.
5	Naturalisation	Perform automatically	Having high-level performance become natural, without needing to think much about it.

Dave’s taxonomy provides a qualitative way of organising skills, and consists of five levels, in increasing order of competency.

1. Imitation: Observing the behaviour of another person and copying this behaviour. This is the first stage in learning a complex skill.
2. Manipulation: Ability to perform certain actions by following instructions and practising skills.
3. Precision: At this level, the athlete has the ability to carry out a task with few errors and to become more precise without the presence of the original source. The skill has been attained and proficiency is indicated by smooth and accurate performance.
4. Articulation: Ability to co-ordinate a series of actions by combining two or more skills. Patterns can be modified to fit special requirements or to solve a problem.
5. Naturalisation: Displays a high level of performance naturally (‘without thinking’). Skills are combined, sequenced and performed consistently with ease.

Figure 6-2 and Table 6-2 represent some rowing training outcomes based on the competency model. The proposed training outcomes describe a capability, and the subject matter to which that capability applies. These descriptions represent what the learner is able to do and how the achievement is capable of verification when learning has been accomplished.

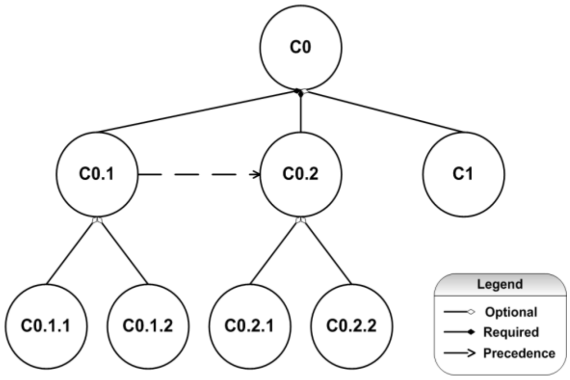

Figure 6-2: Conceptual Model of training outcomes in the Motor Skill Domain

Table 6-2: Some example rowing competencies represented in the competency model

Competency No	Capability	Subject Matter	Proficiency Level	Context	
				Tool	Situation
C0	Perform automatically	Rowing	20-25 strokes per minute	Ergometer machine	Rowing
C1	Articulate	Rowing	15-20 strokes per minute	Same as above	Same as above
C0.1	Perform automatically	Catch	40-45 degrees of flexion	Same as above	Same as above
C0.1.1	Perform automatically	Grip handles	80-90 psi	Same as above	Same as above
C0.1.2	Perform automatically	Positioning shins	90-85 vertical	Same as above	Same as above
C0.2	Perform automatically	Drive	35-40 per second	Same as above	Same as above
C0.2.1	Perform automatically	Pushing leg down	80-90 psi	Same as above	Same as above
C0.2.2	Perform automatically	Pressing body to the leg	25-30 accuracy	Same as above	Same as above

The simplest competency structure consists of a pair of procedural skills, one subordinate to the other. The competency structure describes what the learner must be able to do before something else can be learned. The learning relation is identified by the following sentence: "A learner must be able to do 'X' in order to be able to do 'Y'." For example, in order to achieve C0 (athletes are able to perform rowing automatically), it is required for the athletes to achieve C0.1 (athletes are able to perform catch automatically), C0.2 (athletes are able to perform drive automatically), and C1 (athletes are able to articulate rowing). In order to achieve C0.1 (athletes are able to perform catch automatically), athletes should be able to demonstrate either C0.1.1 (athletes are able to perform grip handles automatically) or C0.1.2 (athletes are able to perform positioning shins automatically). The achievement of C0.1 (athletes are able to perform catch automatically) allows athletes to proceed to C0.2 (athletes are able to perform drive automatically). This shows that we can effectively map these more complicated learning outcomes using the competency model.

The theoretically predicted consequence of a subordinate skill, that has been previously mastered, is that it will facilitate learning of the higher level skill to which it is related. The superordinate competency will be more readily learned if the subordinate competency has been previously acquired and is readily available for recall. In contrast, if the subordinate skill has not been previously mastered, there will be no facilitation of the higher level skill. Each subordinate competency has been identified as such because it is known to contribute positive transfer to the learning or the superordinate competency.

6.2.2 Process

The data flow diagram of Figure 6-3 presents the feedback system functionality, illustrating the data that is exchanged between the system and the environment, and the main data flows within the system. The purpose of the feedback system is the collection of traces of athlete actions and to present to the athlete feedback based upon these traces.

This diagram illustrates where the competence comparator in the framework measures the gap between the required competences of the coach and current competence of the athlete to generate feedback and information output for the athlete.

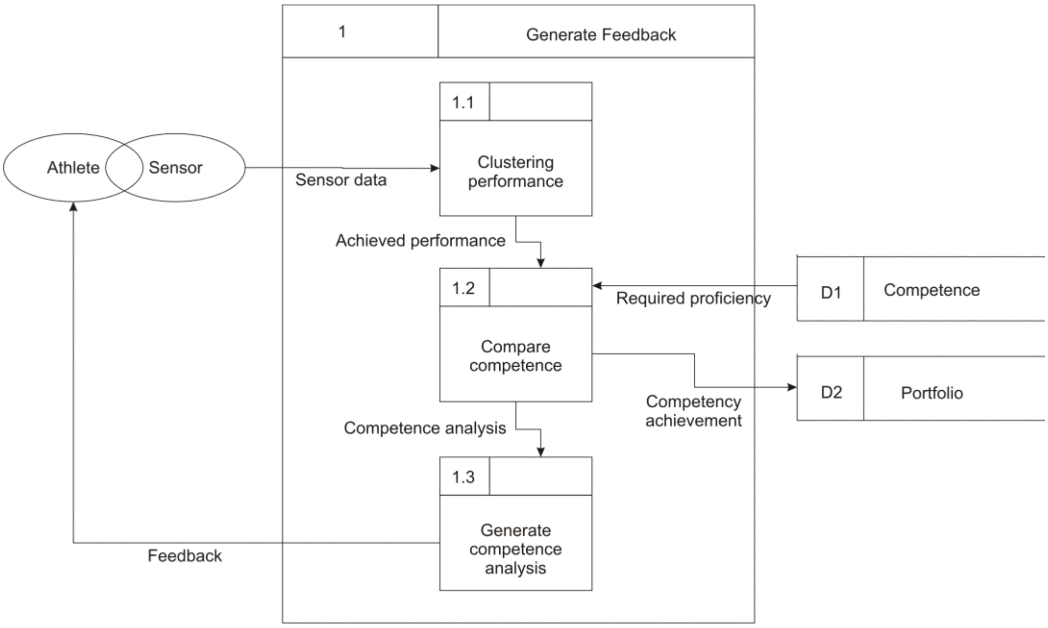

Figure 6-3: Pedagogical feedback system

1. Clustering performance

Sensors are responsible for capturing appropriate measures of the athlete's interactions. The system will then cluster the sensor data onto the set of acquired competence known as achieved performance.

2. Compare competence

Having determined the required competence from the competence database, the system will map both athlete and coach competences. To generate a gap analysis, the system maps the required proficiency from the database and the achieved performance from the athlete. This involves assessment of current competences and a comparison of competences.

3. Generate competence analysis

Feedback relies on the athlete's previous actions as well as on the interaction context in which an action occurs. This feedback is critical for learning. Important questions to consider are how often feedback should be provided, how precise this should be, and when it should be provided. Without the knowledge that an error has been made, the athlete will not be motivated to change their behaviour on the next trial and thus improve performance. Feedback relating to the movement should be as simple as possible and convey important information about the intended learning outcome. This feedback should be compatible with the required competence, so that error information is easily attainable to determine the intended learning outcome.

Whenever an athlete has performed a training activity, the relevant proficiency level of the athlete will be automatically updated if the previous level was less than the required proficiency level. This automatic mechanism can trace the competence development without being a burden to people. The fusion process takes only the newest competence record into account. Using this method implies that the associated competences of all learning activities and assessment activities in the learning network are appropriately described, and that they are equally credible and trustworthy. If the objective proficiency level of one activity is described as more advanced than the actual associated competence, after an athlete successfully performs this activity, their competence estimate will be updated to a level that may be higher than the level of potential competence.

Once the system decides how much feedback to give, it must determine the content of the advice. The feedback should contain enough information so that the athlete can proceed to the next step. Furthermore, the advice given to the athlete should be appropriate for their ability level. By using this technique, the athlete will not be required to wade through many levels of hints before receiving useful help. However, the athlete is usually not interested in the details; they rather want to know about higher level information such as ‘progress’ or ‘achievements’. Therefore it is not useful to show each event or cue separately.

Figure 6-4 illustrates the process of generating feedback based on traversing the competence network.

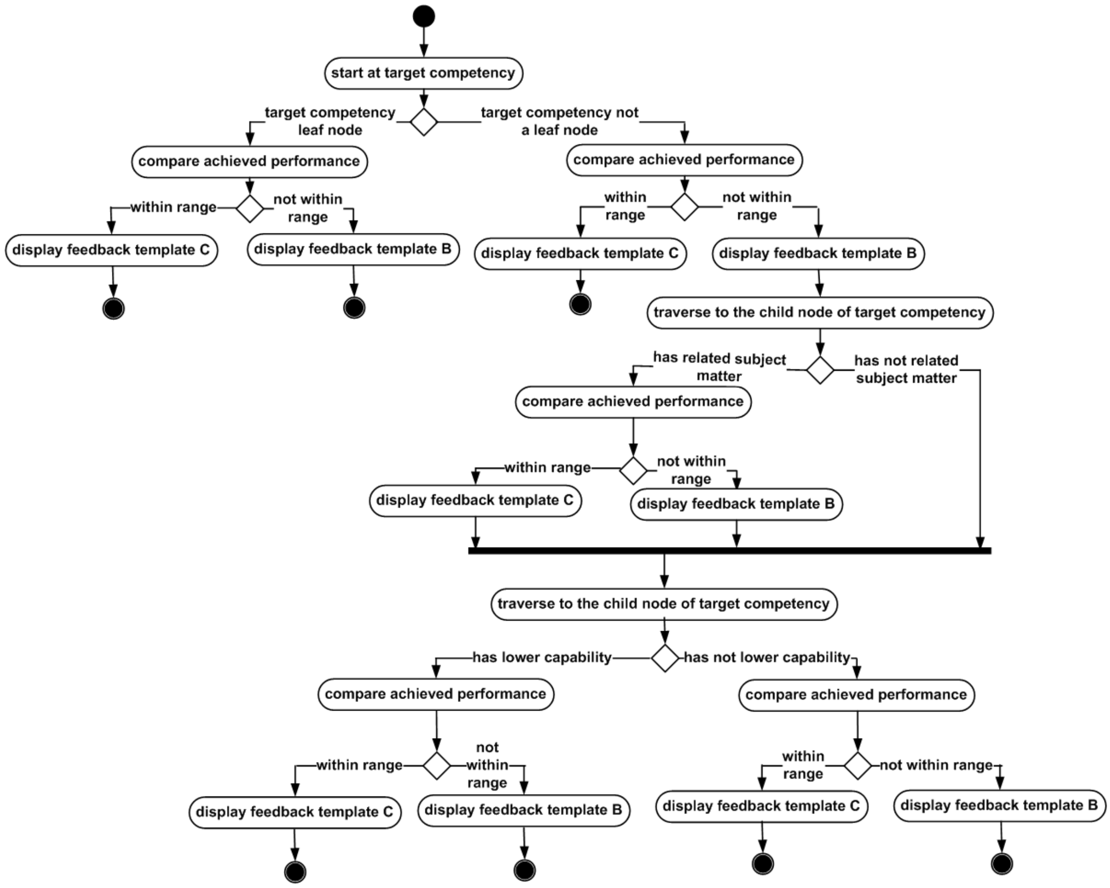

Figure 6-4: Process of generating feedback

The system starts at the target competence. It gets the achieved performance of the athlete from the sensor data. Artificial data was used to represent achieved performance in the experiments described later; in this example achieved performance for rowing is 23 strokes/minute. The system gets the required proficiency from the competence network.

To compare achieved performance with the required proficiency, the system looks at the range of the required proficiency. For the example, the range of the required proficiency for rowing is from 21 strokes/minute to 24 strokes/minute. The system then compares the achieved performance with the range of the required proficiency.

Table 6-3 illustrates a feedback template. The system uses a template to display feedback. The template is a method to turn competence elements into connected English for feedback. There was a prototype for template A, but it is not being used in the experiment.

Table 6-3: Feedback template

Template Number	Feedback template
A	[capability verb] [subject matter]
B	[capability verb] [subject matter] with achieved performance by [achieved performance] but required proficiency [proficiency level] using [situation] [tool].
C	[capability verb] [subject matter] with achieved performance by [achieved performance] and within the range required proficiency [proficiency level] using [situation] [tool].

If the achieved performance is within the range of the required proficiency, the system displays feedback based on template C. For the example, this becomes ‘execute automatically rowing with achieved performance by 23 strokes/minute and within the range required proficiency 22-24 strokes/minute using rowing ergometer machine.’

If the achieved performance is not within the range of the required proficiency, the system displays feedback based on template B. For the example, this becomes ‘execute automatically rowing with achieved performance by 18 strokes/minute but required proficiency 22-24 strokes/minute using rowing ergometer machine.’

In the case where the target competence is not a leaf node, if the achieved proficiency is not within the required range, the system displays feedback as above and then traverses to the child node that has the related subject matter as the target node.

6.2.3 Interface for Displaying Feedback

Based on the framework of pedagogical feedback, three interfaces have been identified that are essential in the process of generating feedback. The interfaces are:

- interface for the coach to determine the required competence,
- interface for the athlete to achieve the acquired competence, and
- interface for displaying feedback for the athlete.

This thesis focuses on the interface for displaying feedback for the athlete that is illustrated as feedback and information output in the framework. The user interface was designed to allow the athlete to view their feedback.

Figure 6-5 illustrates the interface for the pedagogical feedback system. The interface was organised into six sections, showing all the information on one screen therefore avoiding the use of the scrollbar (Stasko & Zhang, 2000).

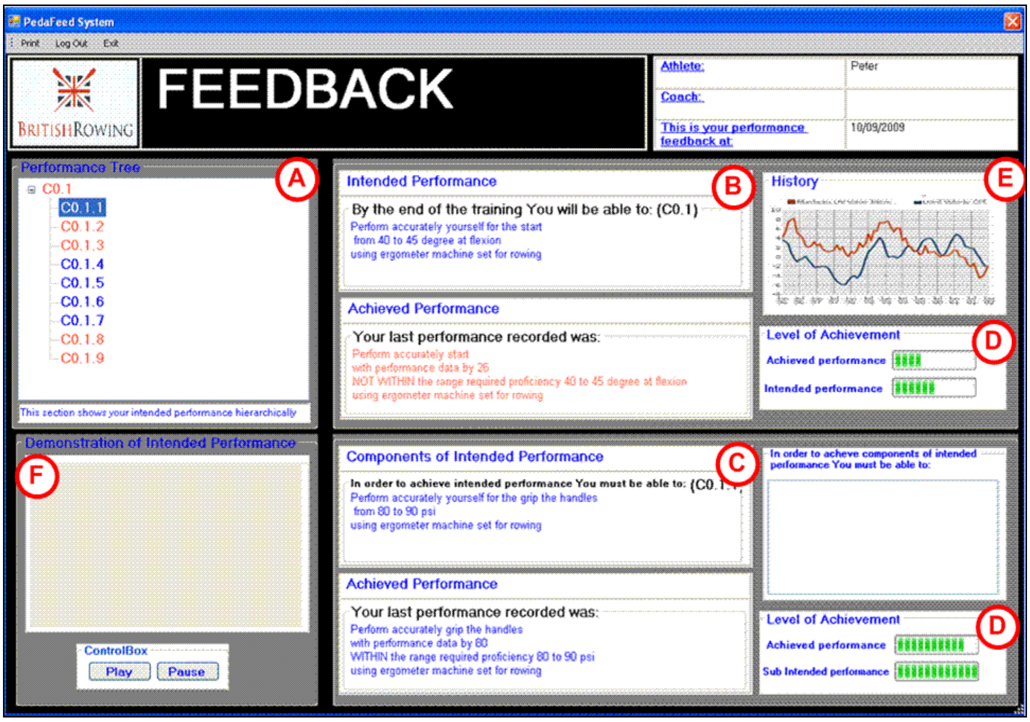

Figure 6-5: Screenshot of pedagogical feedback interface

Section 'A' shows the hierarchy of intended performance. Intended performance is the representation of competency. This term was used to help athletes understand their intended training outcome easily. The hierarchy is flexible and is a user-friendly visualisation of competency and its components (Shenton et al., 1995). Depending on the performance actually achieved, the competence is shown in a different colour. The colour can be used by the athlete to identify which intended performance they still need to develop or as evidence of the intended performance that they have developed. Colour coding was used to differentiate the athlete's correct and incorrect movements (Johnson & Shneiderman, 1991). For example, the blue font indicates that the achieved performance is within the range of required proficiency, while the red font indicates the achieved performance is not within range. The detail of intended performance and its components can be seen by clicking the appropriate entry, e.g. C0.1.1. Its details will then be displayed in sections 'B' and 'C'.

Section 'B' shows the intended performance and the achieved performance. The font colours for intended performance and achieved performance are identical to the corresponding font colours of the entries in section ‘A’. The consistency of colour is used to prevent confusion in meaning (MSDN, 2010). If the intended performance is not within the range, the athlete is able to see from section ‘A’ which components are the cause of their inability to perform accurately in their intended performance. If the athlete clicks the components of intended performance in section ‘A’ the details of the components of intended performance will be displayed in section ‘C’.

Section ‘C’ shows the components of intended performance and the achieved performance. Section ‘D’ shows graphical indicators for intended performance and achieved performance. The indicators provide a simplified representation of the athlete’s performance and their intended performance (Glahn, Specht, & Koper, 2007). The indicators visualise the information that enable the athletes to immediately interpret and compare their achieved performance to their intended performance.

Section ‘E’ shows a graph of the athletes’ achieved performance and intended performance. The graph presents the history of the athlete’s achieved performance and their intended performance. This allows the athletes to analyse their achieved performance and to carry out the intended performance more accurately.

Section ‘F’ shows a video demonstration of intended performance. Such a demonstration enables the athletes to view a correct performance if their own is not within the range of required proficiency.

6.3 Implementation

Based on the system design discussed above, an implementation of a pedagogical feedback prototype was produced. The pedagogical feedback system was written using Microsoft Visual C# 2008 accessing a Microsoft Office Access 2007 database.

6.3.1 Data Implementation

Figure 6-6 demonstrates relations between the data tables of the pedagogical feedback system in Microsoft Access. Microsoft Access was chosen for the database software because it provided rapid application development.

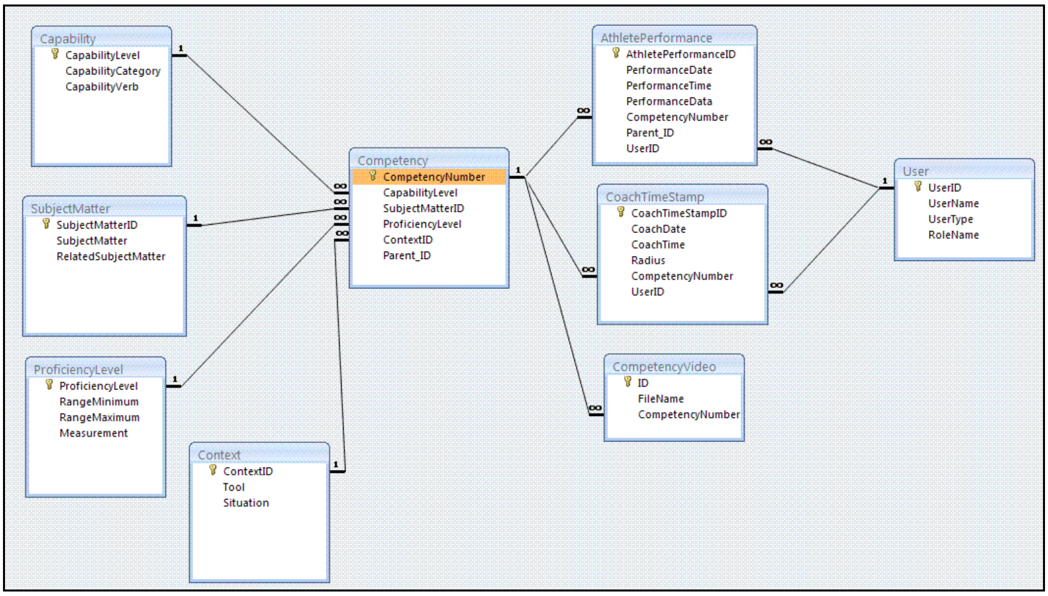

Figure 6-6: Relations between data tables

The 'User' table stores basic information about the user. The table stores the name of the user ('UserName') and the user's role ('RoleName') to indicate whether the user is an athlete or a coach. The user table relates to the 'AthletePerformance' table and the 'CoachTimeStamp' table.

The 'AthletePerformance' table stores the achieved performance of the athlete. This includes information on the date and time of the achieved performance. The table relates to the 'CoachTimeStamp' table and the 'Competency' table.

The 'CoachTimeStamp' table stores the required competency for the athlete specified by the coach. Also included are the date, time, and range of time that athletes should perform for the required competency.

The 'Competency' table stores the capability associated with subject matter content, a proficiency level, any required tools, and a definition of the situation that contextualises the competency. Corresponding to the competency network in Figure 6-2, the table requires the field 'CompetenceNumber', which indicates superordinate competency, and the field 'Parent_ID', which indicates subordinate competency. Four database tables related to competency were created: Subject Matter, Capability, Proficiency Level, and Context. Figure 6-7 shows a screenshot of the 'Competency' table.

Competency

Competence Number	Capability Level	Subject Matter	Proficiency Level	Context	Parent_ID
C0	5	1	1	1	
C0.1	5	2	6	1	C0
C0.1.1	5	3	26	1	C0.1
C0.1.2	5	4	26	1	C0.1
C0.1.3	5	5	26	1	C0.1
C0.1.4	5	6	31	1	C0.1
C0.1.5	5	7	31	1	C0.1
C0.1.6	5	8	31	1	C0.1
C0.1.7	5	9	31	1	C0.1
C0.1.8	5	10	31	1	C0.1
C0.1.9	5	11	36	1	C0.1
C0.2	5	12	11	1	C0

Figure 6-7: Competency table

The 'SubjectMatter' table (Figure 6-8) stores the subject description of what the athlete can do by the end of the training. To represent sub-procedure as in Figure 6-1, the 'RelatedSubjectMatter' field was used to store pointers to the 'SubjectMatter' values. For the example, 'grip the handles', and 'positioning palms downwards' were the sub-procedure for 'catch procedure'.

SubjectMatter

Subject MatterID	Subject Matter	RelatedSubjectMatter
1	rowing procedure	0
2	catch procedure	1
3	grip the handles	2
4	positioning palms downwards	2
5	positioning fingers in a curve	2
6	positioning back of your body rounded	2
7	positioning the top of your knees to be level v	2
8	positioning heels arise	2
9	positioning elbows extended	2
10	positioning arms extended	2
11	positioning shins vertical	2
12	drive procedure	1

Figure 6-8: Subject Matter table

The 'Capability' table (Figure 6-9) stores information on the behaviour that can be observed based on Dave's taxonomy. The 'CapabilityCategory' field refers to the five capability categories in Dave's taxonomy (Table 6-1). The 'CapabilityVerb' refers to the key verbs in each 'CapabilityCategory'.

Capability

Capability Level	Capability Category	Capability Verb
1	imitation	Copy
2	manipulation	Perform
3	precision	Complete
4	articulation	Integrate
5	naturalization	Perform accurately

Figure 6-9: Capability table

The 'ProficiencyLevel' table (Figure 6-10) stores information on the measurement of the degree to which the competency has been achieved. The range of required proficiency is composed of the 'RangeMinimum' and 'RangeMaximum' fields.

ProficiencyLevel

Proficiency	Range Minimum	Range Maximum	Measurement
1	20	25	strokes per minute
2	15	20	strokes per minute
3	10	15	strokes per minute
4	5	10	strokes per minute
5	2	5	strokes per minute
6	40	45	degree at flexion
7	35	40	degree at flexion
8	30	35	degree at flexion
9	25	30	degree at flexion
10	0	25	degree at flexion
11	35	40	per second
12	30	35	per second

Figure 6-10: Table of proficiency level

The 'Context' table (Figure 6-11) stores information on the particular context and conditions of the competency.

Context

ContextID	Tool	Situation
1	ergometer machine	rowing

Figure 6-11: Table of context

6.3.2 Process and Interface Implementation

The pedagogical feedback system was written in Visual C#. The Visual C# programming language was used as it provides maintainability, and encourages good code structure. The Microsoft Access database was accessed by the Visual C# code.

Figure 6-12 shows the sample code for generating feedback for the pedagogical feedback system. The lines labelled 'A' show code for comparing achieved performance from the athlete with required proficiency from the competence. The lines labelled ‘B’ show code for displaying feedback.

```
static public bool CompareIntendedPerformance()
{   bool result = false;

    System.Data.DataRow[] dataRow = competencyFeedback.CompetencyDataTable.GetDataCache().
                                                                    Select("CompetencyNumber='" +
                                                                    TempCoachRow_.CompetencyNumber + "'");

    if (dataRow.Length > 0)
    {
        TempCompetencyRow_ = (competencyFeedback.CompetencyRow)dataRow[0];
        competencyFeedback.CapabilityRow capabilityRow = TempCompetencyRow_.GetCapabilityRow();
        competencyFeedback.ProficiencyLevelRow proficiencyRow = TempCompetencyRow_.GetProficiencyLevelRow();
        competencyFeedback.SubjectMatterRow subjectMatterRow = TempCompetencyRow_.GetSubjectMatterRow();
        competencyFeedback.ContextRow contextRow = TempCompetencyRow_.GetContextRow();

        int value = TempAthleteRow_.PerformanceData;
        int min = proficiencyRow.RangeMinimum;
        int max = proficiencyRow.RangeMaximum;
        string rangeRequiredProficiency = proficiencyRow.RangeMinimum.ToString() + " to " + proficiencyRow.RangeMaximum.ToString();
        IntendedPerformanceResult = capabilityRow.CapabilityVerb + " at " + rangeRequiredProficiency;
        //if within range
        if (value >= min && value <= max)   <- (A)
        {
(B) ->      PerformanceResult = string.Format(Resource1.FeedbackTemplateC, capabilityRow.CapabilityVerb,
                                                                    subjectMatterRow.SubjectMatter, value.ToString(),
                                                                    rangeRequiredProficiency, proficiencyRow.Measurement);

            result = true;
        }
        //else if not within range   <- (A)
        else
        {
(B) ->      PerformanceResult = string.Format(Resource1.FeedbackTemplateB, capabilityRow.CapabilityVerb,
                                                                    subjectMatterRow.SubjectMatter, value.ToString(),
                                                                    rangeRequiredProficiency);
        }
    }
    else
    {   TempCompetencyRow_ = null;}
        return result;}
```

Figure 6-12: Sample code for generating feedback

Visual C# was then used to create the interface to deliver pedagogical feedback system to the user.

6.4 Summary

This chapter has described the design of the pedagogical feedback system and illustrated its implementation. This was followed by a description of the process of generating pedagogical feedback based on the competency structure. The effectiveness of the pedagogical feedback system will be demonstrated through experimental results.

The next chapter discusses how the experiments were conducted.

Chapter 7

Experiment: Protocol

7.1 Overview

To ensure the effectiveness of pedagogical feedback for CBST, four experiments were conducted. This chapter discusses the data measurement and data collection methods for each of the experiments. First, the experimental aim, experimental variables, and experimental method are generally discussed. Then, each experiment is detailed, sub-divided into participants, materials, and procedure.

7.2 Experimental Aim

The aim of all the experiments was to explore athletes' opinions on the pedagogical feedback generated by the 'PedaFeed' system and the current feedback received through the 'Sean-Analysis' system.

PedaFeed (Pedagogical Feedback) feedback type was the feedback system developed in this study as described in Chapter 6. Sean-Analysis (Session Management) feedback type was the feedback system for the rowing simulator. The system has been extensively used as a coaching and training tool (Rowperfect, 2006). It is able to accurately reproduce the physics of rowing and also generates feedback on the training session stroke-by-stroke.

The purpose of conducting experiments was to evaluate the acceptability of the pedagogical feedback to the athletes as their established feedback system. The experiments also sought to determine whether athletes were more satisfied with the pedagogical feedback or the current feedback system.

7.3 Experimental Variables

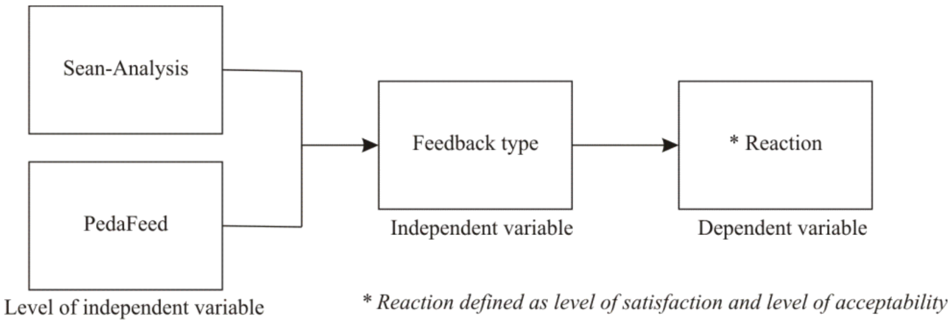

Figure 7-1: Set of variables in experimental design

Figure 7-1 illustrates the variables for all experiments, expressed in terms of independent (predictors) variable and dependent (outcomes) variable. The independent variable was the feedback type, composed of two levels, Sean-Analysis and PedaFeed.

The dependent variables were athlete opinions. Such opinions correspond to ‘Reaction’, the first level of evaluation proposed by Kirkpatrick (1976). Kirkpatrick’s evaluation model has been considered to be the most useful framework in the evaluation of training (Falletta, 1998). In this study, the reaction focuses on the issue of how satisfied the athletes were with the feedback provided, and how much they accepted the feedback type for the implementation of CBST.

In the following discussion, to indicate participant’s opinion on their level of satisfaction and level of acceptability towards feedback type, reaction ratings are applied.

7.4 Experimental Questions

The experiments were designed to explore the following questions:

- Is there a difference between the Sean-Analysis feedback type and PedaFeed feedback type in the reaction ratings by the athlete?

- Which reaction ratings showed differences between the Sean-Analysis feedback type and PedaFeed feedback type?
- Are reaction ratings for the PedaFeed feedback type higher those for Sean-Analysis feedback type?
- What are the relationships between reaction ratings for the Sean-Analysis feedback type and PedaFeed feedback type?

7.5 Experimental Research Methods

The four experiments received ethics approval ES/10/02/002 from the Ethics Committee of the Electronics and Computer Science School, University of Southampton.

An email was sent to the organiser of the rowing clubs located in Southampton. The email was to request the organiser to arrange the slots for the club's members to participate in this experiment. The rowing clubs participating in the experiments were:

- Southampton University Boat Club
- Itchen Imperial Rowing Club
- Southampton Amateur Rowing Club

G*Power software (Erdfelder, Faul, & Buchner, 1996) was used to calculate the required number of participants to be recruited for given effect sizes, alpha levels, and power values. The effect size expresses whether the difference observed is a difference that matters. For this research, the effect size was set to 1.25. Such an effect size was appropriate for an exploratory study. The value of alpha was set at 0.05, and the required power at 0.8. The program calculated the expected sample size as $n = 4$. This means at least four participants are needed for each experiment to detect an effect size of 1.25 with 80% power (probability that the test will reject a false null hypothesis.)

Repeated-measures design was performed to explore differences between the Sean-Analysis feedback type and PedaFeed feedback type using the same participants. Experiments were conducted by counterbalancing the order in which the participants interacted with the feedback type. Counterbalancing controls the ordering effect and ensure no systematic variation was produced between the Sean-Analysis feedback type and PedaFeed feedback type. Randomisation was used to determine the order in which participants interacted with the feedback type. That is, it was randomly determined whether a chosen participant interacted with the Sean-Analysis feedback type before PedaFeed feedback type (group A), or the PedaFeed feedback type before Sean-Analysis feedback type (group B). Figure 7-2 illustrates the experimental design.

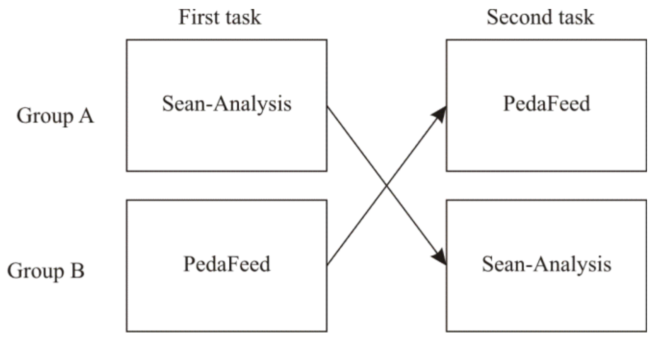

Figure 7-2: Counterbalanced experimental design

Each participant received:

- Consent form
- Scenario
- Worksheet
- Questionnaire

The following sections discuss the four experiments.

7.6 Experiment One

The aim of the experiment was to explore differences between the PedaFeed feedback type and Sean-Analysis feedback type.

Sixteen voluntary novice to expert rowers ($n = 16$) from Southampton University Boat Club, participated in the experiment.

7.6.1 Materials

The training scenario (Appendix 3) was given to the participants. The goal of the scenario was to represent the actual training that the participants would conceivably perform. Such a scenario provides the description of the intended training outcome for the training described. For the purpose of the experiment, Intended Performance (IP) was used to indicate intended training outcomes.

To row for 2,000 metres in under seven minutes, athletes should be able to achieve the required IP. Figure 7-3 and Table 7-1 represent the IP for positioning procedure. The IP was broken down into several components. In order to achieve C0.1 (execute accurately the positioning procedure within 40-45 degrees of flexion using rowing ergometer machine), the athletes should be able to perform C0.1.1 (accurately grip the handles within 80-90 psi using rowing ergometer machine) and C0.1.2 (accurately with palms downwards within 80-90 psi using rowing ergometer machine).

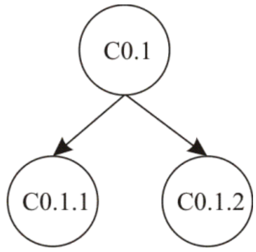

Figure 7-3: Some examples of catch IP

Table 7-1: Description for catch IP

IP	Capability	Subject Matter	Proficiency Level	Context
C0.1	Execute accurately	Positioning procedure	40-45 degrees of flexion	Rowing ergometer machine
C0.1.1	Execute accurately	Grip the handles	80-90 psi	Same as above
C0.1.2	Execute accurately	Palms downwards	80-90 psi	Same as above

The feedback type provides feedback on how well the athletes have achieved their IP. Figure 7-4 shows a graphical user interface for Sean-Analysis feedback type and Figure 7-5 shows a graphical user interface for PedaFeed feedback type. The details of PedaFeed feedback type’s interface is discussed in Section 6.2.3.

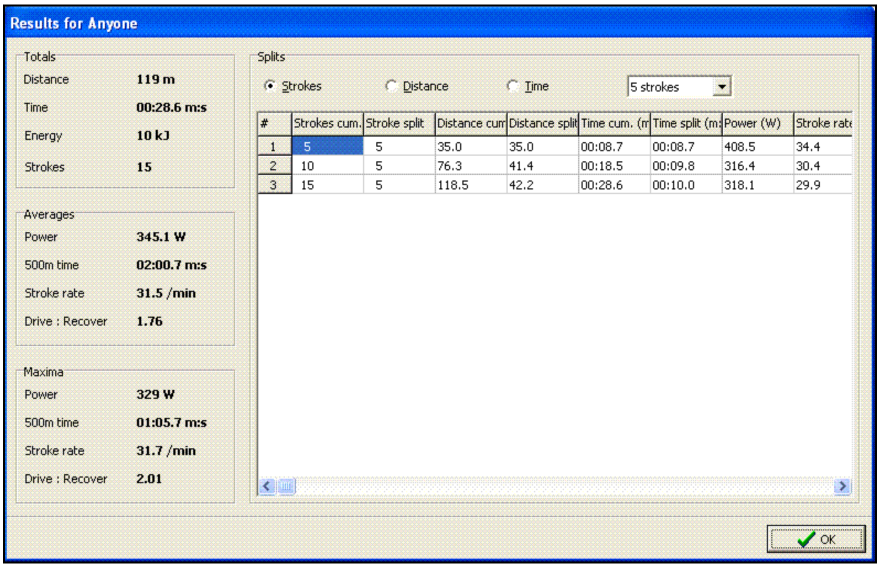

Figure 7-4: Graphical user interface for Sean-Analysis feedback type

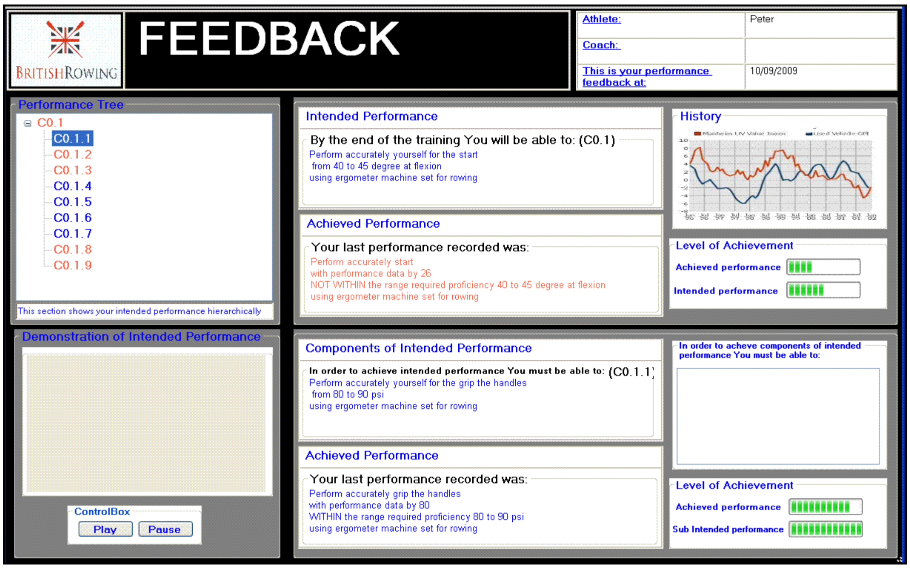

Figure 7-5: Graphical user interface for PedaFeed feedback type

The instruction to use the feedback type was described in the worksheet. The worksheet for Sean-Analysis feedback type is shown in Appendix 4 and for PedaFeed feedback type is shown in Appendix 5.

The questionnaire (Appendix 6) asked the athletes to rate the feedback type on a five-point Likert scale (‘Strongly disagree’, ‘Disagree’, ‘No opinion’, ‘Agree’, and ‘Strongly agree’). These were coded as 1, 2, 3, 4, and 5 respectively. The questionnaire comprised ten items as follows.

- Item 1:
  In the given screen, I found all the information I needed to achieve my intended performance. The reaction was coded as 'information to achieve IP'.
- Item 2:
  The system allowed me to judge the progression of my performance. The reaction was coded as 'progression judgement'.
- Item 3:
  The system helped me to know the causes of why I am not achieving my intended performance. The reaction was coded as 'causes of not achieving IP'.
- Item 4:
  The information given by the system was relevant to my intended performance. The reaction was coded as 'relevant to IP'.
- Item 5:
  The system gave me adequate information on what I should do in my next training. The reaction was coded as 'adequate information for next training'.
- Item 6:
  I prefer to read numerical scores rather than text description. The reaction was coded as 'prefer numerical scores'.
- Item 7:
  The display of achieved performance motivated me to refine my training. The reaction was coded as 'motivation to refine training'.
- Item 8:
  I am able to immediately interpret my achieved performance. The reaction was coded as 'immediately interpret information'.
- Item 9:
  The information allowed me to discriminate between good and bad performance. The reaction was coded as 'performance discrimination'.
- Item 10:
  I am satisfied with the overall information given by the system. The reaction was coded as 'information satisfaction'.

7.6.2 Procedure

The experimental procedure was divided into the following phases.

1. Introduction

   Participants were informed of the general purpose of the experiment and its structure. Participants were also informed that they could drop out of the experiment at any time they wished.

2. Administration

   Participants were asked to sign the informed consent form to confirm that their participation was voluntary.

3. Tasks

   For the first task, half of the participants received the Sean-Analysis feedback type (group A) and the other half received PedaFeed feedback type (group B). For both types, participants were instructed to read the scenario description and interact with the feedback they were given, based on the worksheet provided. Participants were instructed to raise their hands when they had finished interacting with the system. Participants were also advised to work at their own pace and were not given any time limit. The participants were assisted if they had any difficulties with the worksheet.

   For the second task, Group A participants who received the Sean-Analysis feedback during the first task received PedaFeed feedback type, and Group B participants who received the PedaFeed feedback type during the first task received Sean-Analysis feedback type. Participants were given the same instructions as before.

4. Questionnaire

   After each task, each participant received the questionnaire described earlier. Participants were given as much time as they wanted to complete the questionnaire.

Overall, the whole experiment took about 60 minutes.

7.7 Experiment Two

The experiment was conducted following on from the findings of Experiment One, where the aims were to further investigate differences between feedback types as a function of supporting positioning and of presentation order.

The first aim of Experiment Two was to explore differences between the PedaFeed feedback type and Sean-Analysis feedback type in supporting the athlete's positioning within their level of achieved performance. The purpose of conducting this experiment was to explore the differences between feedback types in determining the athlete's achieved performance to recommend remedial actions for the next training activity.

The second aim was to explore differences due to the order of performance for each of the feedback types. The purpose of conducting this experiment was to investigate whether participants' interaction with the first task affected their interaction with the second task. As for Experiment One, group A participants interacted with the Sean-Analysis feedback type first and group B participants interacted with the PedaFeed feedback type first (Figure 7-6).

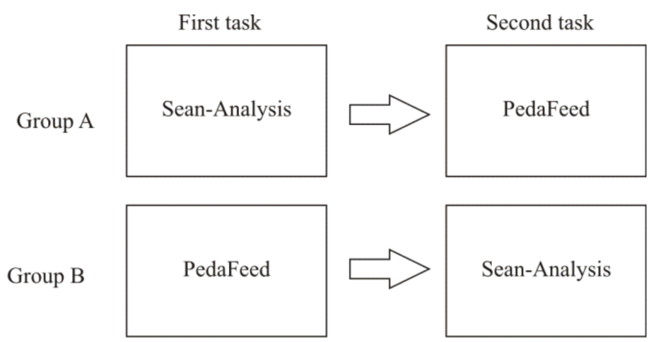

Figure 7-6: Order of interaction

With the independent variables as feedback type and order of interaction and dependent variable as reaction, differences between reaction ratings were explored (Figure 7-7).

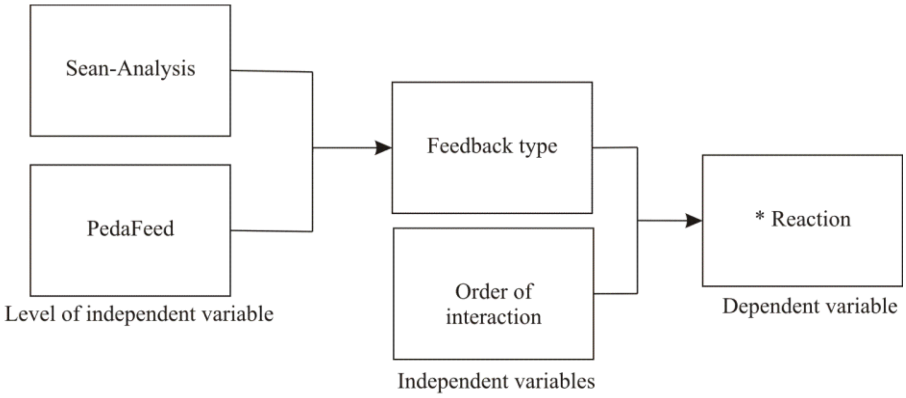

Figure 7-7: Set of variables

Twelve voluntary rowers (n = 12) from Itchen Imperial Rowing Club participated in the experiment. Intermediate rowers and expert rowers participated in the study.

7.7.1 Materials

A new function 'Suggestion for the next training' was added to the PedaFeed feedback type. Based on the process of generating feedback discussed in Figure 6-4, suggestions for the next training will only be displayed for the child node of the target competency that is not within the range of the required proficiency. This method corresponds to the positioning definition 'assess learner competences and recommend a sequence of learning material according to learning goals' (Berlanga, Burek, & Wild, 2009). Figure 7-8 shows a sample code for the implementation of suggestion for the next training.

```
private void nextSuggestion_Click(object sender, EventArgs e)
 {
     TreeNode node = mNode;

     if (node != null)
     {
         TreeNode parentNode = node.Parent;

         if (parentNode == null)
         {
             if (node.Nodes.Count > 0)
             {
                 parentNode = node;
                 node = node.Nodes[0];

                 while (node != null)
                 {
                     if (!Global.IsWithinRange(node.Text))
                     {
                         SetPerformanceResult(parentNode.Text);
                         SetSubPerformanceResult(node.Text, parentNode.Text);
                         mNode = node;

                         break;
                     }

                     node = node.NextNode;
                 }
             }
         }
         else
         {
             while (node.NextNode != null)
             {
                 node = node.NextNode;
                 if (!Global.IsSubWithinRange(node.Text, parentNode.Text))
                 {

                     SetPerformanceResult(parentNode.Text);
                     SetSubPerformanceResult(node.Text, parentNode.Text);
                     mNode = node;

                     break;
                 }
             }
         }
     }

     performanceTreeView.SelectedNode = mNode;}
```

Figure 7-8: Sample code for suggesting next training

The interface of the PedaFeed feedback type was modified to clarify the function of suggestions for the next training. A section 'Suggestion for the next training' was added to the interface. This section comprises: components of intended performance; buttons for previous suggestion and next suggestion; and indicators for level of achievement. The 'Components of intended performance' section displays the suggestions for training that athletes should undertake next. The suggestion displays the components of intended performance that are not within range. 'Level of achievement' indicates the performance that the athlete has achieved. Buttons for previous suggestion and next suggestion allow the athlete to easily navigate through the suggestions of the training. The graphical indicators allow the athlete to monitor their achieved performance in relation to the components of intended performance. Such an indicator approach focuses on the achievements of the athlete rather than the shortcomings; the aim of this is to raise the athletes awareness of their performance (Papanikolaou, Mabbott, Bull, & Grigoriadou, 2006). Figure 7-9 illustrates the resulting screenshot for the PedaFeed system.

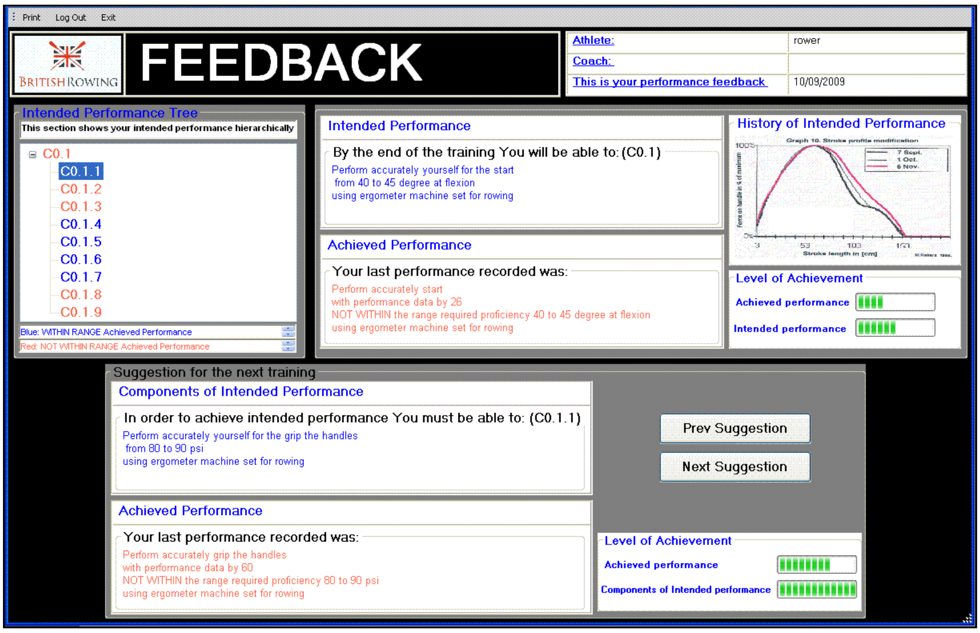

Figure 7-9: Experiment Two screenshot of the PedaFeed feedback type

The scenario and Sean-Analysis feedback type worksheet were the same as Experiment One. The PedaFeed feedback type worksheet was slightly changed to reflect the revised functionality of the system (Appendix 8).

The questionnaire (Appendix 9) asked the athletes to rate each item on a five-point Likert scale (‘Strongly disagree’, ‘Disagree’, ‘Not sure’, ‘Agree’, and ‘Strongly agree’). These were coded as 1, 2, 3, 4, and 5 respectively. Questions 1, 9, and 10 were changed from the previous experiment. The questionnaire comprised ten items as follows:

- Item 1:

  The system helped me to reflect on what is taught to me by the coach. The reaction was coded as ‘training reflection’.
- Item 2:

  The system allowed me to judge the progression of my performance. The reaction was coded as ‘progression judgement’.
- Item 3:

  The system helped me to know the causes of why I am not achieving my intended performance. The reaction was coded as ‘causes of not achieving IP’.

- Item 4:
  The information given by the system was relevant to my intended performance. The reaction was coded as ‘relevant to IP’.
- Item 5:
  The system gave me adequate information on what should I do in my next training. The reaction was coded as ‘adequate information for next training’.
- Item 6:
  The display of achieved performance motivated me to refine my training. The reaction was coded as ‘motivation to refine training’.
- Item 7:
  I was able to immediately interpret the information provided by the system. The reaction was coded as ‘immediately interpret’.
- Item 8:
  The information allowed me to discriminate between good and poor performance. The reaction was coded as ‘performance discrimination’.
- Item 9:
  I was able to know how close I was to my intended performance. The reaction was coded as ‘close to IP’.
- Item 10:
  The system gave corrective information about poor performance. The reaction was coded as ‘corrective information’.

7.7.2 Procedure

The experimental procedure was the same as Experiment One.

7.8 Experiment Three

Experiment Three was conducted following the findings from Experiment Two. The experimental aim was to explore differences between the PedaFeed feedback type and Sean-Analysis feedback type after athletes were more familiar with the feedback system. The factor of familiarity may have a significant influence on learners learning something efficiently and effectively (Karacan, Cagiltay, & Tekman, 2010). Familiarity reflects knowledge which is available to the individual either obtained by the use of the product, or information obtained through external sources (Casaló, Flavián, & Guinalíu, 2008). It is assumed that athletes that have a basic familiarity with important concepts and procedures in the domain, before using the feedback system, can immediately start to practice skills. Therefore, the participants and the experimental procedure were changed.

Expert athletes were chosen, as they are more familiar with the Sean-Analysis feedback type. Four voluntary expert rowers (*n* = 4) from Southampton Amateur Rowing Club participated in the experiment.

7.8.1 Materials

The user interface of the PedaFeed feedback type was changed by combining elements from Experiment One and Experiment Two. The section 'History of Intended Performance' in Experiment One and Experiment Two was taken out in order to allow the athlete to focus on the intended performance, components of intended performance, and achieved performance. The section 'Components of Intended Performance' had two functions: firstly to display detailed information on components of intended performance when the athlete clicked the intended performance tree. The second function was to display information on the suggestion of training when the athlete clicked the button for suggestion for next training or previous suggestion. Figure 7-10 illustrates the screenshot of the PedaFeed feedback type.

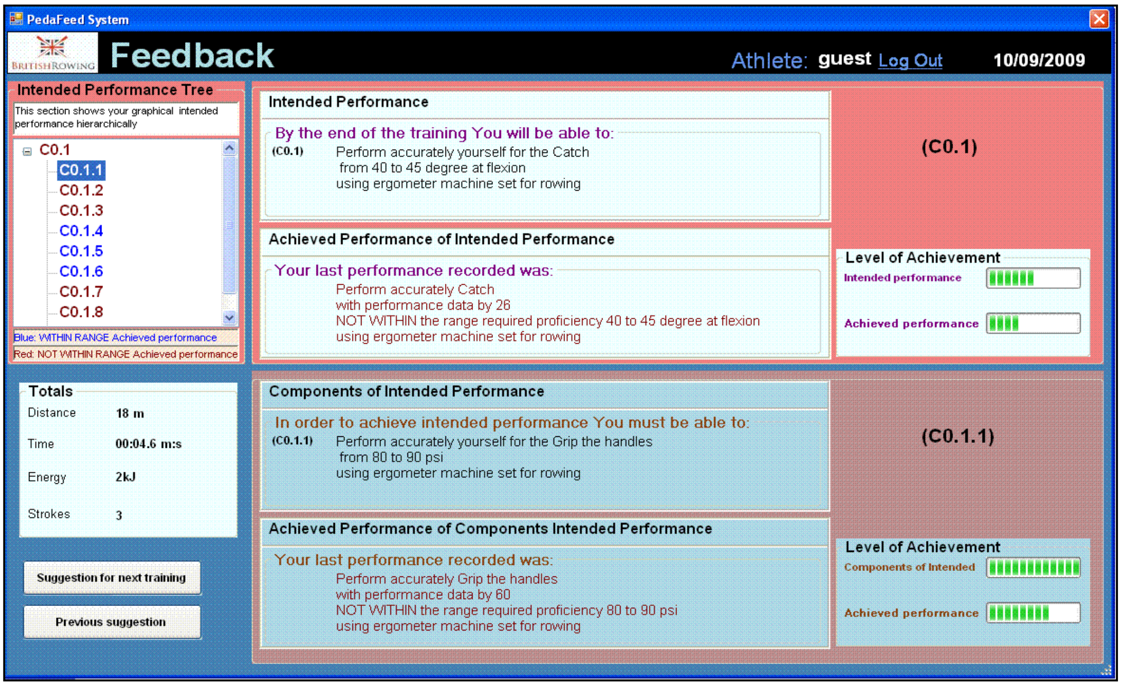

Figure 7-10: Experiment Three screenshot of PedaFeed the feedback type

Training materials (Appendix 11) were given to the participants. The scenario (Appendix 12) was changed to connect IP with the IP concept in the training materials. The Sean-Analysis feedback type worksheet was the same as Experiment Two. The PedaFeed feedback type worksheet was slightly changed (Appendix 13).

The questionnaire was the same as that of Experiment Two.

7.8.2 Procedure

The experimental procedure was the same procedure as Experiment One except that, during the interaction phase, participants were given training before the scenario and the worksheet were handed to them. The aim of the training was to familiarise athletes with intended training outcomes and the PedaFeed feedback type in order for them to be able to immediately interpret the information generated by the feedback system. Such training allowed the athletes to carry out an effective evaluation of the feedback system.

Athletes were given a tutorial on intended training outcomes, and a demonstration on the use of the PedaFeed feedback type. Participants were trained on rowing training strategy and the IP concept. The participants who received the PedaFeed feedback type were also trained on the functionality of the system.

7.9 Experiment One, Two and Three: Data Combined

Following the findings from Experiment One, Two, and Three, the same questions from Experiment One, Two, and Three were combined to explore the differences between the Sean-Analysis feedback type and PedaFeed feedback type by improving the power of the statistical analysis. More participants will increase the power because the standard error of the mean decreases as the square root of the number of participants (Desmond & Glover, 2002). These questions comprised seven items as follows. These were coded as 1, 2, 3, 4, and 5 respectively.

- Item 1:
  The system allowed me to judge the progression of my performance. The reaction was coded as 'progression judgement'.
- Item 2:
  The system helped me to know the causes of why I am not achieving my intended performance. The reaction was coded as 'causes of not achieving IP'.
- Item 3:
  The information given by the system was relevant to my intended performance. The reaction was coded as 'relevant to IP'.
- Item 4:
  The system gave me adequate information on what should I do in my next training. The reaction was coded as 'adequate information for next training'.
- Item 5:
  The display of achieved performance motivated me to refine my training. The reaction was coded as 'motivation to refine training'.
- Item 6:
  I am able to immediately interpret my achieved performance. The reaction was coded as 'immediately interpret information'.
- Item 7:
  The information allowed me to discriminate between good and bad performance. The reaction was coded as 'performance discrimination'.

7.10 Experiment Four

Experiment Four was conducted following the findings from Experiment Three and combined dataset of Experiment One, Two, and Three. The aim of the experiment was to explore differences between the PedaFeed feedback type and Sean-Analysis feedback type in supporting athletes' self-assessment of their achieved performance.

Eight voluntary intermediate and expert rowers (n = 8) from Itchen Imperial Rowing Club, participated in the experiment.

7.10.1 Materials

The user interface of PedaFeed feedback type, training material, scenario and the Sean-Analysis feedback type worksheet were the same as for Experiment Three. The PedaFeed feedback type worksheet was slightly changed (Appendix 18).

The questionnaire (Appendix 19) asked the athletes to rate the feedback type on a five-point Likert scale ('Strongly disagree', 'Disagree', 'No opinion', 'Agree', and 'Strongly agree'). These were coded as 1, 2, 3, 4, and 5 respectively. The questions were all changed from previous experiment. The questionnaire comprised eight items as follows.

- Item 1:
  I am able to identify and target the technique that needs to be developed to reach my intended performance. The reaction was coded as 'identify and target technique'.
- Item 2:
  The achieved performance verified that I had achieved my intended performance. The reaction was coded as 'verified achievement of IP'.
- Item 3:
  I am able to track my capability level. The reaction was coded as 'track capability level'.
- Item 4:
  The system allowed me to ensure that each technique is mastered. The reaction was coded as 'ensured each technique is mastered'.

- Item 5:
  The system gave adequate information on the set of techniques that build toward the intended performance. The reaction was coded as ‘adequate information on the set of techniques’.
- Item 6:
  The system gave clear information on what I must be able to do before something else should be learned. The reaction was coded as ‘clear information’.
- Item 7:
  I am able to diagnose why I did not reach my intended performance. The reaction was coded as ‘diagnose failure of IP’.
- Item 8:
  The system encouraged self-regulated learning. The reaction was coded as ‘encouraged self-regulated learning’.

7.10.2 Procedure

The experimental procedure was the same as Experiment Three.

7.11 Summary

This chapter has discussed the experimental design for the four experiments conducted. Repeated-measures design was performed to determine athletes’ reaction to the differences between the Sean-Analysis feedback type and PedaFeed feedback type. Such differences focused on athletes’ opinion of the requirements and information output of the feedback type.

The following chapter presents the statistical results for each experiment.

Chapter 8

Experiment: Results

8.1 Overview

This chapter presents the statistical and graphical analyses of the data collected. For all experiments discussed in Chapter 7, the general form of the hypothesis and statistics are presented. Then, for each experiment, the details are presented.

8.2 Hypothesis

Based on the experimental aim presented in Section 7.2, the hypothesis to be tested is formulated as follows.

The null hypothesis states (H_0) there is no difference between mean reaction ratings for the Sean-Analysis feedback type and mean reaction ratings for the PedaFeed feedback type.

The alternative hypothesis (H_A) states that there is a difference between mean reaction ratings for the Sean-Analysis feedback type and mean reaction ratings for the PedaFeed feedback type. Symbolically:

$$H_0 : \mu \textit{Sean-Analysis} = \mu \textit{PedaFeed}$$

$$H_A : \mu \textit{Sean-Analysis} \neq \mu \textit{PedaFeed}$$

Where:

μSean-Analysis = mean reaction ratings for the Sean-Analysis feedback type *μPedaFeed* = mean reaction ratings for the PedaFeed feedback type

8.3 Statistical analysis

Repeated-measures analysis was used to investigate the hypothesis because participants were involved in both Sean-Analysis feedback type and PedaFeed feedback type. Such analysis was used to accommodate the likelihood that reaction ratings are correlated from the same participants (Field, 2005).

Multivariate analysis (MANOVA) was used to detect whether reaction ratings differ between feedback types. Such analysis generates four test statistics: (1) Pillai's trace, (2) Wilks' lambda, (3) Hotelling's trace, and (4) Roy's largest root. The *p* values of these statistics are used to accept or reject the null hypothesis.

Univariate tests were performed when the result from MANOVA rejected H_0. A univariate test investigates whether individual mean reaction ratings for the Sean-Analysis feedback type differ from the PedaFeed feedback type.

Profile plots of mean reaction ratings for Sean-Analysis feedback type and mean reaction ratings for PedaFeed feedback type are presented. The plots directly visualise the differences.

Pearson's correlation coefficient was used to investigate the relationships between reaction ratings for the Sean-Analysis feedback type and reaction ratings for the PedaFeed feedback type.

Having identified the relationships between reaction ratings, hierarchical clustering was performed. The clustering was to explore the classification of similarities among reaction ratings. Such clustering is represented in a Dendrogram using the Ward method (Field, 2005). Experience with the clusters suggested a cluster distance cut-off of 13, as will be explained in each experiment.

The repeated-measures analysis was conducted using PASW Statistic 18 (SPSS, 2010). For all analyses missing values were ignored.

8.4 Experiment One

From Chapter 7, the aim of this experiment was to explore differences between the PedaFeed feedback type and Sean-Analysis feedback type. With 13 participants undertaking the experiment ($n = 13$), reaction was measured in terms of:

- information to achieve IP
- progression judgement
- causes of not achieving IP
- information relevant to IP
- adequate information for next training
- preference for numerical scores
- motivation to refine training
- immediately interpret information
- performance discrimination
- information satisfaction

Table 8-1: Multivariate tests

Within Subjects Effect	Statistical Method	Value	F	Hypothesis df	Error df	Sig.
Feedback Type	Pillai's trace	0.774	1.028	10.000	3.000	0.557
	Wilks' lambda	0.226	1.028	10.000	3.000	0.557
	Hotelling's trace	3.426	1.028	10.000	3.000	0.557
	Roy's largest root	3.426	1.028	10.000	3.000	0.557

Table 8-1 shows multivariate tests of mean reaction ratings for feedback type. For these data, the MANOVA test statistics do not reach significance ($p > 0.05$). This shows there was no significant difference on mean reaction ratings for feedback type, data taken together. Overall, mean reaction ratings for the Sean-Analysis feedback type were not significantly different from the mean reaction ratings for PedaFeed feedback type.

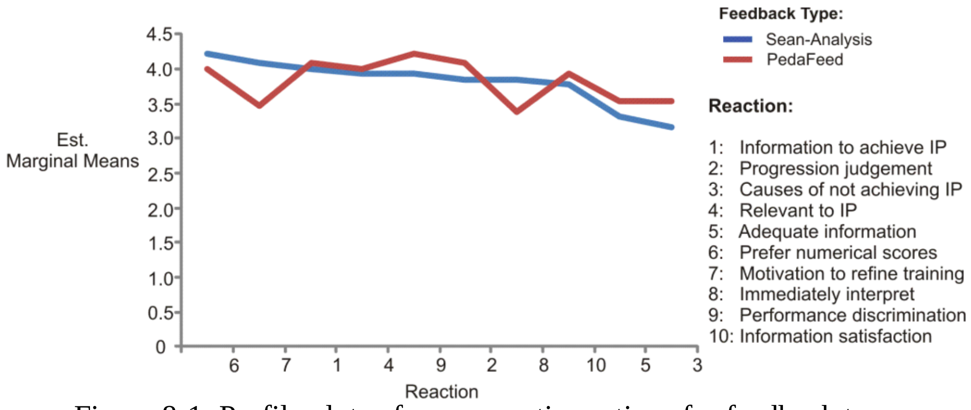

Figure 8-1: Profile plots of mean reaction ratings for feedback type

Figure 8-1 presents the mean reaction ratings for the Sean-Analysis feedback type and for PedaFeed feedback type. Inspection of the profile graph supports the findings that the differences were not significant.

Results from Experiment One support H_0 and reject H_A. There is no difference between mean reaction ratings for the Sean-Analysis feedback type and mean reaction ratings for PedaFeed feedback type.

Table 8-2: Correlations

Reaction ratings	Information to achieve IP	Progression judgement	Causes of not achieving IP	Relevant to IP	Adequate information for next training	Prefer numerical scores	Motivation to refine training	Immediately interpret	Performance discrimination	Information satisfaction
Information to achieve IP	1	**.612***	.319	.343	.326	.174	.153	.218	**.403***	**.519***
Progression judgement	**.612***	1	**.528***	**.550***	.356	.005	.107	.352	**.599***	**.580***
Causes of not achieving IP	.319	**.528***	1	**.771***	**.721***	.008	.253	**.403***	**.515***	**.693***
Relevant to IP	.343	**.550***	**.771***	1	**.577***	.089	.289	.314	**.701***	**.754***
Adequate information for next training	.326	.356	**.721***	**.577***	1	.186	**.415***	.286	**.575***	**.646***
Prefer numerical scores	.174	.005	.008	.089	.186	1	.217	.173	.247	.123
Motivation to refine training	.153	.107	.253	.289	**.415***	.217	1	.256	.285	.226
Immediately interpret	.218	.352	**.403***	.314	.286	.173	.256	1	.359	**.416***
Performance discrimination	**.403***	**.599***	**.515***	**.701***	**.575***	.247	.285	.359	1	**.761***
Information satisfaction	**.519***	**.580***	**.693***	**.754***	**.646***	.123	.226	**.416***	**.761***	1

* Correlation is significant at the 0.05 level (2-tailed)

Table 8-2 provides a matrix of the correlation coefficients for reaction ratings with the data from the two feedback types combined.

Each reaction ratings is perfectly correlated with itself and so *r* = 1 along the diagonal table.

There was a significant relationship between reaction ‘information to achieve IP’ ratings and reaction ‘progression judgement’ ratings, *r* = 0.612.

Reaction ‘progression judgement’ ratings were significantly correlated with reaction ‘causes of not achieving IP’ ratings, *r* = 0.528, and reaction ‘relevant to IP’ ratings, *r*

= 0.550; the reaction ‘relevant to IP’ ratings was also correlated with reaction ‘causes of not achieving IP’ ratings, r = 0.771.

Reaction ‘immediately interpret’ ratings was significantly correlated with reaction ‘causes of not achieving IP’ ratings, r = 0.403.

Reaction ‘causes of not achieving IP’ ratings was correlated with reaction ‘adequate information for next training’ ratings, r = 0.721.

Reaction ‘adequate information for next training’ ratings was correlated with reaction ‘relevant to IP’ ratings, r = 0.577, and also correlated with reaction ‘motivation to refine training’ ratings, r = 0.415.

There was a significant relationship between reaction ‘performance discrimination’ ratings and:

- reaction ‘information to achieve IP’ ratings, r = 0.403
- reaction ‘progression judgement’ ratings, r = 0.599
- reaction ‘causes of not achieving IP’ ratings, r = 0.515
- reaction ‘relevant to IP’ ratings, r = 0.701
- reaction ‘adequate information for next training’ ratings, r = 0.575

Reaction ‘information satisfaction’ ratings was significantly correlated with:

- reaction ‘information to achieve IP’ ratings, r = 0.519
- reaction ‘progression judgement’ ratings, r = 0.580
- reaction ‘causes of not achieving IP’ ratings, r = 0.693
- reaction ‘relevant to IP’ ratings, r = 0.754
- reaction ‘adequate information for next training’ ratings, r = 0.646
- reaction ‘immediately interpret’ ratings, r = 0.416
- reaction ‘performance discrimination’ ratings, r = 0.761

All other correlations were not significant.

To explore these relationships further, a cluster analysis was undertaken.

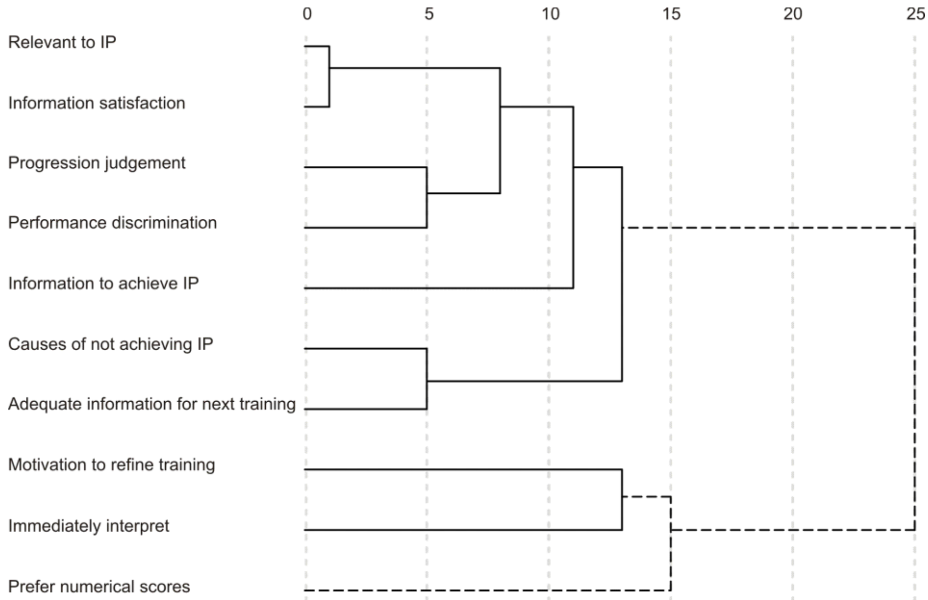

Figure 8-2: Dendrogram of hierarchical cluster analysis

Figure 8-2 provides the cluster analysis of reaction ratings. Ignoring the two final cluster lines shown dashed, there are two broad clusters. The final clustering of ‘prefer numerical scores’ was shown as dashed because this rating did not show significant correlations with any other ratings, corresponding with a cluster distance cut-off of approximately 13.

Cluster one comprises:

- reaction ‘relevant to IP’ ratings
- reaction ‘information satisfaction’ ratings
- reaction ‘progression judgement’ ratings
- reaction ‘performance discrimination’ ratings
- reaction ‘information to achieve IP’ ratings
- reaction ‘causes of not achieving IP’ ratings
- reaction ‘adequate information for next training’ ratings

Cluster two comprises:

- reaction ‘motivation to refine training’ ratings
- reaction ‘immediately interpret’ ratings

8.5 Experiment Two

The experiment had two aims. The first was to explore differences between the PedaFeed feedback type and Sean-Analysis feedback type in supporting the athlete's positioning within their level of achieved performance. Second, the experiment was to explore differences between the PedaFeed feedback type and Sean-Analysis feedback type on the order of interaction. With 12 participants undertaking the experiment (n = 12), reaction was measured in terms of:

- training reflection
- progression judgement
- causes of not achieving IP
- relevant to IP
- adequate information for next training
- motivation to refine training
- immediately interpret
- performance discrimination
- close to IP
- corrective information

8.5.1 First Aim for Experiment Two

Table 8-3: Multivariate tests

Within Subjects Effect	Statistical Method	Value	F	Hypothesis df	Error df	Sig.
Feedback Type	Pillai's trace	0.806	0.832	10.000	2.000	0.659
	Wilks' lambda	0.194	0.832	10.000	2.000	0.659
	Hotelling's trace	4.160	0.832	10.000	2.000	0.659
	Roy's largest root	4.160	0.832	10.000	2.000	0.659

Table 8-3 shows multivariate tests of mean reaction ratings for feedback type. The results show there was no significant difference on mean reaction ratings for feedback type, data taken together (p > 0.05). Overall, mean reaction ratings for the Sean-Analysis feedback type were not significantly different from those for PedaFeed feedback type.

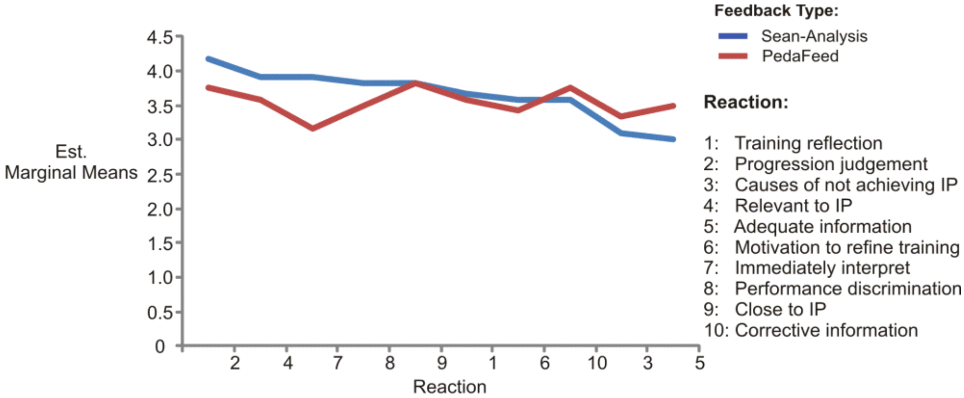

Figure 8-3: Profile plots of mean reaction ratings for feedback type

Figure 8-3 presents mean reaction ratings for the Sean-Analysis feedback type and for PedaFeed feedback type. Inspection of the profile graph supports the findings that the differences were not significant.

8.5.2 Second Aim for Experiment Two

The purpose of conducting the second aim of experiment two was to investigate whether participants' interaction with the first task affected their interactions with the second task. Group A participants interacted with the Sean-Analysis feedback type first and group B participants interacted with the PedaFeed feedback type first (Figure 8-4).

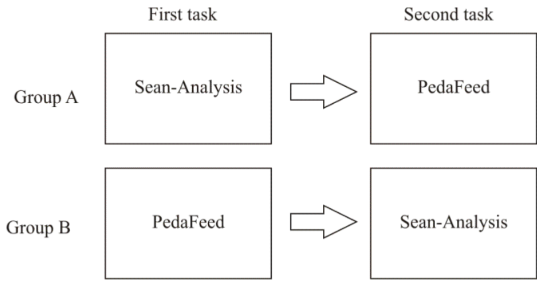

Figure 8-4: Order of interaction

Table 8-4: Multivariate tests

Within Subjects Effect	Statistical Method	Value	F	Hypothesis df	Error df	Sig.
Feedback Type	Pillai's trace	.884	.759	10.00	1.000	.722
	Wilks' lambda	.116	.759	10.00	1.000	.722
	Hotelling's trace	7.589	.759	10.00	1.000	.722
	Roy's largest root	7.589	.759	10.00	1.000	.722
Feedback Type * Order_Interaction	Pillai's trace	.829	.484	10.00	1.000	.819
	Wilks' lambda	.171	.484	10.00	1.000	.819
	Hotelling's trace	4.838	.484	10.00	1.000	.819
	Roy's largest root	4.838	.484	10.00	1.000	.819

Overall, there was no significant interaction between order of interaction and feedback type ($p > 0.05$). There was no significant difference on mean reaction ratings for feedback type, data taken overall ($p > 0.05$).

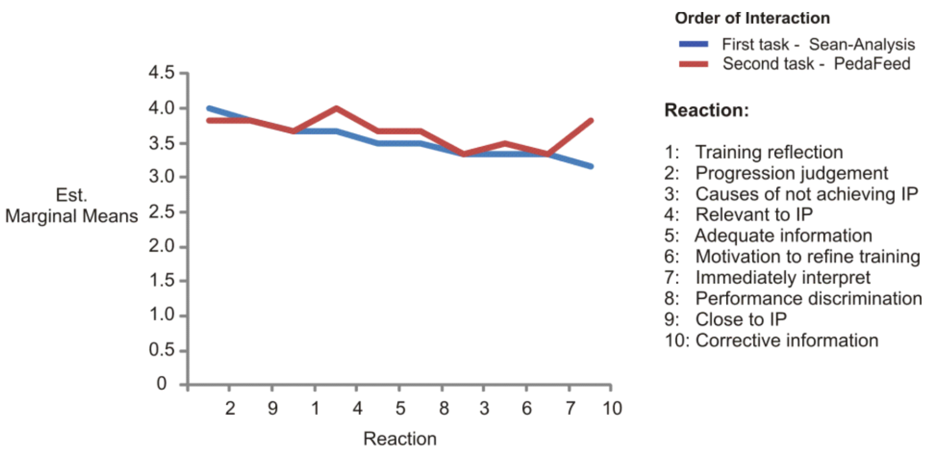

Figure 8-5: Profile plots of mean reaction ratings for Group A

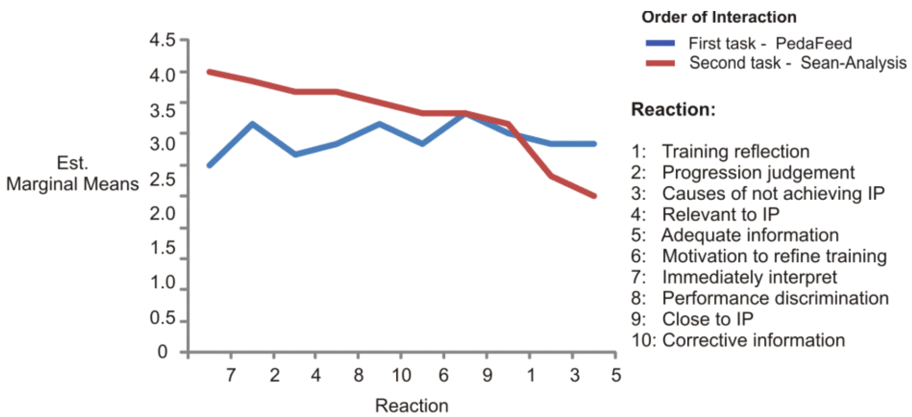

Figure 8-6: Profile plots of mean reaction ratings for Group B

Figure 8-5 and Figure 8-6 present mean reaction ratings for order of interaction between feedback types. Inspection of the profile graphs support the finding of no significant interaction between order of interaction and feedback type.

Results from both experimental aims in Experiment Two support H_0. There is no difference between mean reaction ratings for the Sean-Analysis feedback type and mean reaction ratings for PedaFeed feedback type.

Table 8-5: Correlations

Reaction ratings	**Training reflection**	**Progression judgement**	**Causes of not achieving IP**	**Relevant to IP**	**Adequate information for next training**	**Motivation to refine training**	**Immediately interpret**	**Performance discrimination**	**Close to IP**	**Corrective information**
Training reflection	1	.067	.280	-.275	.085	.399	.198	.000	**.417***	.353
Progression judgement	.067	1	-.059	.066	.299	**.413***	.253	.206	.103	-.030
Causes of not achieving IP	.280	-.059	1	-.162	**.460***	.040	.014	.138	.152	.225
Relevant to IP	-.275	.066	-.162	1	**-.471***	.093	**.462***	.291	-.097	-.216
Adequate information for next training	.085	.299	**.460***	**-.471***	1	.000	-.371	-.078	.000	-.173
Motivation to refine training	.399	**.413***	.040	.093	.000	1	**.415***	.131	.000	.387
Immediately interpret	.198	.253	.014	**.462***	-.371	**.415***	1	.341	.013	.253
Performance discrimination	.000	.206	.138	.291	-.078	.131	.341	1	-.045	.236
Close to IP	**.417***	.103	.152	-.097	.000	.000	.013	-.045	1	.371
Corrective information	.353	-.030	.225	-.216	-.173	.387	.253	.236	.371	1

* Correlation is significant at the 0.05 level (2-tailed)

Table 8-5 provides a matrix of the correlation coefficients for reaction ratings with the data from the two feedback types and order of interaction combined.

Reaction 'training reflection' ratings was significantly correlated with reaction 'close to IP' ratings, $r = 0.417$.

There was a significant relationship between reaction 'progression judgement' ratings and reaction 'motivation to refine training' ratings, $r = 0.413$.

Reaction 'causes of not achieving IP' ratings was significantly correlated with reaction 'adequate information for next training' ratings, r = 0.460, and reaction 'adequate information for next training' ratings was negatively correlated with reaction 'relevant to IP' ratings, r = –0.471.

Reaction 'relevant to IP' ratings was significantly correlated with reaction 'immediately interpret' ratings, r = 0.462.

There was a significant relationship between reaction 'motivation to refine training' ratings and reaction 'immediately interpret' ratings, r = 0.415.

All other correlations were not significant.

To explore the relationships further, a cluster analysis was undertaken.

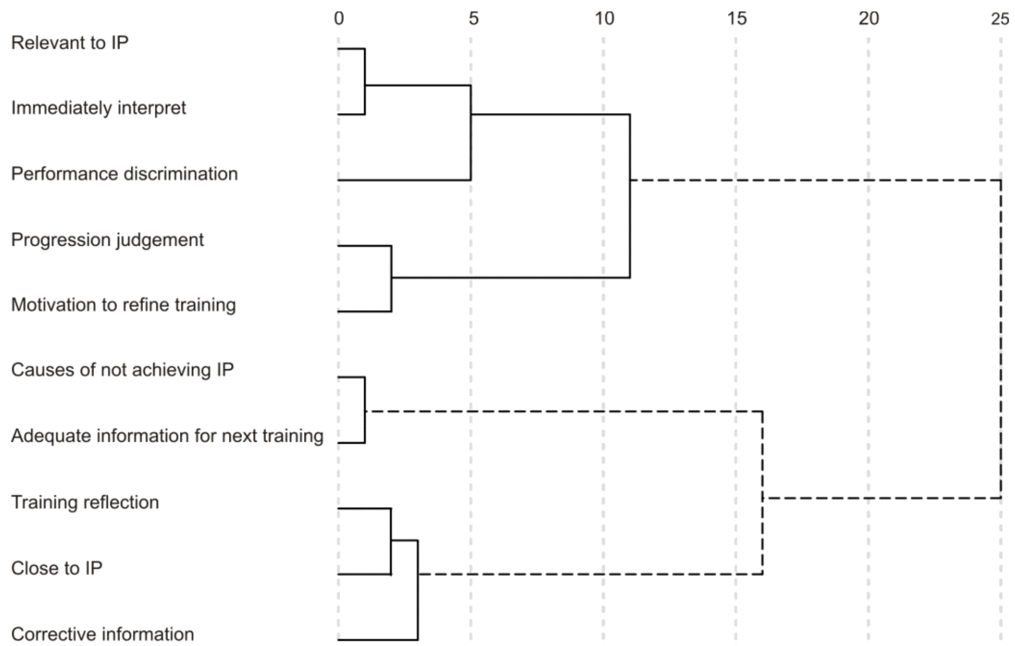

Figure 8-7: Dendrogram of hierarchical cluster analysis

Figure 8-7 provides the cluster analysis of reaction ratings. Ignoring the two final cluster lines shown dashed, there are three clusters. For this data, the cut-off for rendering a cluster line as dashed was taken at a cluster distance > approximately 13. The clusters are:

Cluster one:

- reaction 'relevant to IP' ratings
- reaction 'immediately interpret' ratings

- reaction ‘performance discrimination’ ratings
- reaction ‘progression judgement’ ratings
- reaction ‘motivation to refine training’ ratings

Cluster two:

- reaction ‘causes of not achieving IP’ ratings
- reaction ‘adequate information for next training’ ratings

Cluster three:

- reaction ‘training reflection’ ratings
- reaction ‘close to IP’ ratings
- reaction ‘corrective information’ ratings

8.6 Experiment Three

The experimental aim was to explore differences between the PedaFeed feedback type and Sean-Analysis feedback type when athletes were more familiar with the feedback system. With 4 participants undertaking the experiment (n = 4), reaction was measured in terms of:

- training reflection
- progression judgement
- causes of not achieving IP
- adequate information for next training
- motivation to refine training
- immediately interpret
- performance discrimination
- close to IP
- corrective information

Table 8-6: Multivariate tests

Within Subjects Effect	Statistical Method	Value	F	Hypothesis df	Error df	Sig.
Feedback Type	Pillai's trace	0.833	1.667	3.000	1.000	0.505
	Wilks' lambda	0.167	1.667	3.000	1.000	0.505
	Hotelling's trace	5.000	1.667	3.000	1.000	0.505
	Roy's largest root	5.000	1.667	3.000	1.000	0.505

Table 8-6 shows multivariate tests of mean reaction ratings for feedback type. The results show there was no significant difference on mean reaction ratings for feedback type, data taken together, ($p > 0.05$). Overall, mean reaction ratings for the Sean-Analysis feedback type were not significantly different from those for PedaFeed feedback type.

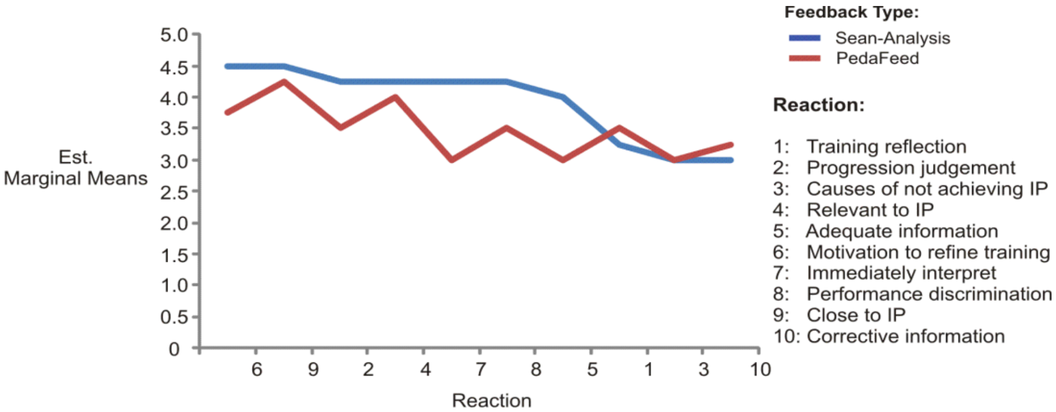

Figure 8-8: Profile plots of mean reaction ratings for feedback type

Figure 8-8 presents the mean reaction ratings for the Sean-Analysis feedback type and for PedaFeed feedback type. The figure provides a clearer picture of the differences, showing mean reaction ratings for Sean-Analysis feedback type as higher for seven out of ten mean reaction ratings, but based on Table 8-6, these were not significant.

Experiment Three supports H_0. There is no difference between mean reaction ratings for the Sean-Analysis feedback type and mean reaction ratings for PedaFeed feedback type.

No correlations were performed because sample size is too small.

8.7 Experiment One, Two, and Three: Data Combined

The aim of combining the data was to explore differences between PedaFeed feedback type and Sean-Analysis feedback type by improving the power of the statistical analysis. With 30 participants in the combined dataset (n = 30), reaction was measured in terms of:

- progression judgement
- causes of not achieving IP
- relevant to IP
- adequate information for next training
- motivation to refine training
- immediately interpret
- performance discrimination

Table 8-7: Multivariate tests

Within Subjects Effect	**Statistical Method**	**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Feedback Type	Pillai's trace	0.491	3.167	7.000	23.000	0.017
	Wilks' lambda	0.509	3.167	7.000	23.000	0.017
	Hotelling's trace	0.964	3.167	7.000	23.000	0.017
	Roy's largest root	0.964	3.167	7.000	23.000	0.017

Table 8-7 shows multivariate tests of mean reaction ratings for feedback type. For these data, the MANOVA statistics reach significance ($p < .05$). This shows there was a significant difference on mean reaction ratings for feedback type, data taken together. Overall, mean reaction ratings for the Sean-Analysis feedback type were significantly different from those for PedaFeed feedback type.

Table 8-8: Univariate tests

Source	Reaction	Statistical method	Type III Sum of Squares	df	Mean Square	F	Sig.
Feedback Type	Progression judgement	Lower-bound	0.267	1	0.267	0.525	0.475
	Causes of not achieving IP	Lower-bound	2.400	1	2.400	2.012	0.167
	Relevant to IP	Lower-bound	0.017	1	0.017	0.019	0.891
	Adequate information for next training	Lower-bound	1.067	1	1.067	0.969	0.333
	Motivation to refine training	Lower-bound	2.400	1	2.400	6.000	0.021
	Immediately interpret	Lower-bound	6.017	1	6.017	9.440	.005
	Performance discrimination	Lower-bound	.000	1	.000	.000	1.000

Table 8-8 shows univariate tests of mean reaction ratings for feedback type. SPSS reports four statistics for each univariate test, corresponding to statistical adjustments to accommodate violations of sphericity. For this data, the adjustments made no difference to the results, and so only the 'Lower-bound' statistics are reported. For these data, reaction 'motivation to refine training' ratings and reaction 'immediately interpret' ratings reach significance ($p < .05$). This shows the differences between mean reaction ratings for the Sean-Analysis feedback type and for PedaFeed feedback type are mainly attributed to reaction 'motivation to refine training' ratings and 'immediately interpret' ratings.

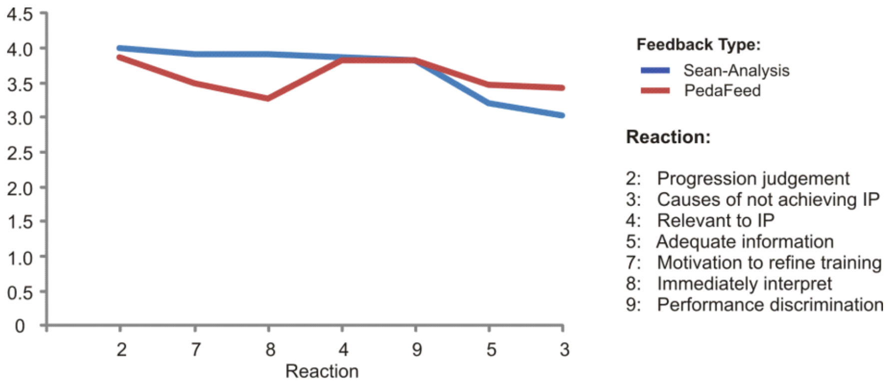

Figure 8-9: Profile plots of mean reaction ratings for feedback type

Figure 8-9 presents the mean reaction ratings for the Sean-Analysis feedback type and for PedaFeed feedback type. The differences were significantly highest in reaction 'motivation to refine training' ratings and reaction 'immediately interpret' ratings. Overall, mean reaction ratings for the Sean-Analysis feedback type was significantly higher than those for PedaFeed feedback type.

Results from combining the data support H_A and reject H_0. There is a difference between mean reaction ratings for the Sean-Analysis feedback type and for PedaFeed feedback type.

Table 8-9: Correlations

Reaction	Progression judgment	Causes of not achieving IP	Relevant to IP	Adequate information for next training	Motivation to refine raining	Immediately interpret	Performance discrimination
Progression judgment	1	**.260***	**.372***	**.314***	.230	**.312***	**.472***
Causes of not achieving IP	**.260***	1	**.379***	**.605***	.165	**.279***	**.418***
Relevant to IP	**.372***	**.379***	1	.215	**.263***	**.362***	**.550***
Adequate information for next training	**.314***	**.605***	.215	1	**.313***	.114	**.419***
Motivation to refine training	.230	.165	**.263***	**.313***	1	**.380***	**.325***
Immediately interpret	**.312***	**.279***	**.362***	.114	**.380***	1	**.381***
Performance discrimination	**.472***	**.418***	**.550***	**.419***	**.325***	**.381***	1

* Correlation is significant at the 0.05 level (2-tailed)

Table 8-9 provides a matrix of the correlation coefficients for reaction ratings with the data from the two feedback types combined.

Reaction ‘progression judgement was significantly correlated with:

- reaction ‘causes of not achieving IP’ ratings, r = 0.260
- reaction ‘relevant to IP’ ratings, r = 0.372
- reaction ‘adequate information for next training’ ratings, r = 0.314

Reaction ‘causes of not achieving IP’ ratings was correlated with reaction ‘relevant to IP’ ratings, r = 0.379, reaction ‘adequate information for next training’ ratings, r = 0.605, and also reaction ‘relevant to IP’ ratings was correlated with reaction ‘motivation to refine training’ ratings, r = 0.263.

Reaction ‘adequate information for next training’ ratings was significantly correlated with reaction ‘motivation to refine training’ ratings, r = 0.313.

There was a significant relation between reaction ‘immediately interpret’ ratings and:

- reaction ‘progression judgement’ ratings, r = 0.312
- reaction ‘causes of not achieving IP’ ratings, r = 0.279
- reaction ‘relevant to IP’ ratings, r = 0.362

- reaction ‘motivation to refine training’ ratings, r = 0.380

Reaction ‘performance discrimination’ ratings was significantly correlated with:

- reaction ‘progression judgement’ ratings, r = 0.472
- reaction ‘causes of not achieving IP’ ratings, r = 0.418
- reaction ‘relevant to IP’ ratings, r = 0.550
- reaction ‘adequate information for next training’ ratings, r = 0.419
- reaction ‘motivation to refine training’ ratings, r = 0.325
- reaction ‘immediately interpret’ ratings, r = 0.381

All other correlations were not significant.

To explore the relationships further, a cluster analysis was undertaken.

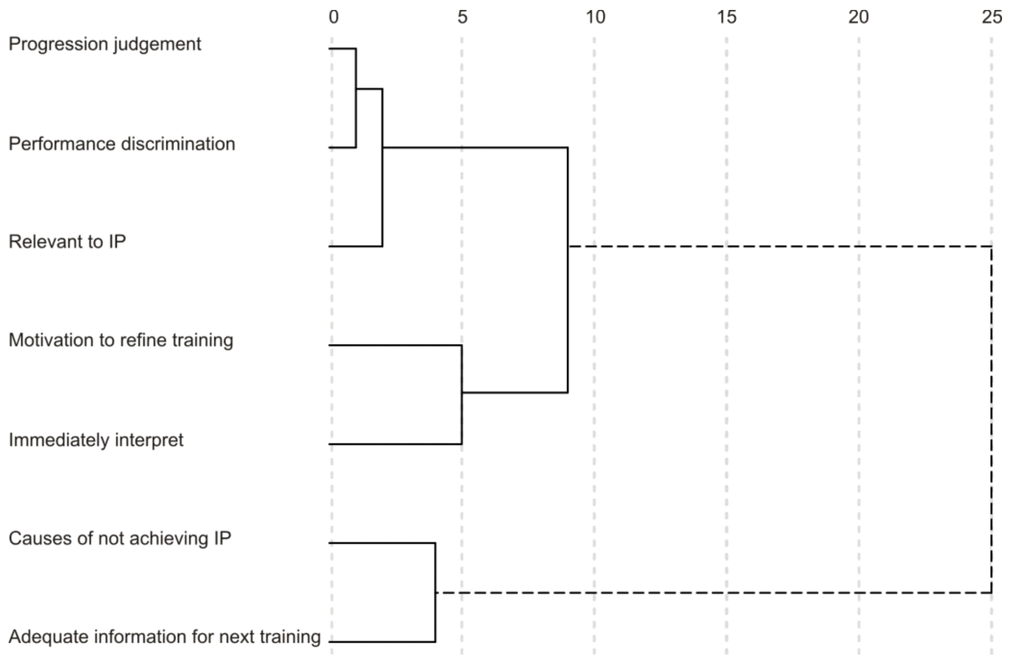

Figure 8-10: Dendrogram of hierarchical cluster analysis

Figure 8-10 provides the cluster analysis of reaction ratings. Ignoring the final cluster line shown dashed, the clusters are:

Cluster one:

- reaction ‘progression judgement’ ratings
- reaction ‘performance discrimination’ ratings
- reaction ‘relevant to IP’ ratings
- reaction ‘motivation to refine training’ ratings
- reaction ‘immediately interpret’ ratings

Cluster two:

- reaction ‘ causes of not achieving IP’ ratings
- reaction ‘adequate information for next training’ ratings

8.8 Experiment Four

The aim of the experiment was to explore differences between the PedaFeed feedback type and Sean-Analysis feedback type in supporting an athlete’s self-assessment of their achieved performance. With 8 participants undertaking the experiment (n = 8), reaction was measured in terms of:

- identify and target technique
- verified achievement of IP
- track capability level
- ensured each technique is mastered
- adequate information on the set of techniques
- clear information
- diagnose failure of IP
- encouraged self-regulated learning

For this experiment two MANOVA tests were performed due to an insufficient degree of freedom. This is because there were eight dependent variables and eight participants in this study that gives insufficient degree of freedom for the error terms. The data were divided into two parts.

The first part consisted of the first four reaction items:

- identify and target technique
- verified achievement of IP
- track capability level
- ensured each technique is mastered

The second part consisted of the second four reaction items:

- adequate information on the set of techniques
- clear information
- diagnose failure of IP
- encouraged self-regulated learning

Table 8-10: Multivariate tests for first part of the data

Between Subjects Effect	Statistical Method	Value	F	Hypothesis df	Error df	Sig.
Feedback Type	Pillai's trace	.994	157.857	4.000	4.000	.000
	Wilks' lambda	.006	157.857	4.000	4.000	.000
	Hotelling's trace	157.857	157.857	4.000	4.000	.000
	Roy's largest root	157.857	157.857	4.000	4.000	.000

Table 8-10 shows multivariate tests for first part of mean reaction ratings on the feedback type. For these data, the MANOVA test statistics reach significance where ($p < .001$). This shows, there was a significant difference on mean reaction ratings for feedback type, data taken together. Overall, the mean reaction ratings for Sean-Analysis feedback type was highly significantly different from those for PedaFeed feedback type.

Table 8-11: Univariate tests for first part of the data

Source	Reaction	Statistical method	Type III Sum of Squares	df	Mean Square	F	Sig.
Feedback Type	Identify and target technique	Lower-bound	1.000	1	1.000	7.000	.033
	Verified achievement of IP	Lower-bound	.250	1	.250	1.000	.351
	Track capability level	Lower-bound	.063	1	1.000	1.000	.351
	Ensured each technique is mastered	Lower-bound	1.563	1	1.563	11.667	.011

Table 8-11 shows univariate tests of mean reaction ratings for feedback type. For these data, reaction 'identify and target technique' ratings, and reaction 'ensured each technique is mastered' ratings reach significance ($p < .05$). This shows the differences for the first part of mean reaction ratings for the Sean-Analysis feedback type and for PedaFeed feedback type are mainly attributed to reaction 'identify and target technique' ratings, and reaction 'ensured each technique is mastered' ratings

Table 8-12: Multivariate tests for second part of the data

Within Subjects Effect	Statistical Method	Value	F	Hypothesis df	Error df	Sig.
Feedback Type	Pillai's trace	.987	77.667	4.000	4.000	.000
	Wilks' lambda	.013	77.667	4.000	4.000	.000
	Hotelling's trace	77.667	77.667	4.000	4.000	.000

Table 8-12 shows multivariate test for second part of mean reaction ratings on the feedback type. For these data, the MANOVA test statistics reach significance where (p < .001). This shows there was a significance difference on mean reaction ratings for feedback type, data taken together. Overall, the mean reaction ratings for Sean-Analysis feedback type was highly significantly difference from those for PedaFeed feedback type.

Table 8-13: Univariate tests for second part of the data

Source	Reaction	Statistical method	Type III Sum of Squares	df	Mean Square	F	Sig.
Feedback Type	Adequate information on the set of techniques	Lower-bound	1.000	1	1.000	7.000	.033
	Clear information	Lower-bound	2.250	1	2.250	21.000	.003
	Diagnose failure of IP	Lower-bound	1.563	1	1.563	11.667	.011
	Encouraged self-regulated learning	Lower-bound	.562	1	.562	4.200	.080

Table 8-13 shows univariate tests of mean reaction ratings for feedback type. For these data, reaction 'adequate information on the set of techniques', reaction 'clear information' ratings, and reaction 'diagnose failure of IP' ratings reach significance (p < .05). This shows the differences for the second part of mean reaction ratings for the Sean-Analysis feedback type and for PedaFeed feedback type are mainly attributed to reaction 'adequate information on the set of techniques', reaction 'clear information' ratings, and reaction 'diagnose failure of IP' ratings.

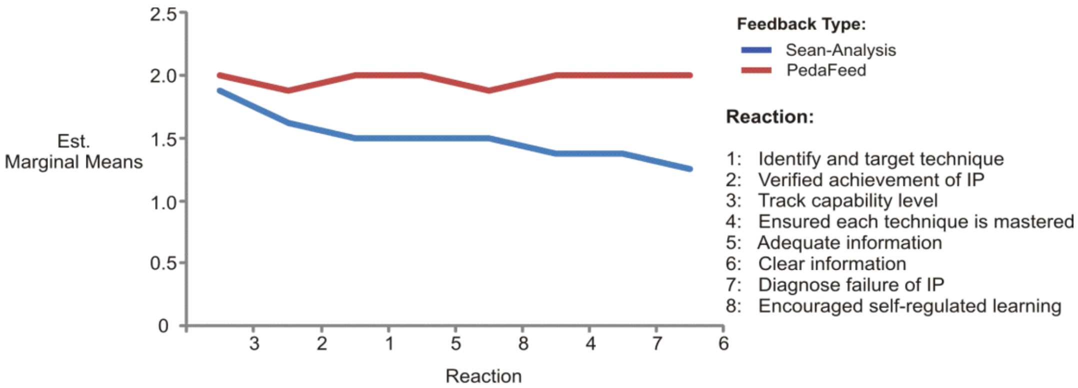

Figure 8-11: Profile plots of mean reaction ratings for feedback type

Figure 8-11 presents the mean reaction ratings for the Sean-Analysis feedback type and for PedaFeed feedback type. Inspection of the profile graph supports the findings that there is a significant difference in mean reaction ratings for Sean-Analysis feedback type and PedaFeed feedback type. Overall, mean reaction ratings for PedaFeed feedback type was significantly higher than mean reaction ratings for Sean-Analysis feedback type.

Experiment Four supports H_A. There is a difference between mean reaction ratings for the Sean-Analysis feedback type and for PedaFeed feedback type.

Table 8-14: Correlations

Reaction	**Identify and target technique**	**Verified achievement of IP**	**Track capability level**	**Ensured each technique is mastered**	**Adequate information on the set of techniques**	**Clear information on what must be able to do**	**Diagnose failure of IP**	**Encouraged self-regulated learning**
Identify and target technique	1	**.667***	.447	**.545***	**1.000***	**.745***	**.856***	**.856***
Verified achievement of IP	**.667***	1	.447	.234	**.667***	.447	**.545***	**.545***
Track capability level	.447	.447	1	.383	.447	.333	.383	.383
Ensured each technique is mastered	**.545**	.234	.383	1	**.545***	**.592***	**.709***	.418
Adequate information on the set of techniques	**1.000***	**.667***	.447	**.545***	1	**.745***	**.856***	**.856***
Clear information on what must be able to do	**.745***	.447	.333	**.592***	**.745***	1	**.870***	**.592***
Diagnose failure of IP	**.856***	**.545***	.383	**.709***	**.856***	**.870***	1	**.709***
Encouraged self-regulated learning	**.856***	**.545***	.383	.418	**.856***	**.592***	**.709***	1

* Correlation is significant at the 0.05 level (2-tailed)

Table 8-14 provides a matrix of the correlation coefficients for reaction ratings with the data from two feedback types combined.

There was a significant relationship between reaction ‘identify and target technique’ ratings with reaction ‘verified achievement of IP’ ratings, r = 0.667, and reaction ‘ensured each technique is mastered’ ratings, r = 0.545, and reaction ‘verified achievement of IP’ ratings was also correlated with reaction ‘adequate information on the set of techniques’ ratings, r = 0.667.

Reaction ‘identify and target technique’ ratings was perfectly correlated with reaction ‘verified achievement of IP’ ratings, r = 1.000.

Reaction ‘clear information on what must be able to do’ ratings was correlated with reaction ‘identify and target technique’ ratings, r = 0.745, reaction ‘ensured each technique is mastered’ ratings, r = 0.592, and reaction ‘adequate information on the set of techniques’ ratings, r = 0.745.

Reaction ‘diagnose failure of IP’ ratings was significantly correlated with:

- reaction ‘identify and target technique’ ratings, $r = 0.856$
- reaction ‘verified achievement of IP’ ratings, $r = 0.545$
- reaction ‘ensured each technique is mastered’ ratings, $r = 0.709$
- reaction ‘adequate information on the set of techniques’ ratings, $r = 0.856$
- reaction ‘clear information on what must be able to’ ratings, $r = 0.870$

There was a significant relationship between reaction ‘encouraged self-regulated learning’ ratings and:

- reaction ‘identify and target technique’ ratings, $r = 0.856$
- reaction ‘verified achievement of IP’ ratings, $r = 0.545$
- reaction ‘adequate information on the set of techniques’ ratings, $r = 0.856$
- reaction ‘clear information on what must be able to do’ ratings, $r = 0.592$
- reaction ‘diagnose failure of IP’ ratings, $r = 0.709$

All other correlations are not significant.

To explore these relationships further, a cluster analysis was undertaken.

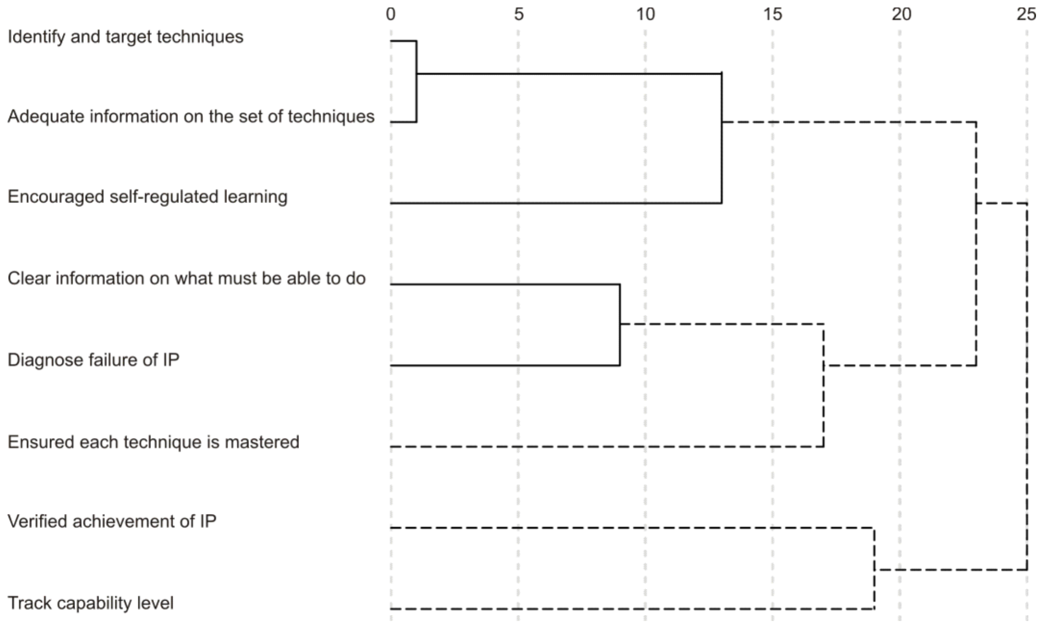

Figure 8-12: Dendrogram of hierarchical cluster analysis

Figure 8-12 provides the cluster analysis of reaction ratings. Ignoring the four final cluster lines shown dashed, the clusters are:

Cluster one:

- reaction 'identify and target technique' ratings
- reaction 'adequate information on the set of techniques' ratings
- reaction 'encouraged self-regulated learning' ratings

Cluster two:

- reaction 'clear information on what must be able to do' ratings
- reaction 'diagnose failure of IP' ratings

8.9 Summary

This chapter presented the experimental results and analysed the differences between mean reaction ratings for the Sean-Analysis feedback type and mean reaction ratings for PedaFeed feedback type. The combination data of Experiments One, Two and Three, and Experiment Four rejected the null hypothesis (H_0) and accepted the alternative hypothesis (H_A). There is a difference between mean reaction ratings for the Sean-Analysis feedback type and mean reaction ratings for PedaFeed feedback type. Sean-Analysis feedback type was better than PedaFeed feedback type in the combination experiment, PedaFeed feedback type however was better in Experiment Four.

All other experimental results support the null hypothesis (H_0), and determined that there is no difference between mean reaction ratings for the Sean-Analysis feedback type and mean reaction ratings for PedaFeed feedback type.

The following chapter discusses these results.

Chapter 9

Discussion of Results

9.1 Introduction

This chapter discusses the results for each experiment as presented in Chapter 8. The justification of each experiment is presented in relation to the experimental results.

9.2 Overview Discussion of Experiments

This section overviews the experiments in relation to the research questions articulated in Section 7.4. In general, the overall results show that the PedaFeed feedback type was at least as valuable as the Sean-Analysis feedback type as measured by the level of satisfaction and the level of acceptability expressed by the athletes.

Overall, the experimental results for Experiment One, Two, Three, considered separately, show that there is no difference between the Sean-Analysis feedback type and the PedaFeed feedback type in the reaction ratings of the athletes.

When the datasets of Experiment One, Two, and Three are combined, overall experimental results show a siginificant difference in that athletes can immediately interpret information generated by the Sean-Analysis feedback type that allows them to be motivated in refining their training. This supports the findings of Furnborough & Truman (2009) that the ability of learners to interpret and use feedback can sustain their motivation. This point suggests that for future work athletes should be trained more in how to interpret feedback generated by the PedaFeed feedback type and how they can make connections between the feedback they receive and their training (Sadler, 1998). This would allow athletes to be more satisfied and to more easily accept PedaFeed feedback type as compared to Sean-Analysis feedback type.

Experiment Four suggests that the PedaFeed feedback type allows the athletes to control their own training by helping them monitor, judge, and critically assess and correct their performance. In turn, this suggests that the PedaFeed feedback type supports the conceptual model underpinning feedback that is based on developing learner self-regulation (Nicol & Macfarlane-Dick, 2006).

In each of experiments One and Two, and for the combined datasets of Experiment One, Two, and Three, correlations suggest that athletes will be motivated to refine their training if they can immediately interpret the information and they can judge the progression of their performance, while Experiment Four suggests that feedback provides adequate information on the set of techniques and clear information on what must be done to allow the athletes to identify and target techniques, diagnose failure of intended performance, and thus encourage self-regulated learning. These will be discussed in more detail in each of the experiment.

9.3 Experiment One

The aim of this experiment was to explore differences in reaction ratings between the PedaFeed feedback type and Sean-Analysis feedback type.

The results indicated that athletes were satisfied with the feedback generated from the Sean-Analysis feedback type and PedaFeed feedback type. Both feedback types were acceptable in athletes' training and overall showed no significant difference. This suggests that the Sean-Analysis feedback type and PedaFeed feedback type enable athletes to plot their progress and highlight areas of improvement. Both feedback types seemed able to generate feedback that was consistent with the athletes' intended training outcomes.

In exploring the data, the largest difference between the two feedback types was found, for the reaction 'motivation to refine training' ratings, though this only reached *p* = 0.088 (Table A7-0-4). Nevertheless, along with other data, this moderate finding was used to inform Experiment Two.

The dendrogram analysis associated reaction ‘relevant to IP’, ‘information satisfaction’, ‘progression judgement’, ‘performance discrimination’, ‘information to achieve IP’, ‘causes of not achieving IP’, and ‘adequate information for next training’. This indicates that athletes are motivated to refine their training when they are provided with sufficient information for the next training. This supports the findings of Romiszowski (1999) that feedback is more effective in promoting learning when it transmits more complete information. This finding suggests that feedback consisting of training outcomes will give clear guidance to athletes on their performance. Such feedback will allow athletes to identify the information that they should use the for the next training activity.

This analysis suggests the need to explore the athlete’s positioning within their level of achieved performance. The athlete needs supportive information in order to self-determine their position, to self-regulate their training path, and to adjust their performance to their intended training outcome. Such positioning will determine the athlete’s achieved performance and recommend remedial actions that will be discussed in the next experiment.

Findings from univariate tests and dendrogram analysis suggest that athletes need to immediately interpret their positioning within the achieved performance to allow them to judge their performance progression. For the next experiment, the user interface was changed to enable athletes to interpret their positioning immediately and identify what they should do for the next training activity.

From the dendrogram, ‘prefer numerical scores’ was not associated with other reaction ratings. The findings suggest that the feedback of numerical scores does not itself assist athletes to achieve their intended training outcomes. Thus, the provision of numerical scores was not considered in the following experiment.

9.4 Experiment Two

The experiment was conducted following on from the findings of Experiment One, where the aims were to further investigate differences between feedback types as a function of supporting positioning and of presentation order.

For the first aim of the experiment, the results indicated that athletes were satisfied with the feedback provided by the Sean-Analysis feedback type and PedaFeed feedback type. Both feedback types were acceptable to support athletes' positioning within their level of achieved performance and there was no significant difference overall between the two feedback types.

In exploring the data, differences between the two feedback types were found for 'progression judgement' and 'immediately interpret' ratings where each rating reached $p = .054$ and $p = .021$ respectively (Table A10-0-9). Nevertheless, along with other data, this moderate finding was used to inform Experiment Three.

For the second aim, the results also indicated that presentation of feedback type had no significant effect. The results suggest that the following experiments would not need to consider the order of presentation as an independent variable but simply to control it using counterbalanced presentation.

Athletes who rated 'causes of not achieving IP' also rated 'adequate information for next training'. The dendrogram analysis associated both reaction ratings. This indicates that information on the next training activities should support the athletes' intended training outcomes. Athletes who rated 'training reflection' also rated 'close to IP'. The dendrogram analysis associated both reaction ratings with 'corrective information ratings'. This analysis suggests that corrective information given for the athletes should be closed to the intended training outcomes, thus the athletes would be able to perform reflecting what is being taught by the coach.

Athletes associated 'immediately interpret' with 'relevant to IP'. This result suggests that the athletes are much more likely to be able to immediately interpret the feedback if the feedback is relevant to their intended training outcomes. The dendrogram also showed 'immediately interpret' and 'relevant to IP' were associated with 'performance discrimination', 'progression judgement', and 'motivation to refine training'. The dendrogram analysis suggests that athletes should be familiar with the intended training outcome concept. If so, they will be able to immediately interpret the information and thus be able to determine their performance, judge their performance progression, and become motivated to refine their training.

Univariate tests and dendrogram analysis suggest the need to explore athletes' familiarity on the feedback type. The following experiment will consider giving the athletes training to allow them to be able to immediately interpret information generated by the PedaFeed feedback type.

9.5 Experiment Three

Based on the findings suggested by Experiment Two, the aim of this experiment was to explore differences between the PedaFeed feedback type and Sean-Analysis feedback type when athletes are more familiar with the feedback system.

The results of this study reveal that athletes were satisfied and can accept the Sean-Analysis feedback type and PedaFeed feedback type in their training, with no significant difference between the two feedback types.

In exploring the data, the differences between two feedback types was found, for the 'progression judgement' and 'motivation to refine training', though this was only close to a significant value, $p = .058$ respectively (Table A15-0-13). Nevertheless, along with other data, this moderate finding was used to inform Experiment Four.

Univariate tests suggest that the familiarisation had an effect on the athletes' motivation as they realised what things they are able to do in judging the progression of their performance. These results suggest that the level of familiarity encouraged the athletes to explore the feedback system to see how it could effectively support them in identifying their performance gap to enhance their skill acquisition. The familiarity of athletes with the feedback type therefore fostered the athletes' self-assessment in developing their skill to achieve training outcomes (Louys, Hernandez-Leo, D., Perez-Sanagustin, & Schoonenboom, 2009). This suggested that the following experiments explore the athlete's self-assessment of their achieved performance.

9.6 Experiment One, Two, and Three: Data Combined

Based on findings from Experiment One, Two, and Three, the same questions from Experiment One, Experiment Two, and Experiment Three were combined to explore the differences between the Sean-Analysis feedback type and PedaFeed feedback type to improve the power of the statistical analysis.

The results indicated that there is a significant difference between the Sean-Analysis feedback type and PedaFeed feedback type. The univariate tests showed differences between the feedback types on 'motivation to refine training' and 'immediately interpret'. The profile graph shows the Sean-Analysis feedback type was rated higher for both reactions, indicating that the athletes were more satisfied with the Sean-Analysis feedback type compared with PedaFeed feedback type.

The dendrogram also associated 'motivation to refine training' and 'immediately interpret'. Additionally these two ratings clustered with 'progression judgement', 'performance discrimination', and 'relevant to IP'. This point suggests that the motivation to refine training depends on the ability of athletes to immediately interpret the feedback. This indicates that the immediately interpreted feedback appears to be the central issue in generating good feedback. Such feedback has the possibility of affecting the athletes' training activity.

In Experiment Two, 'immediately interpret' was highly correlated with 'relevant to IP'. In this combined dataset, both reactions were also correlated. This point indicates that athletes should immediately interpret information that is related to their intended training outcomes. This finding suggests that achievement of intended training outcomes that can be immediately interpreted has positive effects on motivation of athletes.

These results suggested that the template and interface in displaying achieved performance for the PedaFeed feedback type should be changed. Such changes would help athletes to immediately interpret the information provided for them. These changes would be considered in future work.

9.7 Experiment Four

Based on the findings from Experiment Three and the combined dataset of Experiment One, Two, and Three, the questionnaire was changed to explore differences between the PedaFeed feedback type and Sean-Analysis feedback type in supporting the athlete's self-assessment of their achieved performance.

The results indicated that there is a significant difference between the Sean-Analysis feedback type and PedaFeed feedback type. The univariate tests show the differences between Sean-Analysis feedback type and PedaFeed feedback type attributed from 'identify and target techniques', 'ensured each technique is mastered', 'adequate information on the set of techniques', 'clear information on what must be able to do', and 'diagnose failure of IP'. The profile graph shows all mean reaction ratings for PedaFeed feedback type are higher than Sean-Analysis feedback type, in particular PedaFeed feedback type is better than SeanAnalysis feedback type.

Reaction 'identify and target technique' was highly correlated with 'adequate information on the set of techniques'. The dendrogram associated 'identify and target techniques' and 'adequate information on the set of techniques' with 'encouraged self-regulated learning'. It shows that athletes are better encouraged in self-regulated learning if the feedback system provides adequate information on the set of techniques they have to perform and they are able to identify and target the techniques. The dendrogram also associated 'clear information on what must be able to do' with 'diagnose failure of IP'. This suggests that feedback should provides clear information on the diagnosed failure of their training outcomes that allows the athletes to perform accurately in achieving the intended training outcomes.

As the training path was planned by the coaches, athletes felt in control of their own training. This suggests that the PedaFeed feedback type offers the possibility of helping athletes establish self-efficacy on their training paths and they will be more aware of their own competence in attaining the intended training outcomes. Thus, the PedaFeed feedback type is able to support the function of self-assessment, where self-assessment is defined as an evaluation of one's performance, and the identification of strengths and weakness of the performance with the aim of improving intended training outcomes (Miao, Boon, Van der Klink, Sloep, & Koper, 2009).

9.8 Summary

The experiments have shown the effectiveness of PedaFeed feedback type for the implementation of CBST. Overall results show that PedaFeed feedback type was at least as valuable as the Sean-Analysis feedback type measured by level of satisfaction and level of acceptability by the athlete. The results show that PedaFeed feedback type was more valuable than Sean-Analysis feedback type in terms of encouraging self-assessment of athletes' achieved performance.

The following chapter presents the contributions and future work following this study.

Chapter 10

Contributions and Future Work

10.1 Introduction

This chapter presents the closing remarks of this thesis. The chapter first provides the contributions of the thesis. Finally, the chapter highlights the possible directions for future work.

10.2 Research Contributions

This thesis has explored the design of effective feedback in the motor skill domain through CBST in order to support athletes' achievement of their intended training outcomes. The thesis has suggested that we must start from 'what it takes to learn,' using all we know from learning theories and instructional design, to construct pedagogically designed effective feedback in the motor skill domain with which to provide an effective and efficient CBST. Overall, the experimental results support the research hypothesis, in which 'properly structured pedagogically designed feedback in the motor skill domain allows the generation of effective feedback in CBST'. This supports the conclusion that pedagogical feedback in the motor skill domain is able to provide an excellent pedagogical solution for skill acquisition and performance enhancement of the athletes in CBST, particularly in the context of rowing.

Within this, the key contributions are:

1. Framework for pedagogical feedback
2. Machine-processable representation of training outcomes
3. Algorithms for generating feedback
4. Structured feedback

10.2.1 Framework for Pedagogical Feedback

The integration of learning transactions, competency, cybernetics, and behaviourism into the framework supports the generation of effective feedback. The framework addresses the limitations of current feedback in CBST which focuses on technology rather than pedagogy. The implementation of the framework illustrates an appropriate integration of learning technologies with teaching and learning practice.

The framework provides an architecture where both coaches and athletes may be engaged and involved in generating feedback on performance. Coaches can use this information to modify the training strategies of the athletes in developing their skill. Thus, this framework facilitates effective and efficient teaching and learning processes in CBST applications. The section on Future Work discusses some details of how the framework might provide feedback for coaches in addition to its current provision for athletes.

In supporting the processing, presentation, and recording of feedback, and in supporting the development of an athletes' competence in their achievement of training outcomes, the framework supports integration and articulation with an athlete's portfolio of achievement. A portfolio can be conceptualized as collections of artefacts articulating learners' experiences, achievements, and learning (Gray, 2008). The development of a portfolio allows athletes to monitor and track the progress of their performance and also helps coaches to design better coaching activities for the athletes in achieving the training outcomes. The section on Future Work discusses some details of how the framework might enhance the development of portfolios in offering effective and efficient teaching and learning activities in CBST.

10.2.2 Machine-processable Representation of Training Outcomes

Modelling a domain, a process, or data is a common way of understanding it (Bailey, Zalfan, Davis, Fill, & Conole, 2006). The purpose of modelling is simplification, so that the domain is easier to understand. Often, models are mathematical because they are predictable and repeatable. There are many teaching and learning theories such as behaviourism, cognitivisim, constructivism, and cybernetics. Modelling and validating these theories is problematic because of their inherent aspect of ambiguity and lack of repeatability. This thesis constructed a model of a major aspect of teaching and learning that is machine-processable. This provides repeatable, realistic, less ambiguous, and deterministic results for testing and validating. A machine-processable representation may be expect to be able to validate such models to better understand teaching and learning situations.

Learning and training outcomes are at the heart of teaching and learning activities. This research provides machine-processable representations of training outcomes and statements of competency. The syntax and notation of training outcomes are defined explicitly so that they can be interpreted, instantiated, and automated by a machine. This allows the testing and validation of teaching and learning models which incorporate intended learning or training outcomes, skills, educational objectives, or competency statements as defined in this thesis.

The training outcomes have been expressed as a series of UML models, from which several bindings may be generated automatically. An XML schema can be derived that keeps the model in the tag-names, though other bindings (RDF Schema/OWL, Topic Maps, SGML schemas, relational database schemas) could in principle be generated as well. Thus a competency statement, which can be read, processed, and interpreted by machine, allows advanced algorithm for generating effective feedback, and offers the possibility of a semantic structure for further processing. This is discussed in detail in the section on Future Work under the heading of semantic feedback.

10.2.3 Algorithms for Generating Feedback

The algorithms for generating effective feedback are based on traversing the competency network. The competency network is a simply connected, directed acyclical graph, composed of a set of nodes that represent the skills to be acquired and connected by means of arrows that indicate the tasks to be performed to reach the intended training outcomes. The human readable representation of the competency network provides a common interoperable representation of training flows.

The algorithms demonstrate the potential for flexibility in supporting different pedagogical approaches, and minimum redesign effort in order to be used and re-used in different domains. Future Work will consider the development of better algorithm for feedback.

10.2.4 Structured Feedback

A skill is broken down into a series of task competencies or skill-levels, and each of these is specified as a training outcome. These will typically be identified, and the levels specified, through a detailed analysis. Each skill component will be practised by the athlete until a required competence is attained. Ideally, this practice will take place in a training environment where detailed feedback is given, allowing the athlete to reach the required competence as efficiently as possible.

The structured feedback of the PedaFeed system allows pedagogically informed, personalised, adaptive competency testing and the identification of individual learning paths. These paths, and the feedback content, suggest to the athlete where to start, what is next, what needs to be done, what needs to be known, and where the athlete is currently positioned in the competency structure.

10.3 Future Work

There are a number of suggestions for future work:

1. Provide feedback to coaches
2. Develop athlete’s portfolio

3. Develop semantic feedback
4. Develop better algorithms for feedback
5. Develop the competence structure to enhance feedback
6. Improve the quality of recommendations for future training
7. Improve the implementation of pedagogical feedback
8. Integration of Open Learner Model approach

10.3.1 Provide Feedback to Coaches

This thesis focuses on feedback for athletes. Future work could develop feedback for coaches allowing them to provide better pedagogical support to athletes (Miao, Van der Klink, Boon, Sloep, & Koper, 2009). Such feedback could provide opportunities for coaches to collaborate more directly with their athletes, and could provide for the incorporation of a constructivist approach to training. This may help coaches to learn and develop themselves to better understanding the nature of coaching activities.

The framework supports athletes in their training by providing precisely appropriate feedback. Providing feedback of an athlete to the coach in turn allows the coach to modify and adjust their training strategies to reflect the current competence level of their athlete. The resulting interaction and collaboration between coaches and athletes may well allow athletes to better achieve their intended training outcomes, and be more motivated to perform their training activities.

10.3.2 Develop Athlete's Portfolio

CBST should support an athlete's portfolio by supporting the storage, organization, and sharing of their achievements. Future work could focus on developing athletes' portfolio, where all kinds of the athlete's achievement are linked to better expressions of intended training outcomes (Berlanga, Sloep, Brouns, Bitter-Rijpkema, & Koper, 2008).

Documentation of achievement and self-reflection on the training process are the main reasons athletes use portfolios in training activities and competence development. From the pedagogical point of view, the processes can help athletes better understand how they learn and become better self-directed athletes. Enhancing a portfolio with more detailed training outcomes and with more specific and targetted feedback could improve athletes' performance and development.

10.3.3 Develop Semantic Feedback

Semantic technologies have emerged as a paradigm in teaching-learning activities as it aims at giving information a well-defined meaning and better enabling human and machine to work together (Berners-Lee, Hendler, & Lassila, 2001) through ontologies. Ontologies provide a controlled vocabulary of concepts, where each concept comes with explicitly defined and machine-processable semantics (Gašević, Jovanović, & Devedžić, 2007). Future work could then integrate and coordinate the use of ontologies to develop semantic feedback that will maximize reusability and maintain the compatibility of feedback with other systems and environments.

In this thesis, feedback generated based upon a competence model that represented in Microsoft Access database. To achieve semantic interoperability and increase the level of reusability of feedback, competence could be represented as ontology that will explicitly defined, structured, and shared conceptualization of the competence. By providing a shareable ways for representing competence, help both human and machine to communicate easily in comparing competence to support the exchange of semantic feedback.

10.3.4 Develop Better Algorithms for Feedback

Future work could improve current algorithms by integrating machine learning and data mining algorithms to generate more effective feedback for athletes. Machine learning could be used to analyse the patterns of athletes' performance within their current performance and their portfolio and give improved structures of achieved performance. Data mining algorithms could improve the structures by further developing the classification of achieved performance. The system could then compare the classification with the required competence. This will allow athletes to avoid information overload since the system delivers more personalised feedback that better matches their required and acquired competence.

In addition, the system could also be developed to classify competence as ‘required’ or ‘optional’. Feedback will then be generated to indicate which competence is optional for them to perform in achieving their required competence. By this, athletes more focus more specifically and more exactly where improvements are needed.

Currently task analysis only implements a sequential workflow. In many teaching and learning situations, task analysis ideally requires parallel workflows, especially in the motor skill domain. Future work could incorporate parallel workflows into task analysis and make provision for feedback in parallel workflow situations. Feedback would not only inform the athlete of the sequences of enabling competences that they should perform to achieve their required competence, but could also inform them of parallel competences that they could perform to achieve their required performance. This could allow the athletes to better know their techniques and tactics and to perform more accurately.

10.3.5 Develop the Competence Structure to Enhance Feedback

The competence model discussed in this thesis conceptually abstracted intended training outcomes and context so that feedback can be shared and reused across instructional contexts and domains. The process of comparing required and acquired competences implemented in this thesis, however, only focused on the intended training outcomes. Future work could capture information about the context along with the intended training outcomes in comparing competences to enhance effective feedback.

Context governs how feedback can be structured into a flow of interaction for an athlete in accordance with the tools, situations, etc (Jovanović, Gašević, Knight, & Richards, 2006). The feedback will then contain context information since the training outcomes annotations will be dependent on the context. For example, during the runtime a query specifying the features of the current training context can be sent to the competence database in order to identify training outcomes representing similar training contexts and from them infer the most suitable feedback for the athletes. Thus, by capturing and explicitly representing context into feedback provides a solid ground for an athlete’s personalisation.

10.3.6 Improve the Quality of Recommendations for Future Training

Athletes need guidance to find and select suitable training materials in order to attain their intended training outcomes. Giving athletes relevant information will help them to self-determine their competence level, to self-regulate their training path, and to adjust their competence development to their intended training outcomes (Drachsler, Hummel, & Koper, 2008).

The competence network is a machine-processable representation of training outcomes. Future work could use the network to suggest training materials for the athletes. The system could suggest appropriate training material to the athletes depending upon their position in the competency network and their desire to achieve certain training outcomes. The system could integrate the athletes' current competence level, required intended training outcomes by the coaches, desired outcomes of the athletes, and the context of the training activities to provide more personalised training materials recommendations while at the same time taking into account the context of the athletes such as tools and resources.

10.3.7 Improve the Implementation of Pedagogical Feedback

Artificial data was used to capture athletes' achieved performance. Future work could develop the implementation by capturing athletes' achieved performance in real-time using sensor hardware. This could confirm that the framework for pedagogical feedback can work for real-time and in real-time situations.

10.3.8 Integration of Open Learner Model Approach

Personalisation of learning is commonly assumed to be related to good pedagogy where individualised learning is more effective and efficient (Verpoorten, Glahn, Kravcik, Ternier, & Specht, 2009). Personalisation supports learners to take ownership of and responsibility for their learning processes and for the tools which they use. Thus personalisation is a central aspect of learner control. Currently the PedaFeed system generates feedback to the athlete which is fully controlled by the system and which does not allow athletes to update their information easily when required. Future work could open the contents of the learner model to the athlete, to allow them both more control over their own learning process and more specific information about their own learning progress (Bull & Kay, 2008). Rendering the learner model accessible helps athletes to better understand their training, which can facilitate reflection on their understanding and on the learning process (Mabbott & Bull, 2006). Such a learner model would contain representations of all the athlete's information displayed in the PedaFeed system, including basic information (such as name or athlete ID), intended performance, and achievement of intended performance.

The PedaFeed system could be expanded to allow the athlete to be involved in the maintenance of their learner model, for example by editing it or by negotiating the contents of the learner model with the system. Allowing input from the athlete is based on the expectations that the model may be wrong, and that the athletes themselves may be able to help. For example, athletes may inform the system if they believe the representation of their achieved performance is too high (if they have forgotten to perform accurately the components of intended performance). Permitting the athletes to directly change contents with which they disagree allows the athletes to take greater control over their interaction and enhance awareness of their training.

Learner models can also be opened to coaches to help them better understand the needs of their athletes, and to peers, to enable athletes to compare their performance and progress to that of other athletes, and to facilitate collaboration amongst a co-present or distributed group.

10.4 Concluding Remarks

Pedagogically designed feedback in the motor skill domain allow the generation of effective feedback in the motor skill domain. The key contributions of pedagogically feedback such as the framework, the training outcomes, the algorithms, and the feedback itself provide an excellent pedagogical solution for skill acquisition and performance enhancement.

It is hoped that these findings will add to the body of knowledge in the area of provision of effective student feedback. It is also hoped that proposed pedagogical feedback in the motor skill domain may be able to form a good basis for further investigation by other researchers in various domains.

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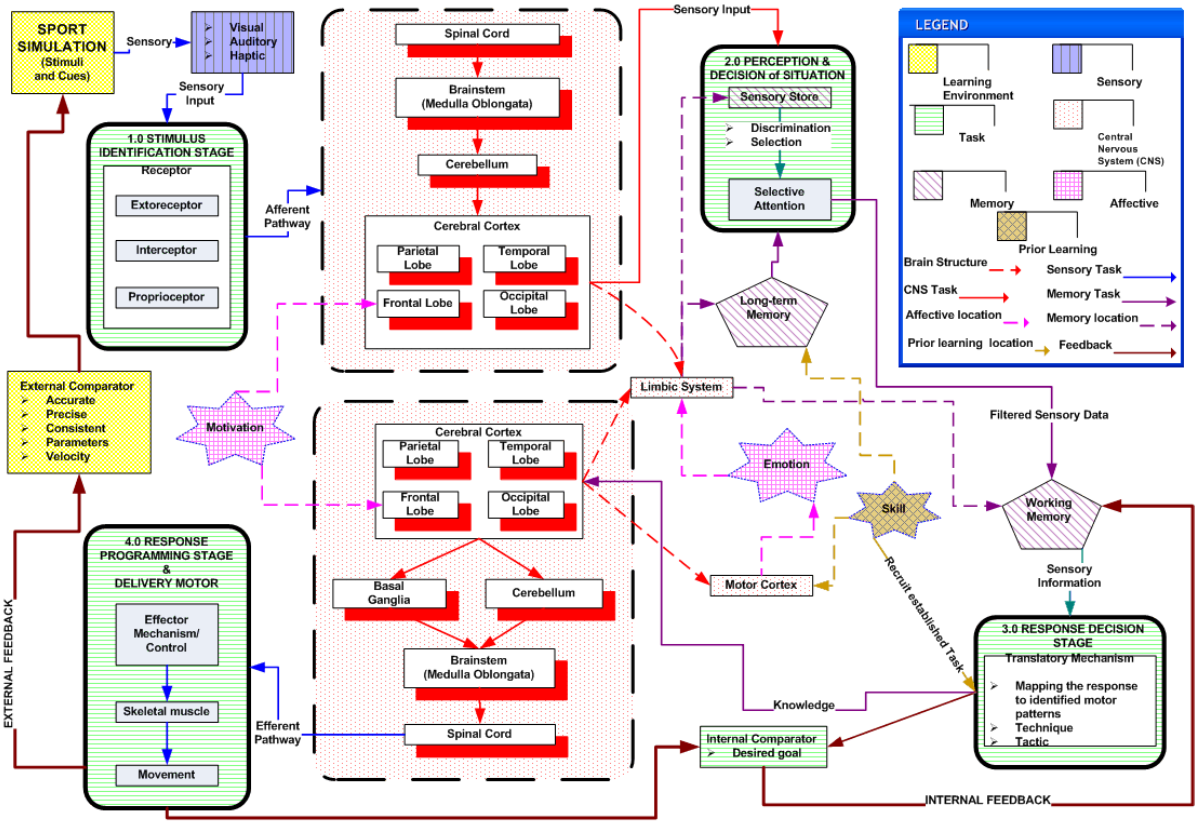
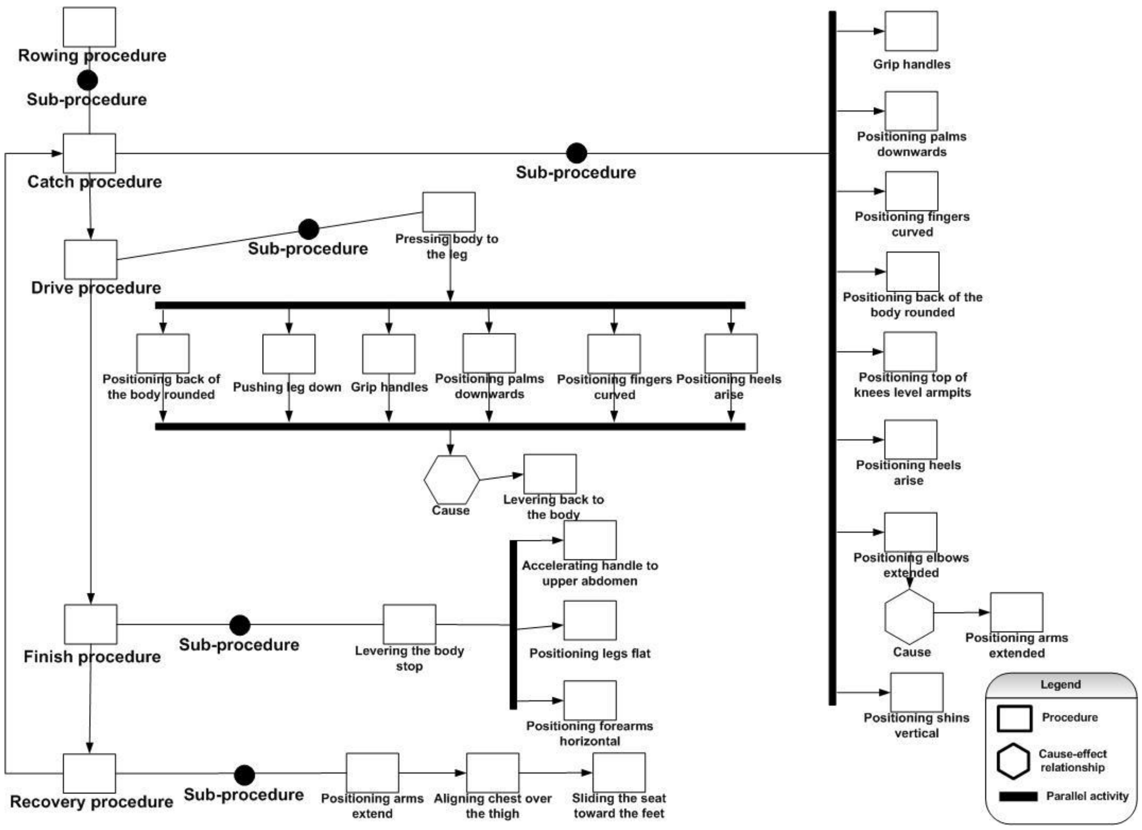
Appendix 1.

Feedback Process



Appendix 2.

Task Analysis: Rowing



Appendix 3.

Experiment One:

Scenario

Instruction

Please read carefully the following scenario.

Scenario

Your goal is to break seven minutes for a 2,000m row. One afternoon in March, your coach lists the specific areas that you have to work on using an ergometer machine for training in rowing.

Intended Performance

By the end of the training, you intend to be able to:

> Position yourself accurately from the start from 40 to 45 degree of flexion, using an ergometer machine set for rowing.

Components of Intended Performance

In order to achieve the intended performance, you must be able to:

- Develop yourself for the start from 35 to 45 degrees of flexion.
- Accurately grip the handles within 80 to 90 psi.
- Position accurately your palms downwards within 80 to 90 psi.
- Position accurately your fingers in a curve within 80 to 90 psi.
- Position accurately back of your body rounded within 25 to 30 degrees.

- Position accurately the top of your knees to be level with your armpits within 25 to 30 degrees.
- Position accurately heels rise within 25 to 30 degrees vertical.
- Position accurately elbows extended between 25 to 30 degrees vertical.
- Position accurately arms extended within 25 to 30 degrees vertical
- Position accurately shins vertical within 80 to 90 degrees vertical.

Please note that in the above performance levels, the value provided is just an assumption.

Feedback

At the end of the training, you would like to view how well you achieved the intended performance.

The following pages, give an instruction on interacting with a system that provides feedback.

Appendix 4.

Experiment One:

Worksheet – Sean Analysis

Instruction

Please follow these directions to use the system.

- Double click the **Sean-Session Analysis icon**.
- You will see **Menu screen** as in Figure 1 below.
- From the **View** menu, select **Row**.

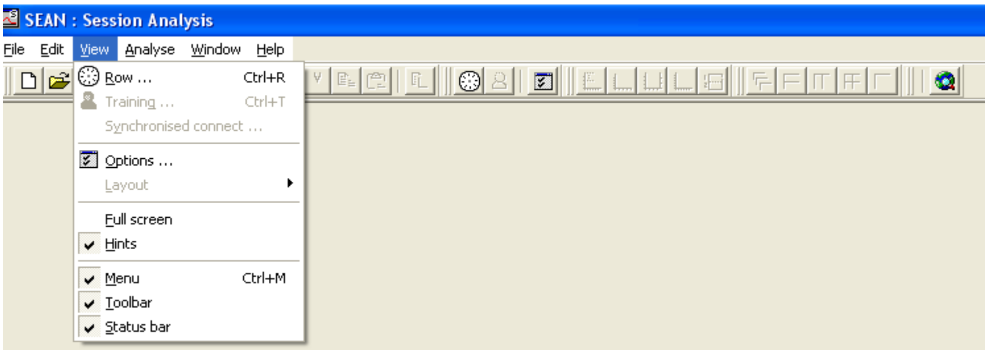


Figure A4-0-1: Menu screen

- You will see **New Row window screen** as Figure 2 below.

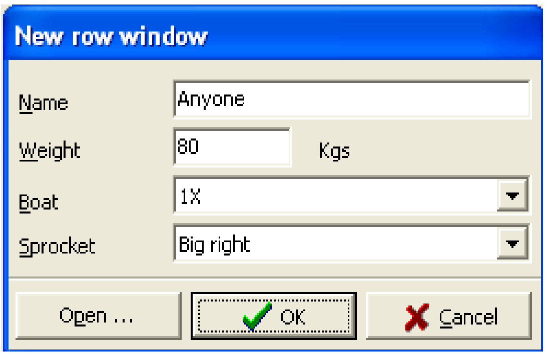


Figure A4-0-2: New row window screen

- Enter the data needed and click the **OK** button.
- The **Row window screen** will be displayed as Figure 3 below.

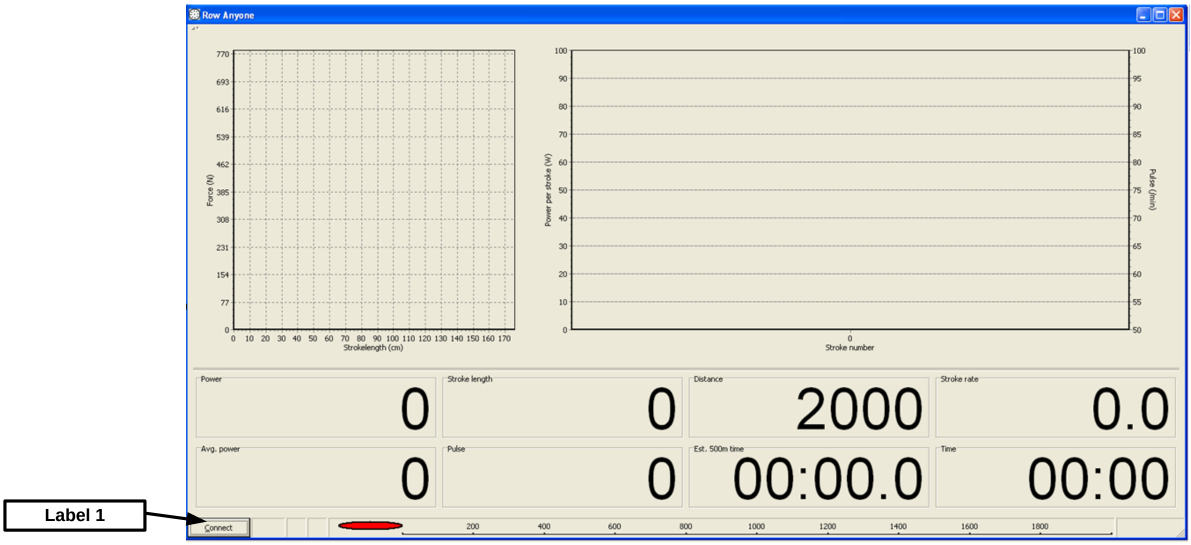


Figure A4-0-3: Row window screen

- Click **Connect** button at Label 1.
- The **Connect screen** will be displayed as Figure 4 below.

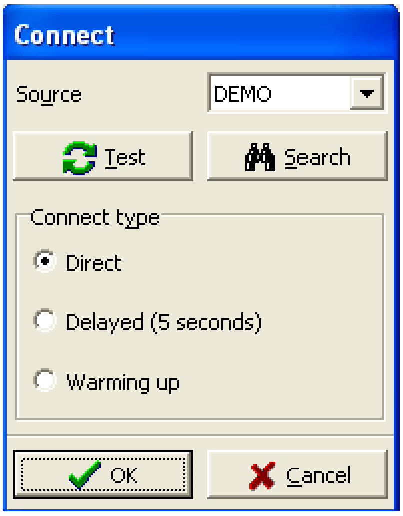


Figure A4-0-4: Connect window screen

- Click the **OK** button.

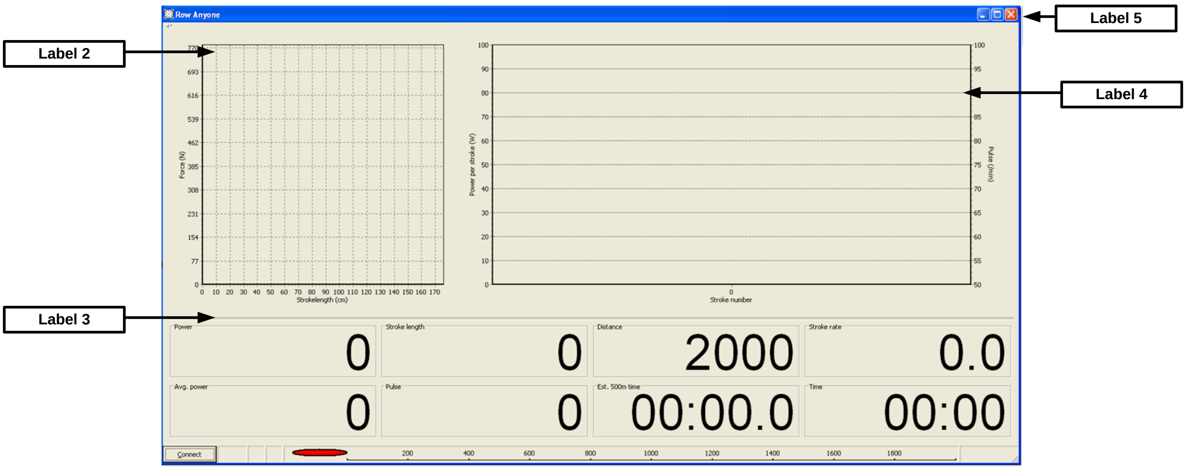


Figure A4-0-5: Demo data at row window screen

- Review demonstration data for your *achieved performance* at **Label 2**, table at **Label 3**, and **Label 4**, in Figure 5 above.
- Click the **Exit** button at **Label 5**.
- The **Result screen** will be displayed as Figure 6 below.

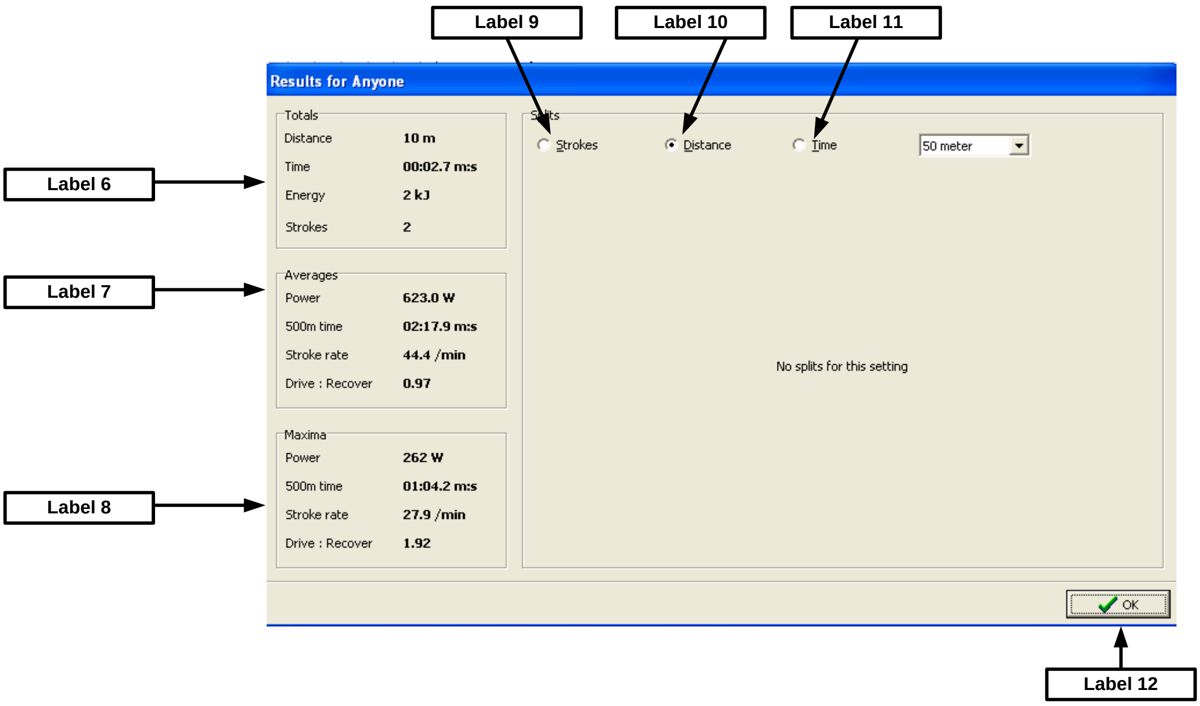


Figure A4-0-6: Result screen

Review your *achieved performance* at **Label 6**, **Label 7**, and **Label 8**.

Click **Label 9**, **Label 10**, and **Label 11** to view your *achieved performance*.

Click the **OK** button at **Label 12**.

Finally, raise your hand when you have completed using the system.

Appendix 5.

Experiment One:

Worksheet – PedaFeed

Instruction

Please follow these directions to use the system.

- Double click the **PedaFeed** icon.
- You will see **Login screen** as in Figure 1 below.

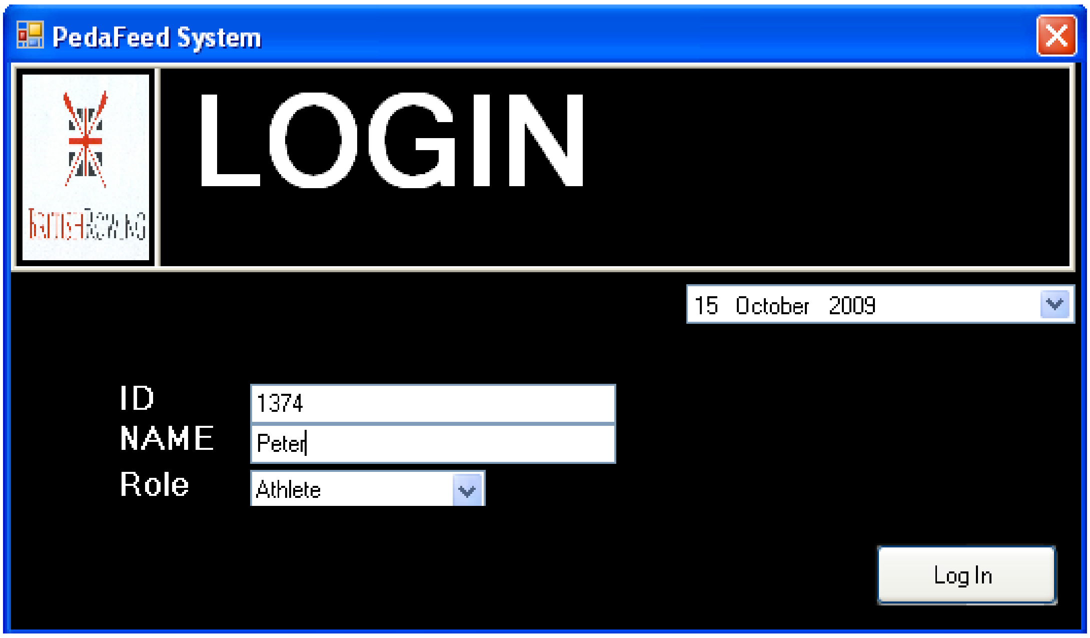


Figure A5-0-7: Login interface

- Select the date '**15 October 2009**' from the drop down list.
- Fill in:

ID	1374
NAME	Peter

- Select the Role **'Athlete'** from the drop down list.

- Then, click the **'Log In'** button.
- The feedback screen will appear.

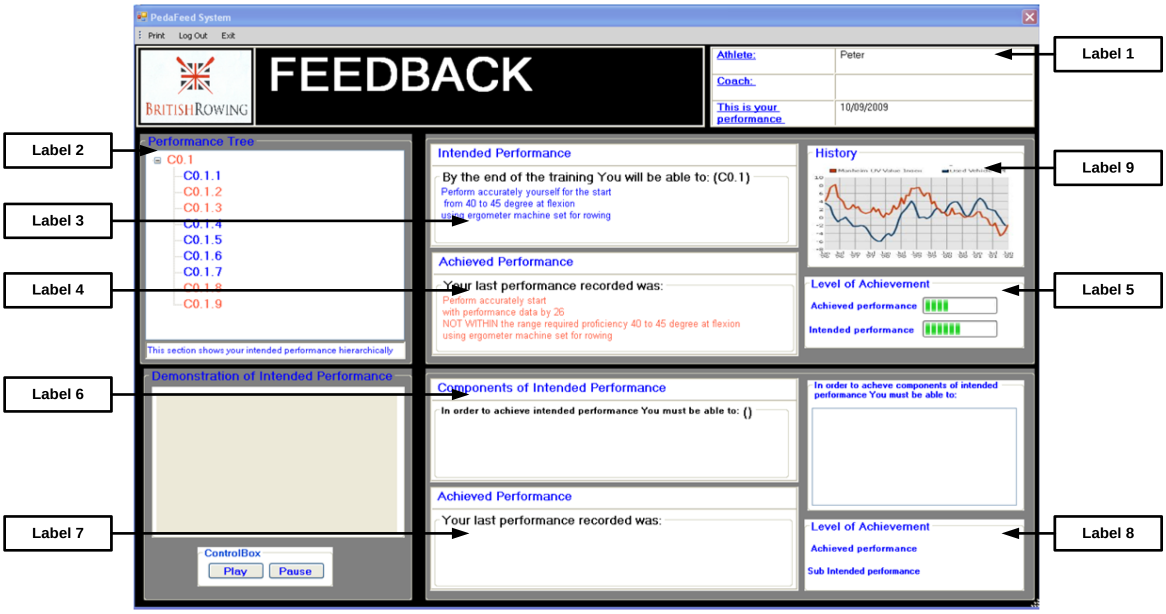


Figure A5-0-8: Feedback interface

- Please refer to **Label 1**, and review your training data.
- Please refer to **Label 2**, and review your ***intended performance*** graphically.
- Then click on **C0.1** in **Label 2**.
- Please refer to **Label 3**, and review your ***intended performance*** in detail.
- Please refer to **Label 4**, to view your *achieved performance*.
- Please review at **Label 5** to differentiate graphically your *achieved performance* in relation to ***intended performance***.
- Click any components of ***intended performance*** in **Label 2**.
- Please refer to **Label 6** to view the components of ***intended performance*** in detail.
- Please refer to **Label 7**, to view your *achieved performance*.
- Please review at **Label 8** to differentiate graphically your *achieved performance* in relation to components ***intended performance***.
- Please refer to **Label 9**, to review your *achieved performance* in relation to the ***intended performance***.
- Click **Exit** in the menu bar.
- Finally, raise your hand when you have completed using the system.

Appendix 6.
Experiment One: Questionnaire

Instruction

Please give us your frank answers and comments.
They will help us to evaluate the effectiveness of feedback in Computer-based Sport Training (CBST).
Please circle the appropriate number after each statement, and then add your comments.

Part 1: System evaluation

The system is defined as the feedback system that you have received during the experiment.

Num.	Questions	Strongly disagree	Disagree	No opinion	Agree	Strongly agree
1	In the given screen, I found all the information I needed to achieve my ***intended performance***.	1	2	3	4	5
2	The system allowed me to judge the progression of my performance.	1	2	3	4	5
3	The system helped me to know the causes why I am not achieving my ***intended performance***.	1	2	3	4	5
4	The information given in the system was relevant to my ***intended performance***.	1	2	3	4	5
5	The system gave me adequate information on what I should do in my next training.	1	2	3	4	5
6	I prefer to read numerical scores rather than a text description.	1	2	3	4	5
7	The display of *achieved performance* motivated me to refine my training.	1	2	3	4	5
8	I am able to immediately interpret my *achieved performance*.	1	2	3	4	5
9	The information allowed me to discriminate between good and bad performance.	1	2	3	4	5
10	I am satisfied with the overall information given by the system.	1	2	3	4	5

Part 2

Please give any comments and suggestions that you feel would improve the development of effective feedback in CBST.

Thank you for your co-operation for participating in the experiment. ☺

Appendix 7.

Experiment One:

Results

Table A7-0-1: Descriptive statistics

Feedback Type	Reaction	Mean	Std. Deviation	N
Sean-Analysis	Information to achieve IP	4.0000	0.91287	13
	Progression judgement	3.8462	0.89872	13
	Causes of not achieving IP	3.1538	0.98710	13
	Relevant to IP	3.9231	0.95407	13
	Adequate information	3.3077	1.18213	13
	Prefer numerical scores	4.2308	0.83205	13
	Motivation to refine training	4.0769	0.64051	13
	Immediately interpret	3.8462	0.80064	13
	Performance discrimination	3.9231	1.11516	13
	Information satisfaction	3.7692	0.92681	13
PedaFeed	Information to achieve IP	4.0769	0.64051	13
	Progression judgement	4.0769	0.64051	13
	Causes of not achieving IP	3.5385	1.05003	13
	Relevant to IP	4.0000	0.81650	13
	Adequate information	3.5385	0.96742	13
	Prefer numerical scores	4.0000	1.08012	13
	Motivation to refine training	3.4615	0.77625	13
	Immediately interpret	3.3846	0.96077	13
	Performance discrimination	4.2308	0.72501	13
	Information satisfaction	3.9231	0.64051	13

Table A7-0-2: Multivariate tests

Effect		Statistical method	Value	F	Hypothesis df	Error df	Sig.
Between Subjects	Intercept	Pillai's Trace	0.998	165.644[a]	10.000	3.000	0.001
		Wilks' Lambda	0.002	165.644[a]	10.000	3.000	0.001
		Hotelling's Trace	552.147	165.644[a]	10.000	3.000	0.001
		Roy's Largest Root	552.147	165.644[a]	10.000	3.000	0.001
Within Subjects	Feedback Type	Pillai's Trace	0.774	1.028[a]	10.000	3.000	0.557
		Wilks' Lambda	0.226	1.028[a]	10.000	3.000	0.557
		Hotelling's Trace	3.426	1.028[a]	10.000	3.000	0.557
		Roy's Largest Root	3.426	1.028[a]	10.000	3.000	0.557

Table A7-0-3: Mauchly's test of sphericity

Within Subjects Effect	Reaction	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Feedback Type	Information to achieve IP	1.000	.000	0	.	1.000	1.000	1.000
	Progression judgement	1.000	.000	0	.	1.000	1.000	1.000
	Causes of not achieving IP	1.000	.000	0	.	1.000	1.000	1.000
	Relevant to IP	1.000	.000	0	.	1.000	1.000	1.000
	Adequate information	1.000	.000	0	.	1.000	1.000	1.000
	Prefer numerical scores	1.000	.000	0	.	1.000	1.000	1.000
	Motivation to refine training	1.000	.000	0	.	1.000	1.000	1.000
	Immediately interpret	1.000	.000	0	.	1.000	1.000	1.000
	Performance discrimination	1.000	.000	0	.	1.000	1.000	1.000
	Information satisfaction	1.000	.000	0	.	1.000	1.000	1.000

Table A7-0-4: Univariate tests

Source	Reaction	Statistical method	Type III Sum of Squares	df	Mean Square	F	Sig.
Feedback Type	Information to achieve IP	Lower-bound	0.038	1.000	0.038	0.055	0.819
	Progression judgement	Lower-bound	0.346	1.000	0.346	0.454	0.513
	Causes of not achieving IP	Lower-bound	0.962	1.000	0.962	0.698	0.420
	Relevant to IP	Lower-bound	0.038	1.000	0.038	0.034	0.856
	Adequate information	Lower-bound	0.346	1.000	0.346	0.274	0.610
	Prefer numerical scores	Lower-bound	0.346	1.000	0.346	1.317	0.273
	Motivation to refine training	Lower-bound	2.462	1.000	2.462	3.459	0.088
	Immediately interpret	Lower-bound	1.385	1.000	1.385	1.929	0.190
	Performance discrimination	Lower-bound	0.615	1.000	0.615	0.711	0.416
	Information satisfaction	Lower-bound	0.154	1.000	0.154	0.170	0.687

Table A7-0-5: Confidence intervals

Reaction	Feedback Type	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Information to achieve IP	Sean-Analysis	4.000	0.253	3.448	4.552
	PedaFeed	4.077	0.178	3.690	4.464
Progression judgement	Sean-Analysis	3.846	0.249	3.303	4.389
	PedaFeed	4.077	0.178	3.690	4.464
Causes of not achieving IP	Sean-Analysis	3.154	0.274	2.557	3.750
	PedaFeed	3.538	0.291	2.904	4.173
Relevant to IP	Sean-Analysis	3.923	0.265	3.347	4.500
	PedaFeed	4.000	0.226	3.507	4.493
Adequate information	Sean-Analysis	3.308	0.328	2.593	4.022
	PedaFeed	3.538	0.268	2.954	4.123
Prefer numerical scores	Sean-Analysis	4.231	0.231	3.728	4.734
	PedaFeed	4.000	0.300	3.347	4.653
Motivation to refine training refine training	Sean-Analysis	4.077	0.178	3.690	4.464
	PedaFeed	3.462	0.215	2.992	3.931
Immediately interpret	Sean-Analysis	3.846	0.222	3.362	4.330
	PedaFeed	3.385	0.266	2.804	3.965
Performance discrimination	Sean-Analysis	3.923	0.309	3.249	4.597
	PedaFeed	4.231	0.201	3.793	4.669
Information satisfaction	Sean-Analysis	3.769	0.257	3.209	4.329
	PedaFeed	3.923	0.178	3.536	4.310

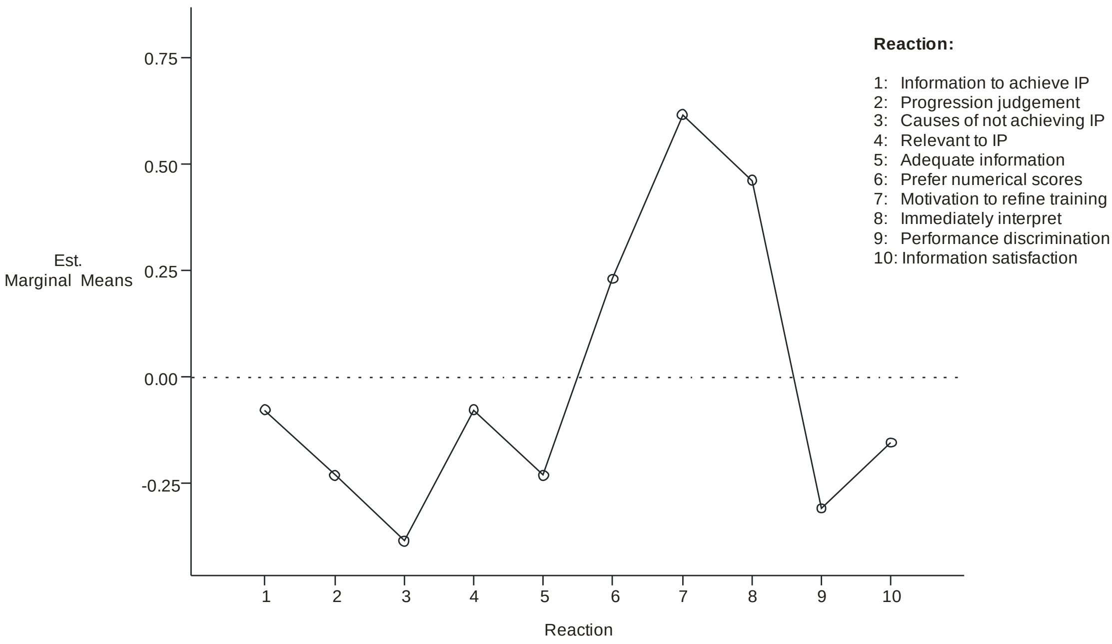


Figure A7-0-9: Means profile plots of mean reaction differences scores

Appendix 8.

Experiment Two:

Worksheet – PedaFeed

Instruction

Please follow these directions to use the system.

- Double click the PedaFeed icon.
- You will see Login screen as Figure 1 below.

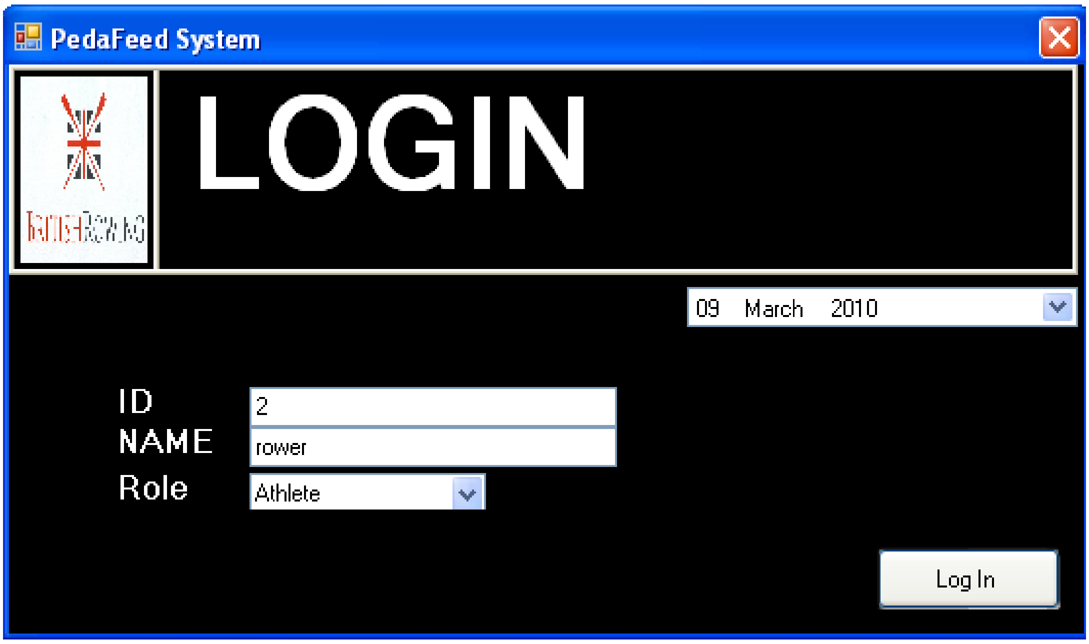


Figure A8-0-10: Login interface

- Select the date **'09 March 2010'**from the drop down list.
- Fill in:

ID	2
NAME	rower

- Select the Role **'Athlete'** from the drop down list.
- Then, click the **'Log In'** button.
- The **feedback screen** will appear as in Figure 2 below.

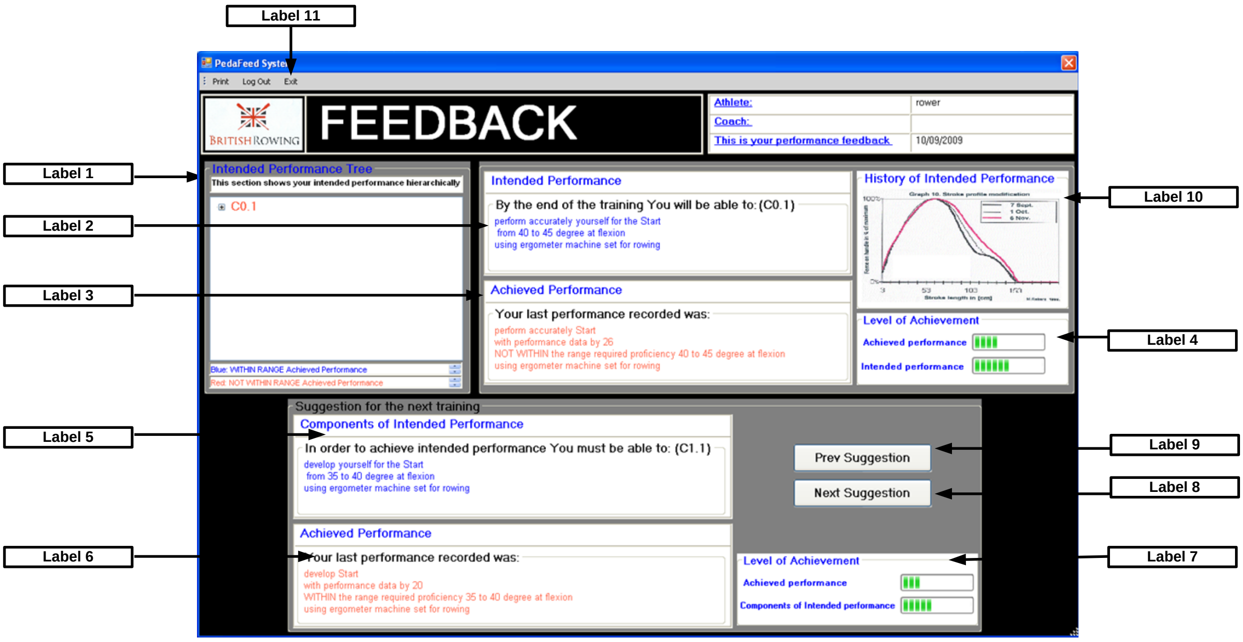


Figure A8-0-11: Feedback interface

- Please refer to **Label 1**, and review your ***intended performance***.
- Click **[+]** in the **Label 1** box.
- Click C0.1 in the Label 1 box.
- Refer to **Label 2** and review your ***intended performance*** in detail.
- Refer to **Label 3** to view your *achieved performance*.
- Refer to **Label 4** to differentiate graphically your *achieved performance* in relation to the ***intended performance***.
- Refer to **Label 5** to view components of ***intended performance***.
- Refer to **Label 6** to view your *achieved performance*.
- Refer to **Label 7** to differentiate graphically your *achieved performance* in relation to the components of ***intended performance***.
- Click the **Next Suggestion** button at Label 8.
- Refer to Label 5, Label 6, and Label 7.
- Click the **Previous Suggestion** button at Label 9.
- Refer to Label 5, Label 6, and Label 7.

- Click any at components of ***intended performance*** with blue font at **Label 1**.
- Refer to Label 5, Label 6, and Label 7.
- Refer to **Label 10** to view history of your ***intended performance***.
- Click Exit at Label 11.
- Finally, raise your hand when you have completed using the system.

Appendix 9.

Experiment Two: Questionnaire

Instruction

Please give us your frank answers and comments.

They will help us to evaluate the effectiveness of feedback in Computer-based Sport Training (CBST).

Please circle the appropriate number after each statement, and then add your comments.

Part 1: Background

Instruction:

Please tick (✓) the appropriate answer.

How would you rate your level of experience in rowing?	Tick
Beginner	
Intermediate	
Advanced	

Part 2: System evaluation

The system is defined as the feedback system that you have received during the experiment.

Instruction:

Please circle the appropriate number after each statement.

Strongly disagree	Disagree	No opinion	Agree	Strongly agree
1	2	3	4	5

Num.	Questions	Strongly disagree	Disagree	No opinion	Agree	Strongly agree
1	The system helped me to reflect on what is taught to me by the coach.	1	2	3	4	5
2	The system allowed me to judge the progression of my performance.	1	2	3	4	5
3	The system helped me to know the causes why I am not achieving my ***intended performance***.	1	2	3	4	5
4	The information given in the system was relevant to my ***intended performance***.	1	2	3	4	5
5	The system gave me adequate information on what should I do in my next training.	1	2	3	4	5
6	The display of *achieved performance* motivated me to refine my training.	1	2	3	4	5
7	I was able to immediately interpret the information provided by the system.	1	2	3	4	5
8	The information allowed me to discriminate between good and poor performance.	1	2	3	4	5
9	I was able to know how close I was to my ***intended performance***.	1	2	3	4	5
10	The system gave corrective information about poor performance.	1	2	3	4	5

Part 3:

Please give any comments and suggestions that you feel would improve the development of effective feedback in Computer-based Sport Training (CBST).

Thank you for your co-operation for participating in the experiment. ☺

Appendix 10. Experiment Two Results

Table A10-0-6: Descriptive statistics

Feedback Type	Reaction	Mean	Std. Deviation	N
Sean-Analysis	Training reflection	3.6667	0.77850	12
	Progression judgement	4.1667	0.38925	12
	Causes of not achieving IP	3.0833	10.16450	12
	Relevant to IP	3.9167	0.79296	12
	Adequate information	3.0000	1.04447	12
	Motivation to refine training	3.5833	0.66856	12
	Immediately interpret	3.9167	0.90034	12
	Performance discrimination	3.8333	0.57735	12
	Close to IP	3.8333	0.71774	12
	Corrective information	3.5833	0.90034	12
PedaFeed	Training reflection	3.5833	0.51493	12
	Progression judgement	3.7500	0.75378	12
	Causes of not achieving IP	3.3333	0.65134	12
	Relevant to IP	3.5833	0.79296	12
	Adequate information	3.5000	0.90453	12
	Motivation to refine training	3.4167	0.51493	12
	Immediately interpret	3.1667	0.93744	12
	Performance discrimination	3.5000	0.52223	12
	Close to IP	3.8333	0.38925	12
	Corrective information	3.7500	0.62158	12

Table A10-0-7: Multivariate tests

Effect		Statistical method	Value	F	Hypothesis df	Error df	Sig.
Between Subjects	Intercept	Pillai’s Trace	1.000	1636.492a	10.000	2.000	0.001
		Wilks’ Lambda	0.000	1636.492a	10.000	2.000	0.001
		Hotelling’s Trace	8182.460	1636.492a	10.000	2.000	0.001
		Roy’s Largest Root	8182.460	1636.492a	10.000	2.000	0.001
Within Subjects	Feedback Type	Pillai’s Trace	0.806	0.832a	10.000	2.000	0.659
		Wilks’ Lambda	0.194	0.832a	10.000	2.000	0.659
		Hotelling’s Trace	4.160	0.832a	10.000	2.000	0.659
		Roy’s Largest Root	4.160	0.832a	10.000	2.000	0.659

Table A10-0-8: Mauchly’s test of sphericity

Within Subjects Effect	Reaction	Mauchly’s W	Approx. Chi-Square	df	Sig.	Epsilon		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Feedback Type	Training reflection	1.000	.000	0	.	1.000	1.000	1.000
	Progression judgement	1.000	.000	0	.	1.000	1.000	1.000
	Causes of not achieving IP	1.000	.000	0	.	1.000	1.000	1.000
	Relevant to IP	1.000	.000	0	.	1.000	1.000	1.000
	Adequate information	1.000	.000	0	.	1.000	1.000	1.000
	Motivation to refine training	1.000	.000	0	.	1.000	1.000	1.000
	Immediately interpret	1.000	.000	0	.	1.000	1.000	1.000
	Performance discrimination	1.000	.000	0	.	1.000	1.000	1.000
	Close to IP	1.000	.000	0	.	1.000	1.000	1.000
	Corrective information	1.000	.000	0	.	1.000	1.000	1.000

Table A10-0-9: Univariate tests

Source	Reaction	Statistical method	Type III Sum of Squares	df	Mean Square	F	Sig.
Feedback Type	Training reflection	Lower-bound	0.042	1.000	0.042	0.084	0.777
	Progression judgement	Lower-bound	1.042	1.000	1.042	4.661	.054
	Causes of not achieving IP	Lower-bound	0.375	1.000	0.375	0.371	0.555
	Relevant to IP	Lower-bound	0.667	1.000	0.667	1.158	0.305
	Adequate information	Lower-bound	1.500	1.000	1.500	2.200	0.166
	Motivation to refine training	Lower-bound	0.167	1.000	0.167	2.200	0.166
	Immediately interpret	Lower-bound	3.375	1.000	3.375	7.244	0.021
	Performance discrimination	Lower-bound	0.667	1.000	0.667	2.200	0.166
	Close to IP	Lower-bound	0.000	1.000	0.000	0.000	1.000
	Corrective information	Lower-bound	0.167	1.000	0.167	0.379	0.551

Table A10-0-10: Confidence intervals

Reaction	Feedback Type	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Training reflection	Sean-Analysis	3.667	0.225	3.172	4.161
	PedaFeed	3.583	0.149	3.256	3.911
Progression judgement	Sean-Analysis	4.167	0.112	3.919	4.414
	PedaFeed	3.750	0.218	3.271	4.229
Causes of not achieving IP	Sean-Analysis	3.083	0.336	2.343	3.823
	PedaFeed	3.333	0.188	2.919	3.747
Relevant to IP	Sean-Analysis	3.917	0.229	3.413	4.420
	PedaFeed	3.583	0.229	3.080	4.087
Adequate information	Sean-Analysis	3.000	0.302	2.336	3.664
	PedaFeed	3.500	0.261	2.925	4.075
Motivation to refine training	Sean-Analysis	3.583	0.193	3.159	4.008
	PedaFeed	3.417	0.149	3.089	3.744
Immediately interpret	Sean-Analysis	3.917	0.260	3.345	4.489
	PedaFeed	3.167	0.271	2.571	3.762
Performance discrimination	Sean-Analysis	3.833	0.167	3.467	4.200
	PedaFeed	3.500	0.151	3.168	3.832
Close to IP	Sean-Analysis	3.833	0.207	3.377	4.289
	PedaFeed	3.833	0.112	3.586	4.081
Corrective information	Sean-Analysis	3.583	0.260	3.011	4.155
	PedaFeed	3.750	0.179	3.355	4.145

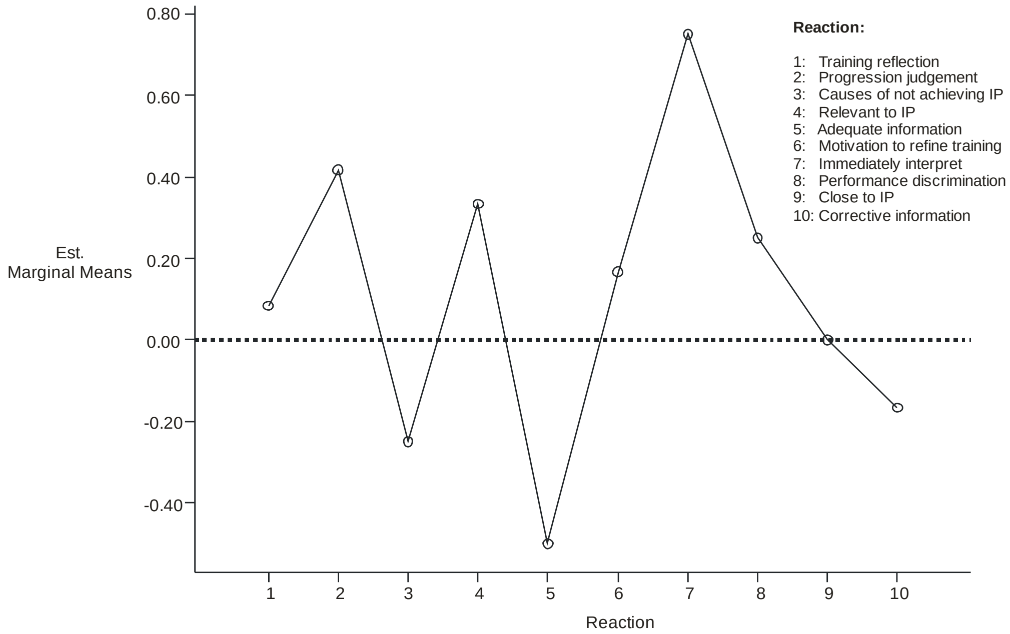


Figure A10-0-12: Means profile plots of mean reaction differences scores

Appendix 11.

Experiment Three: Training Module

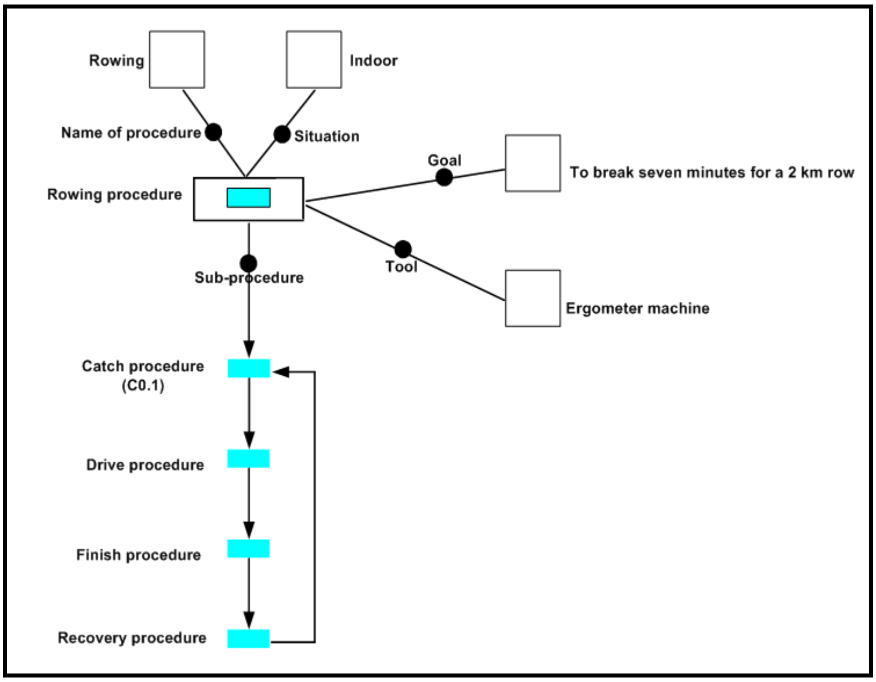


Figure A11-0-13: Component display theory of rowing procedure

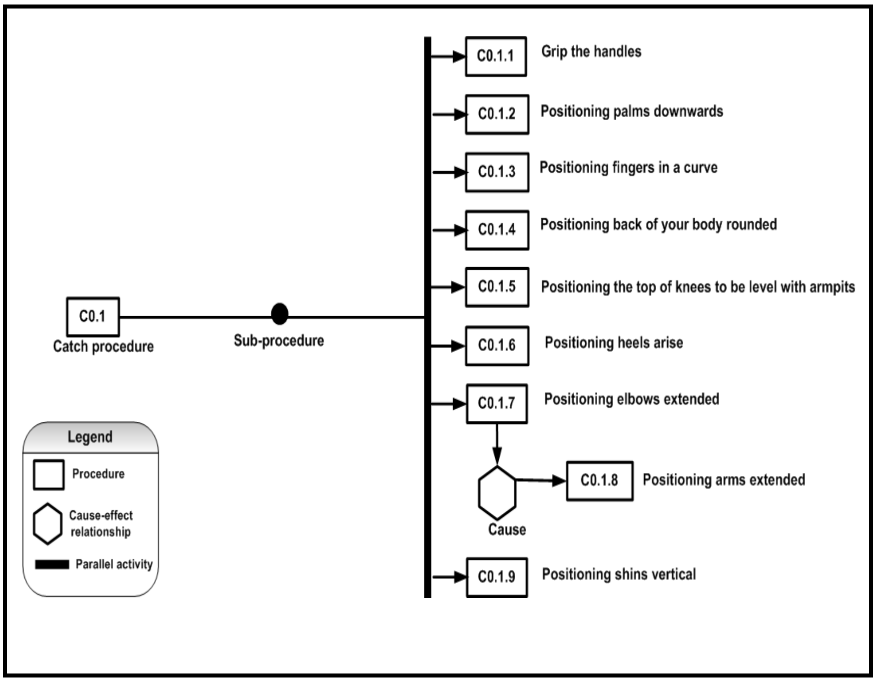


Figure A11-0-14: Task analysis of catch procedure in rowing

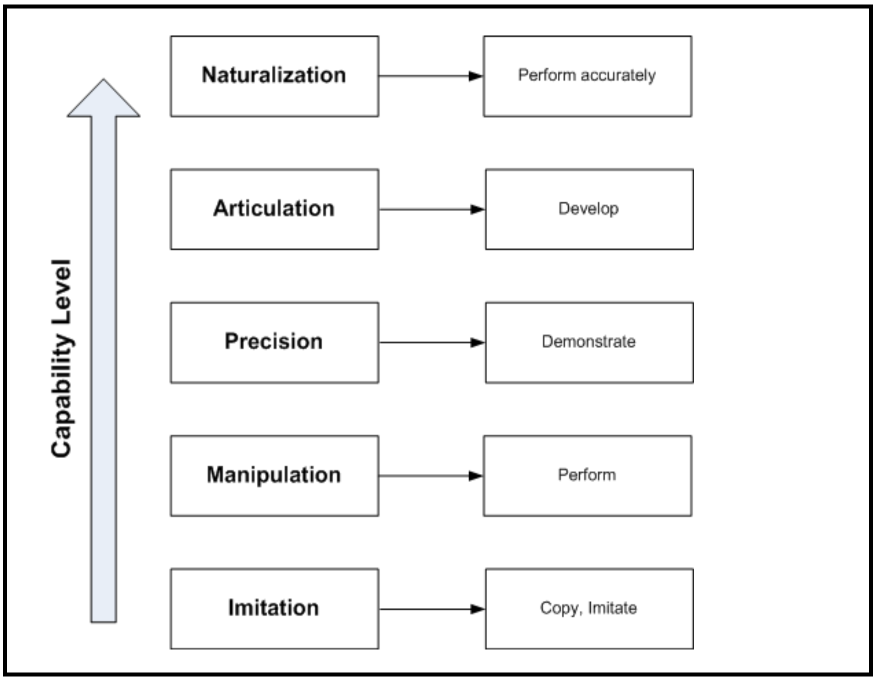
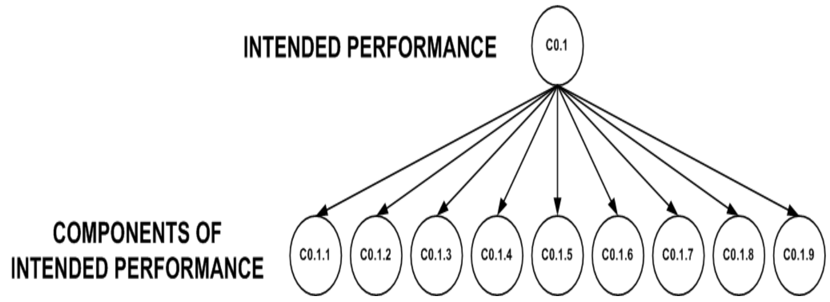


Figure A11-0-15: Capability level based on Dave's taxonomy



Competency Number	Capability	Subject Matter
C0.1	**Perform accurately**	Catch procedure
C0.1.1	**Perform accurately**	Grip the handles
C0.1.2	**Perform accurately**	Positioning palms downwards

Figure A11-0-16: Conceptual model of training outcomes in rowing procedure

Appendix 12.

Experiment Three: Scenario

Instruction

Please read carefully the following scenario.

Scenario

Your goal is to break seven minutes for a 2,000m row. One afternoon in March, your coach lists the specific areas that you have to work on using an ergometer machine for training in rowing.

Intended Performance

By the end of the training, you intend to be able to:

(C0.1) Position yourself accurately from the start from 40 to 45 degree of flexion, using an ergometer machine set for rowing.

Components of Intended Performance

In order to achieve the intended performance, you must be able to:

(C0.1.1) Accurately grip the handles within 80 to 90 psi.
(C0.1.2) Position accurately your palms downwards within 80 to 90 psi.
(C0.1.3) Position accurately your fingers in a curve within 80 to 90 psi.
(C0.1.4) Position accurately back of your body rounded within 25 to 30 degrees.

(C0.1.5) Position accurately the top of your knees to be level with your armpits within 25 to 30 degrees.

(C0.1.6) Position accurately heels rise within 25 to 30 degrees vertical.

(C0.1.7) Position accurately elbows extended between 25 to 30 degrees vertical.

(C0.1.8) Position accurately arms extended within 25 to 30 degrees vertical

(C0.1.9) Position accurately shins vertical within 80 to 90 degrees vertical.

Please note that in the above performance levels, the value provided is just an assumption.

Feedback

At the end of the training, you would like to view how well you achieved the intended performance.

The following pages, give an instruction on interacting with a system that provide feedback.

Appendix 13.

Experiment Three:

Worksheet – PedaFeed

Instruction:

Please follow those directions to use the system.

- Double click the **PedaFeed** icon.
- You will see the **Login screen** as Figure 1 below.

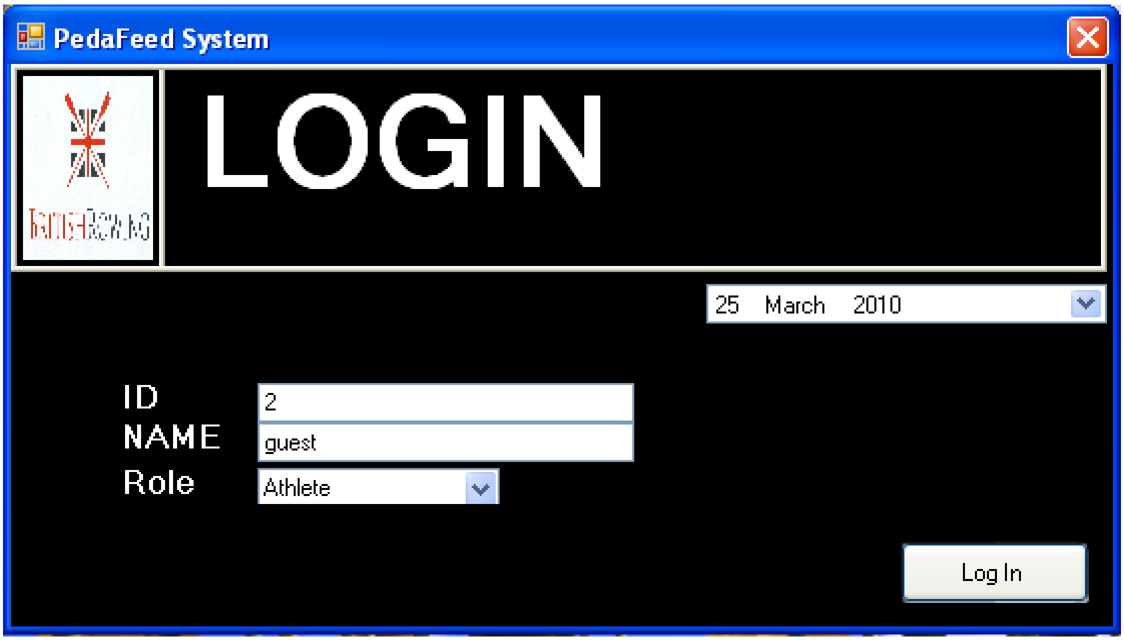


Figure A13-0-17: Login interface

- Select the date **‘25 March 2010’** from the drop down list.
- Fill in:

ID	2
NAME	guest

- Select the Role **'Athlete'** from the drop down list.
- Then, click the **'Log In'** button.
- The feedback screen will appear.

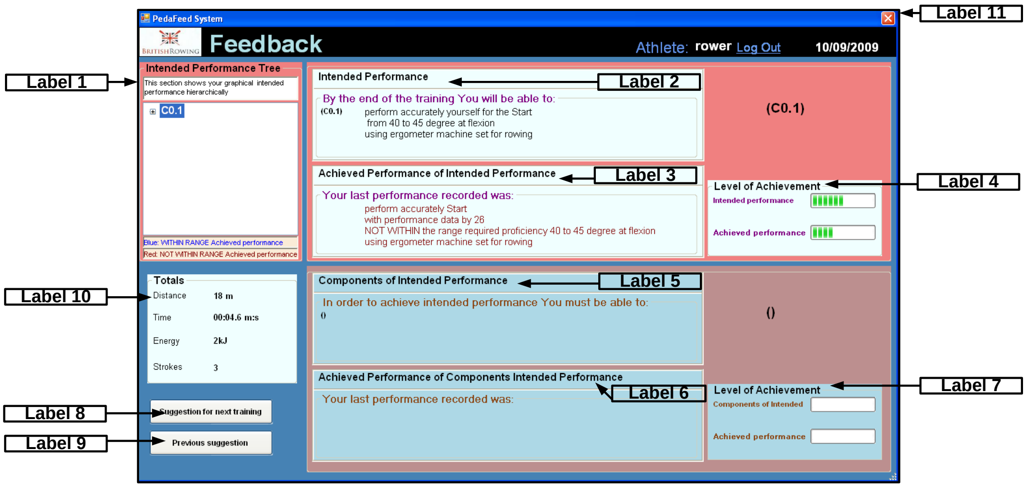


Figure A13-0-18: Feedback interface

- Please refer to **Label 1**, and review your ***intended performance***.
- Click [+] at Label 1.
- Click **C0.1** at **Label 1**.
- Refer to **Label 2** and review your ***intended performance*** in detail.
- Refer to **Label 3** to view your *achieved performance*.
- Refer to **Label 4** to differentiate graphically your *achieved performance* in relation to the ***intended performance***.
- Click any at components of ***intended performance*** with blue font at **Label 1**.
- Refer to **Label 5** to view components of ***intended performance***.
- Refer to **Label 6** to view your *achieved performance*.
- Refer to **Label 7** to differentiate graphically your *achieved performance* in relation to the components of ***intended performance***.
- Click the **Next Suggestion** button at Label 8.
- Refer to Label 5, Label 6, and Label 7.
- Click the **Previous Suggestion** button at Label 9.
- Refer to Label 5, Label 6, and Label 7.
- Refer to **Label 10** to view analysis of your rowing stroke.
- Click Exit at Label 11.
- Finally, raise your hand when you have completed using the system.

Appendix 14.
Experiment Three Questionnaire

Instruction

Please give us your frank answers and comments.
They will help us to evaluate the effectiveness of feedback in Computer-based Sport Training (CBST).
Please circle the appropriate number after each statement, and then add your comments.

Part 1: System evaluation

The system is defined as the feedback system that you have received during the experiment.

Instruction:

Please circle the appropriate number after each statement.

Strongly disagree	Disagree	Not opinion	Agree	Strongly agree
1	2	3	4	5

Num.	Questions	Strongly disagree	Disagree	Not opinion	Agree	Strongly agree
1	The system helped me to reflect on what was taught me by the coach.	1	2	3	4	5
2	The system allowed me to judge the progression of my performance.	1	2	3	4	5
3	The system helped me to know the causes why I am not achieving my ***intended performance***.	1	2	3	4	5
4	The information given in the system was relevant to my ***intended performance***.	1	2	3	4	5
5	The system gave me adequate information on what should I do in my next training.	1	2	3	4	5
6	The display of *achieved performance* motivated me to refine my training.	1	2	3	4	5
7	I was able to immediately interpret the information provided by the system.	1	2	3	4	5
8	The information allowed me to discriminate between good and poor performance.	1	2	3	4	5
9	I was able to know how close I was to my ***intended performance***.	1	2	3	4	5
10	The system gave corrective information about poor performance.	1	2	3	4	5

Part 3:

Please give your comments and suggestions which you feel would improve the development of effective feedback in Computer-based Sport Training (CBST).

Thank you for your co-operation for participating in the experiment. ☺

Appendix 15.

Experiment Three: Results

Table A15-0-11: Descriptive statistics

Feedback Type	Reaction	Mean	Std. Deviation	N
Sean-Analysis	Training reflection	3.2500	0.95743	4
	Progression judgement	4.2500	0.50000	4
	Causes of not achieving IP	3.0000	1.15470	4
	Relevant to IP	4.2500	0.50000	4
	Adequate information	4.0000	0.00000	4
	Motivation to refine training	4.5000	0.57735	4
	Immediately interpret	4.2500	0.95743	4
	Performance discrimination	4.2500	0.50000	4
	Close to IP	4.5000	0.57735	4
	Corrective information	3.0000	1.15470	4
PedaFeed	Training reflection	3.5000	1.00000	4
	Progression judgement	3.5000	0.57735	4
	Causes of not achieving IP	3.0000	1.15470	4
	Relevant to IP	4.0000	0.00000	4
	Adequate information	3.0000	1.15470	4
	Motivation to refine training	3.7500	0.50000	4
	Immediately interpret	3.0000	1.15470	4
	Performance discrimination	3.5000	1.00000	4
	Close to IP	4.2500	0.50000	4
	Corrective information	3.2500	0.95743	4

Table A15-0-12: Mauchly's test of sphericity

Within Subjects Effect	Reaction	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Feedback Type	Training reflection	1.000	0.000	0	.	1.000	1.000	1.000
	Progression judgement	1.000	0.000	0	.	1.000	1.000	1.000
	Causes of not achieving IP	.	.	0	.	.	.	1.000
	Relevant to IP	1.000	0.000	0	.	1.000	1.000	1.000
	Adequate information	1.000	0.000	0	.	1.000	1.000	1.000
	Motivation to refine training	1.000	0.000	0	.	1.000	1.000	1.000
	Immediately interpret	1.000	0.000	0	.	1.000	1.000	1.000
	Performance discrimination	1.000	0.000	0	.	1.000	1.000	1.000
	Close to IP	1.000	0.000	0	.	1.000	1.000	1.000
	Corrective information	1.000	0.000	0	.	1.000	1.000	1.000

Table A15-0-13: Univariate tests

Source	Reaction	Statistical method	Type III Sum of Squares	df	Mean Square	F	Sig.
Feedback Type	Training reflection	Lower-bound	0.125	1.000	0.125	0.086	0.789
	Progression judgement	Lower-bound	1.125	1.000	1.125	9.000	0.058
	Causes of not achieving IP	Lower-bound	0.000	1.000	0.000	1	0.000
	Relevant to IP	Lower-bound	0.125	1.000	0.125	1.000	0.391
	Adequate information	Lower-bound	2.000	1.000	2.000	3.000	0.182
	Motivation to refine training	Lower-bound	1.125	1.000	1.125	9.000	0.058
	Immediately interpret	Lower-bound	3.125	1.000	3.125	3.947	0.141
	Performance discrimination	Lower-bound	1.125	1.000	1.125	2.455	0.215
	Close to IP	Lower-bound	0.125	1.000	0.125	1.000	0.391
	Corrective information	Lower-bound	0.125	1.000	0.125	0.158	0.718

Table A15-0-14: Confidence intervals

Reaction	Feedback Type	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Training reflection	Sean-Analysis	3.250	0.479	1.727	4.773
	PedaFeed	3.500	0.500	1.909	5.091
Progression judgement	Sean-Analysis	4.250	0.250	3.454	5.046
	PedaFeed	3.500	0.289	2.581	4.419
Causes of not achieving IP	Sean-Analysis	3.000	0.577	1.163	4.837
	PedaFeed	3.000	0.577	1.163	4.837
Relevant to IP	Sean-Analysis	4.250	0.250	3.454	5.046
	PedaFeed	4.000	0.000	4.000	4.000
Adequate information	Sean-Analysis	4.000	0.000	4.000	4.000
	PedaFeed	3.000	0.577	1.163	4.837
Motivation to refine training	Sean-Analysis	4.500	0.289	3.581	5.419
	PedaFeed	3.750	0.250	2.954	4.546
Immediately interpret	Sean-Analysis	4.250	0.479	2.727	5.773
	PedaFeed	3.000	0.577	1.163	4.837
Performance discrimination	Sean-Analysis	4.250	0.250	3.454	5.046
	PedaFeed	3.500	0.500	1.909	5.091
Close to IP	Sean-Analysis	4.500	0.289	3.581	5.419
	PedaFeed	4.250	0.250	3.454	5.046
Corrective information	Sean-Analysis	3.000	0.577	1.163	4.837
	PedaFeed	3.250	0.479	1.727	4.773

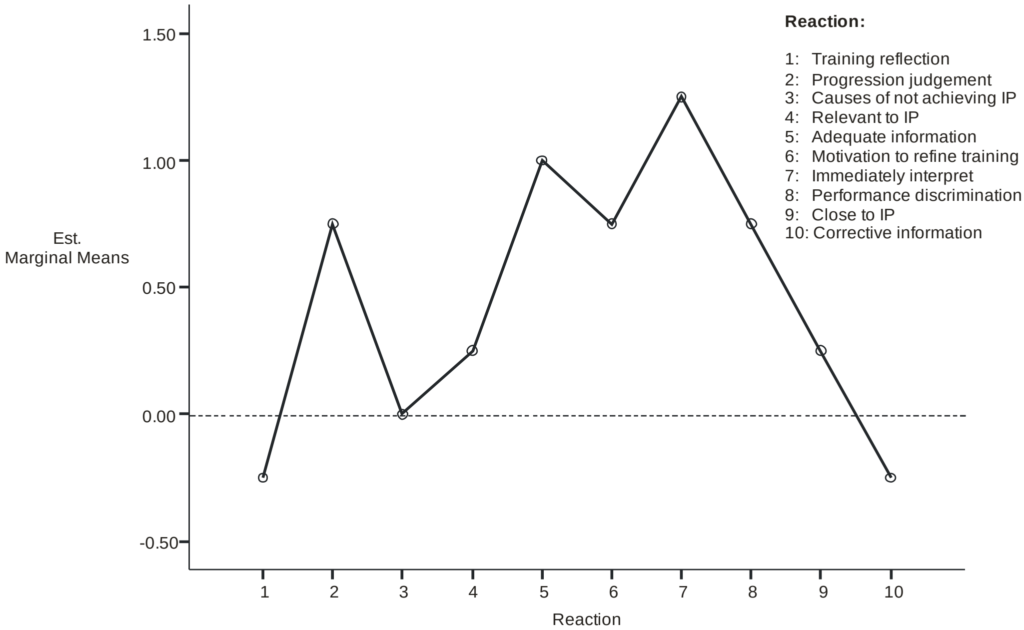


Figure A15-0-19: Means profile plots of mean reaction differences scores

Appendix 16.

Experiment One, Two, and Three:Results

Table A16-0-15: Descriptive statistics

Feedback Type	Reaction	Mean	Std. Deviation	N
Sean-Analysis	Progression judgement	4.0000	0.69481	30
	Causes of not achieving IP	3.0333	1.09807	30
	Relevant to IP	3.8667	0.97320	30
	Adequate information for next training	3.2000	1.12648	30
	Motivation to refine training	3.9000	0.71197	30
	Immediately interpret	3.9000	0.84486	30
	Performance discrimination	3.8333	0.98553	30
PedaFeed	Progression judgement	3.8667	0.68145	30
	Causes of not achieving IP	3.4333	0.93526	30
	Relevant to IP	3.8333	0.74664	30
	Adequate information for next training	3.4667	0.93710	30
	Motivation to refine training	3.5000	0.62972	30
	Immediately interpret	3.2667	0.94443	30
	Performance discrimination	3.8333	0.74664	30

Table A16-0-16: Multivariate tests

Effect		Statistical method	Value	F	Hypothesis df	Error df	Sig.
Between Subjects	Intercept	Pillai's Trace	0.992	422.881	7.000	23.000	0.000
		Wilks' Lambda	0.008	422.881	7.000	23.000	0.000
		Hotelling's Trace	128.703	422.881	7.000	23.000	0.000
		Roy's Largest Root	128.703	422.881	7.000	23.000	0.000
Within Subjects	Feedback Type	Pillai's Trace	0.491	3.167	7.000	23.000	0.017
		Wilks' Lambda	0.509	3.167	7.000	23.000	0.017
		Hotelling's Trace	0.964	3.167	7.000	23.000	0.017
		Roy's Largest Root	0.964	3.167	7.000	23.000	0.017

Table A16-0-17: Mauchly's test of sphericity

Within Subjects Effect	Reaction	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Feedback Type	Progression judgement	1.000	0.000	0	.	1.000	1.000	1.000
	Causes of not achieving IP	1.000	0.000	0	.	1.000	1.000	1.000
	Relevant to IP	1.000	0.000	0	.	1.000	1.000	1.000
	Adequate information for next training	1.000	0.000	0	.	1.000	1.000	1.000
	Motivation to refine training	1.000	0.000	0	.	1.000	1.000	1.000
	Immediately interpret	1.000	0.000	0	.	1.000	1.000	1.000
	Performance discrimination	1.000	0.000	0	.	1.000	1.000	1.000

Table A16-0-18: Confidence intervals

Reaction	Feedback Type	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Progression judgement	Sean-Analysis	4.000	0.127	3.741	4.259
	PedaFeed	3.867	0.124	3.612	4.121
Causes of not achieving IP	Sean-Analysis	3.033	0.200	2.623	3.443
	PedaFeed	3.433	0.171	3.084	3.783
Relevant to IP	Sean-Analysis	3.867	0.178	3.503	4.230
	PedaFeed	3.833	0.136	3.555	4.112
Adequate information for next training	Sean-Analysis	3.200	0.206	2.779	3.621
	PedaFeed	3.467	0.171	3.117	3.817
Motivation to refine training	Sean-Analysis	3.900	0.130	3.634	4.166
	PedaFeed	3.500	0.115	3.265	3.735
Immediately interpret	Sean-Analysis	3.900	0.154	3.585	4.215
	PedaFeed	3.267	0.172	2.914	3.619
Performance discrimination	Sean-Analysis	3.833	0.180	3.465	4.201
	PedaFeed	3.833	0.136	3.555	4.112

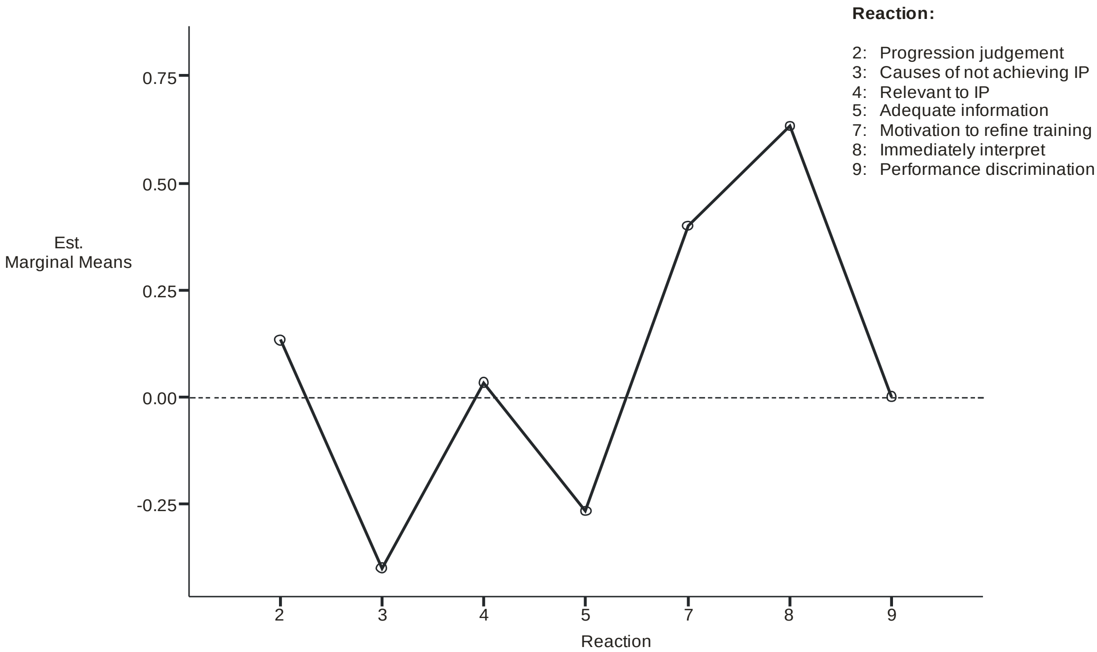


Figure A16-0-20: Means profile plots of mean reaction differences scores

Appendix 17.

Experiment Four: Training Module

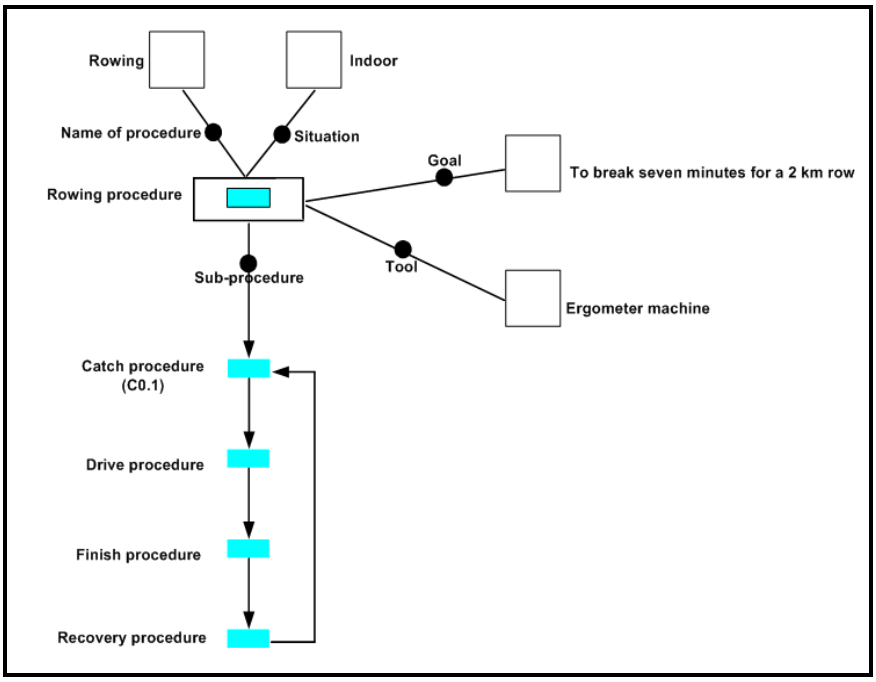


Figure A17-0-21: Task analysis of rowing procedure

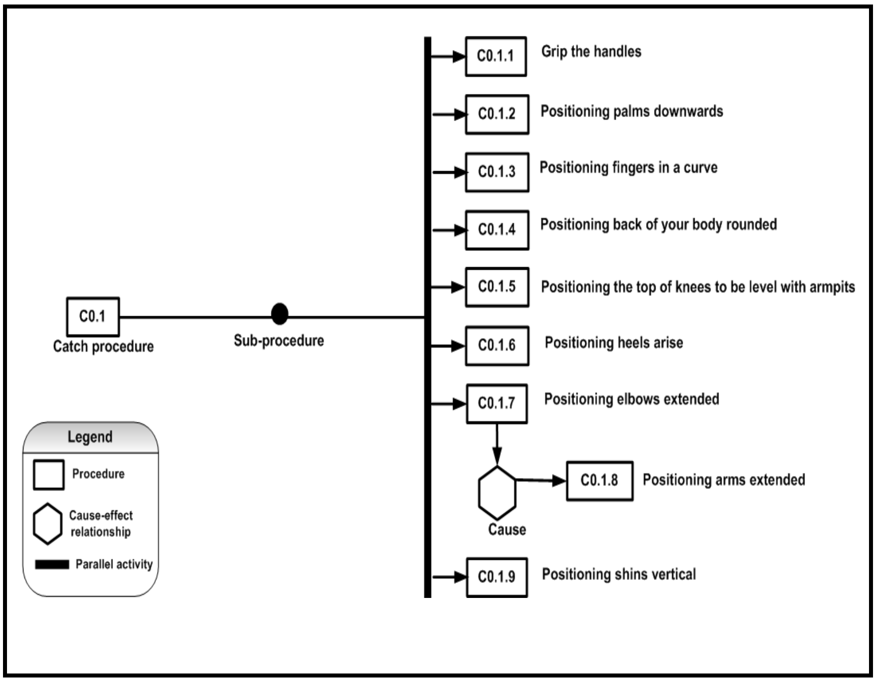


Figure A17-0-22: Task analysis of catch procedure in rowing

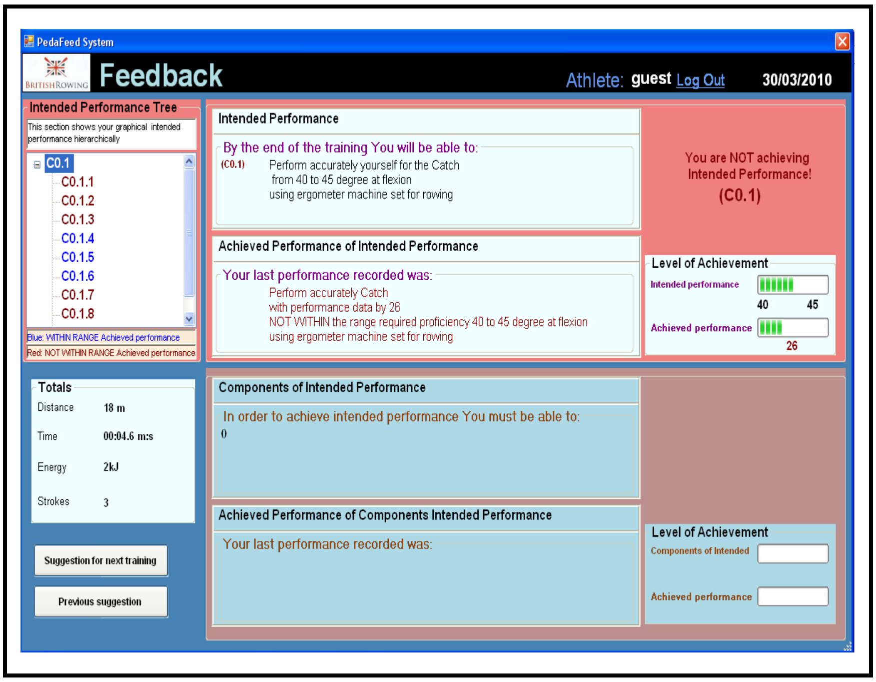


Figure A17-0-23: PedaFeed interface

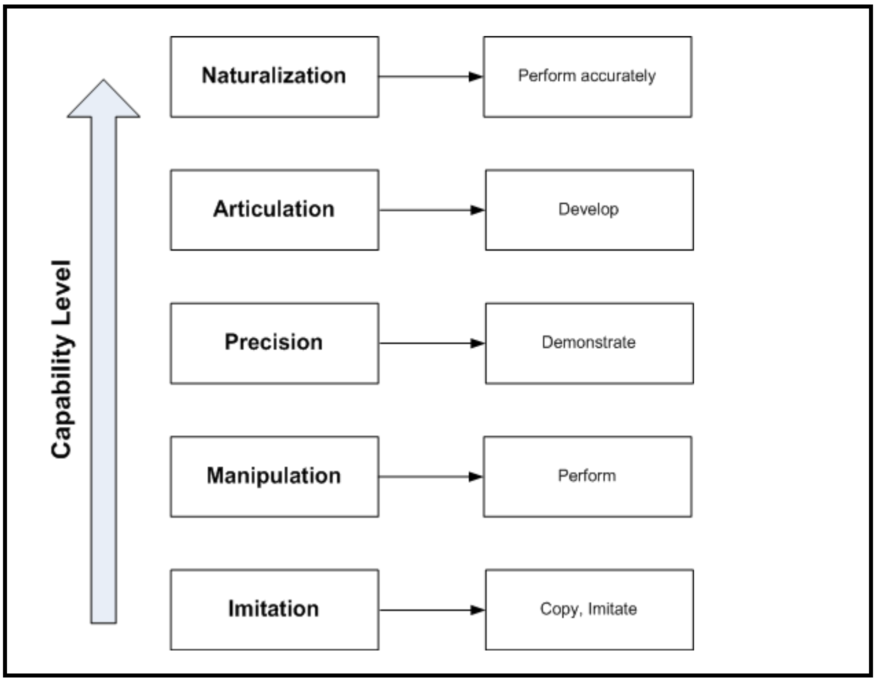
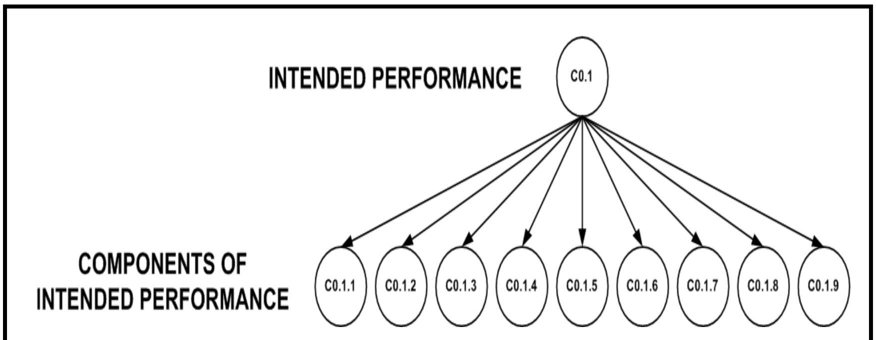


Figure A17-0-24: Capability level based on Dave's taxonomy



Competency Number	Capability	Subject Matter
C0.1	**Perform accurately**	Catch procedure
C0.1.1	**Perform accurately**	Grip the handles
C0.1.2	**Perform accurately**	Positioning palms downwards

Figure A17-0-25: Conceptual model of training outcomes in rowing procedure

Appendix 18.

Experiment Four:

Worksheet – PedaFeed

Instruction:

Please follow these directions to use the system.

- Double click the **PedaFeed** icon.
- You will see the **Login screen** as Figure 1 below.

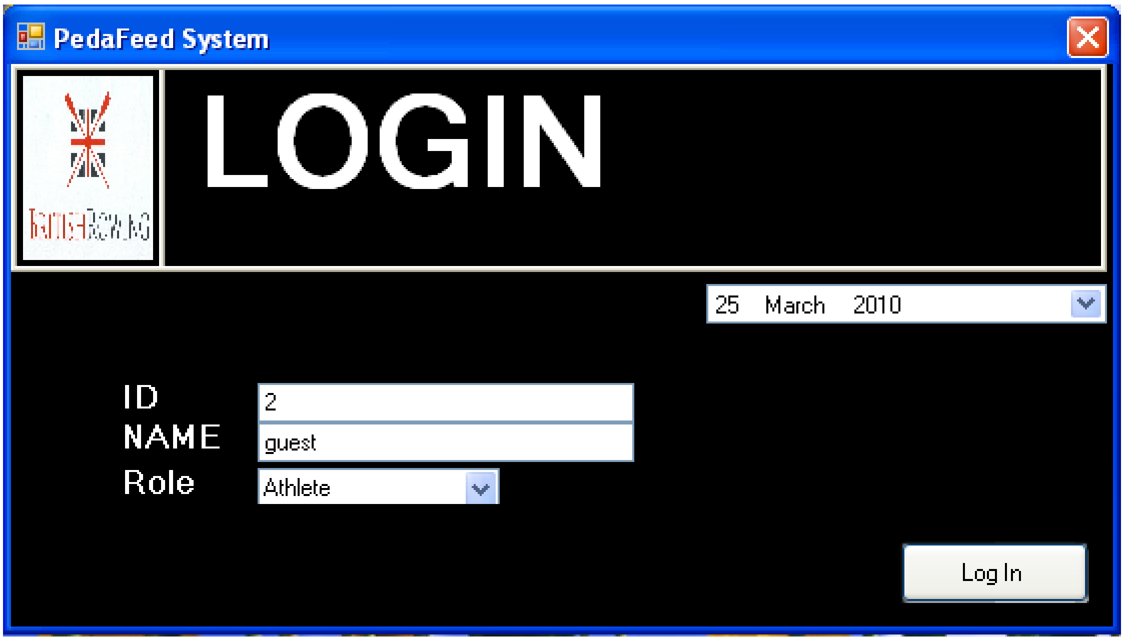


Figure A18-0-26: Login interface

- Select the date **'30 March 2010'** from the drop down list.
- Fill in:

ID	2
Name	guest

- Select the Role **'Athlete'** from the drop down list.

- Then, click the **'Log In'** button.
- The **feedback screen** will appear

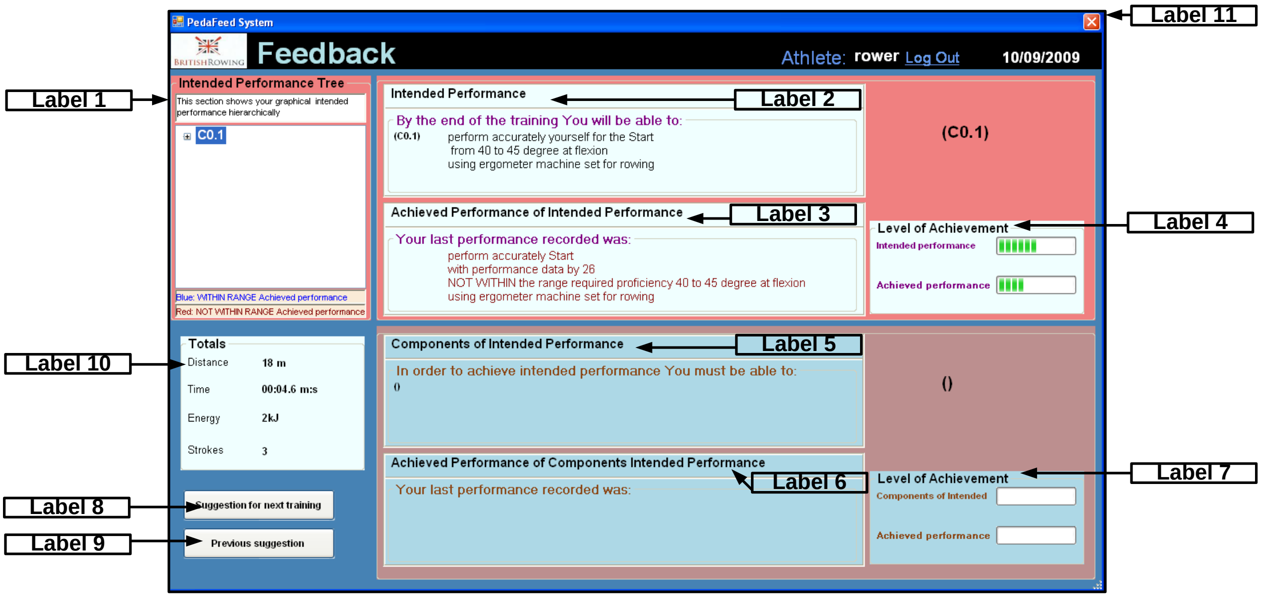


Figure A18-0-27: Feedback interface

- Please refer to **Label 1**, and review your ***intended performance***.
- Click C0.1 at Label 1.
- Refer to **Label 2** and review your ***intended performance*** in detail.
- Refer to **Label 3** to view your *achieved performance*.
- Refer to **Label 4** to differentiate graphically your *achieved performance* in relation to the ***intended performance***.
- Click [+] at **Label 1**.
- Click the **Next Suggestion** button at Label 8.
- Refer to **Label 5** to view components of ***intended performance***.
- Refer to **Label 6** to view your *achieved performance*.
- Refer to **Label 7** to differentiate graphically your *achieved performance* in relation to the components of ***intended performance***.
- Click any at components of ***intended performance*** with blue font at **Label 1**.
- Refer to **Label 5** to view components of ***intended performance***.
- Refer to **Label 6** to view your *achieved performance.*
- Refer to **Label 7** to differentiate graphically your *achieved performance* in relation to the components of ***intended performance***.
- Click the **Previous Suggestion** button at Label 9.

- Refer to Label 5, Label 6, and Label 7.
- Refer to **Label 10** to view analysis of your rowing stroke.
- Click Exit at Label 11.
- Finally, raise your hand when you have completed using the system.

Appendix 19.

Experiment Four: Questionnaire

Instruction

Please give us your frank answers and comments.

They will help us to evaluate the effectiveness of feedback in Computer-based Sport Training (CBST).

Please circle the appropriate number after each statement, and then add your comments.

Part 1: System evaluation

The system is defined as the feedback system that you have received during the experiment.

Instruction:

Please circle the appropriate answer after each statement.

Strongly disagree	Disagree	Not opinion	Agree	Strongly agree
1	2	3	4	5

Num.	Questions	Strongly disagree	Disagree	No opinion	Agree	Strongly agree
1	I am able to identify and target the techniques that need to be developed to reach my ***intended performance***.	1	2	3	4	5
2	The *achieved performance* verified that I had achieved my ***intended performance.***	1	2	3	4	5
3	I am able to track my capability level.	1	2	3	4	5
4	The system allowed me to ensure that each technique is mastered.	1	2	3	4	5
5	The system gave adequate information on the set of techniques that build toward the ***intended performance***.	1	2	3	4	5
6	The system gave clear information on what I must be able to do before something else should be learned.	1	2	3	4	5
7	I am able to diagnose why I didn't reach my ***intended performance***.	1	2	3	4	5
8	The system encouraged self-regulated learning.	1	2	3	4	5

Part 3:

Please give your comments and suggestions which you feel would improve the development of effective feedback in Computer-based Sport Training (CBST).

Thank you for your co-operation for participating in the experiment

Appendix 20. Experiment Four: Results

Table A20-0-19: Descriptive statistics

Feedback Type	Reaction	Mean	Std. Deviation	N
Sean-Analysis	Identify and target technique	1.5000	0.53452	8
	Verified achievement of IP	1.6250	0.51755	8
	Track capability level	1.8750	0.35355	8
	Ensured each technique is mastered	1.3750	0.51755	8
	Adequate information on the set of techniques	1.5000	0.53452	8
	Clear information on what must be able to do	1.2500	0.46291	8
	Diagnose failure of IP	1.3750	0.51755	8
	Encouraged self-regulated learning	1.5000	0.53452	8
PedaFeed	Identify and target technique	2.0000	0.00000	8
	Verified achievement of IP	1.8750	0.35355	8
	Track capability level	2.0000	0.00000	8
	Ensured each technique is mastered	2.0000	0.00000	8
	Adequate information on the set of techniques	2.0000	0.00000	8
	Clear information on what must be able to do	2.0000	0.00000	8
	Diagnose failure of IP	2.0000	0.00000	8
	Encouraged self-regulated learning	1.8750	0.35355	8

Table A20-0-20: Mauchly's test of sphericity

Within Subjects Effect	Reaction	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Feedback Type	Identify and target technique	1.000	0.000	0	.	1.000	1.000	1.000
	Verified achievement of IP	1.000	0.000	0	.	1.000	1.000	1.000
	Track capability level	1.000	0.000	0	.	1.000	1.000	1.000
	Ensured each technique is mastered	1.000	0.000	0	.	1.000	1.000	1.000
	Adequate information on the set of techniques	1.000	0.000	0	.	1.000	1.000	1.000
	Clear information on what must be able to do	1.000	0.000	0	.	1.000	1.000	1.000
	Diagnose failure of IP	1.000	0.000	0	.	1.000	1.000	1.000
	Encouraged self-regulated learning	1.000	0.000	0	.	1.000	1.000	1.000

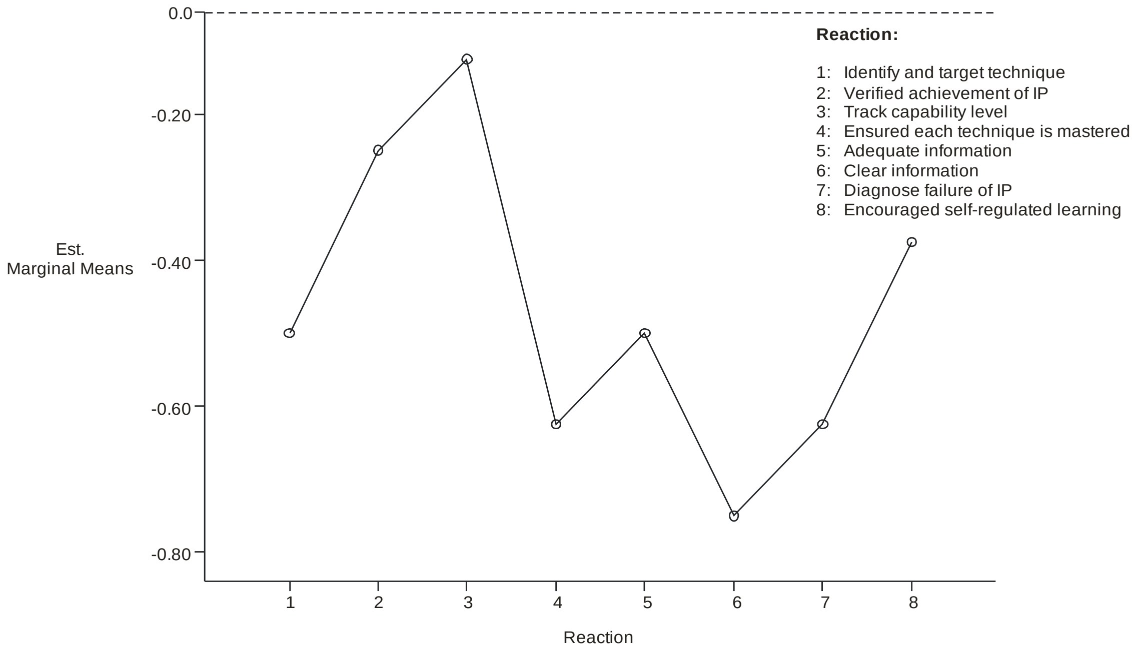


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Figure A20-0-28: Means profile plots of mean reaction differences scores