1 Skill, Ability and Performance

Learning objectives

After reading this chapter, you should be able to:

- understand what is meant by the term 'skill'
- be able to place skills into categories
- be able to analyse the factors underlying skilled performance
- understand what is meant by the term abilities
- understand the theories of ability
- understand the skill–ability interaction
- understand the basics of information processing theory
- understand the basics of ecological psychology (action systems and dynamical systems) theories.

In the first part of this chapter, we examine what is meant by the term 'skill' and how we divide skills into different classifications. The reader is urged to consider the efficacy of these classifications and to question the value of their usage. The second part of the chapter examines ability. The use of the word ability can be misleading. Its use in everyday language compared to its usage in psychology can cause some confusion. Moreover, the reader may wish to question the whole concept of abilities, as defined by psychologists. In the third part of the chapter, we examine the inter-relationship between skill and ability. Finally, the chapter concludes with overviews of information processing theory and some of the ecological psychology theories of skilled performance.

Acquisition and Performance of Sports Skills, Second Edition. Terry McMorris.

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The basis of the explanations of skill and ability used in this chapter are found in information processing theory. Some references to ecological theories are made. However, in general, ecological psychologists tend to use terms such as action and movement to describe skill. They are not concerned about classifications as such. They are interested in how the person's genetic make-up affects their performance, but have little interest in trying to put labels on these factors.

Skill

There are many definitions concerning what we mean by skill. Fortunately most have several common features. It is generally accepted that skill is *learned*, *consistent* and *specific* to the task. Moreover, it is *goal oriented*, i.e. the person is aiming to achieve some specific outcome. This outcome can be quantitative, determined by the performance of a movement that can be measured objectively; or qualitative, measured by subjective judgement. Therefore, in this book we will use the following working definition of skill: *skill is the consistent production of goal-oriented movements, which are learned and specific to the task*.

In order to examine further the nature of skill, we can focus on each of the components, of our working definition, one at a time. First, skills are learned rather than innate. Although we often hear people say that someone is a 'born' footballer or tennis player, this is not correct. Even the very basic skills, such as walking, running, striking and jumping, need to be learned. Subsequent skills that we acquire, such as catching a ball, doing a somersault or hitting a tennis ball, are refinements of the basic skills and need to be learned. Moreover, we cannot say that we have acquired a skill until we can perform it consistently. We have all seen examples of 'beginner's luck'. The novice golfer who hits their first ever tee shot 'straight down the middle' often sees little more of the fairway in that first round of golf.

While I doubt that anyone would question the fact that we cannot say that we have acquired a skill until we can perform it consistently, I think that some readers may have difficulty in accepting that a skill must be learned. I know that many of my students have problems with this concept. It is my belief that the difficulty arises due to what we mean by learning. To most people learning a skill is explicit, i.e. we consciously set out to perform something that we have seen or are told to do. However, learning can also occur implicitly or subconsciously. We often acquire skills without instruction, by simply setting out to achieve a goal. This can be seen when babies learn to crawl in order to reach an object that they wish to touch. They have received no instruction but still manage to crawl. Implicit learning, however, does not only take place in early childhood, it can happen any time when we set out to achieve a goal (see Chapter 8). The key factor is that we can only achieve the goal by learning to carry out the movement.

Whether we learn a skill explicitly or implicitly, the skill is specific to the goal we are trying to achieve. In other words, each skill is unique. That does not mean that there will not be similarities between skills or that the ability to perform one skill will not make the acquisition of another skill easier. The uniqueness of skills can be seen by comparing skills that are very similar to one another. As an example, I will use the lofted pass and chip pass in soccer. Both are struck with the same part of the foot and in both instances the ball needs to be struck beneath the mid-point. In order to go in a straight line, it needs to be kicked along the central axis. For the lofted pass, however, the striker must follow through after contact. For the chip, there is very little follow through and the point of foot–ball contact is much nearer to the bottom of the ball. The uniqueness of the two skills can be seen by the fact that soccer players who are good at performing one of the skills are not necessarily good at performing the other. However, many are good at both skills. The differences between 'similar' skills can also be seen from the fact that even running with a Rugby ball in your hands is different to running freely. Running while dribbling a hockey ball is very different from free running, or even just running while carrying a hockey stick, without having to dribble the ball.

In the previous two paragraphs, we introduced the notion that skill is a goal-oriented activity. The nature of the goal will determine the way in which we evaluate the level of its performance. The goal of many skills is to perform some act that is measured solely by a quantitative outcome. Examples of this are activities like running the 100 m, throwing a javelin and passing a netball to a team-mate. Performance of such skills can be objectively measured. The running of 100 m can be measured in time or by competition against other runners; the javelin by how far you throw; and the netball pass by the accuracy. In such skills it is the *outcome* that is crucial, not how you look while performing the skill. In lay language, skill to perform such tasks often gets mixed up with how one looks while performing the skill. Psychologists call the latter *form*. Form, however, is not the important factor in such skills but outcome is. It is true that many skilful performers, whose outcome is very good, also demonstrate good form (Maria Sharapova for example). However, there are skilful performers who do not look graceful (e.g. the England soccer player Peter Crouch).

I could go on and on giving examples of performers who demonstrate good form and good outcome and athletes whose style does not follow the coaching manual or which is not aesthetically pleasing. The way in which each person achieves a particular goal will differ due to their individual make up. Biomechanists will tell you that very few people, if any, are capable of performing in the way in which biomechanical models of the 'correct' performance suggest. This is because biomechanical models are based on the assumption that the individual possesses a normal range of movement, normal bone structure and so on. Very few of us are totally 'normal' physically. There are very few people who are totally symmetrical, for example. Individual differences will result in people performing the same skill in very different ways.

While a lack of style is acceptable for a skill in which the measurement is an outcome, a breakaway from the accepted norm when performing, would be unsuitable for a skill that is subjectively measured on the basis of its aesthetic appeal. Such qualitative skills are found in gymnastics, dance and ice-skating. In these skills, form, rather than outcome, is the measurement of skillfulness.

Classification of skills

In the previous section, we highlighted the fact that skill is goal oriented. As a result, many psychologists think that, rather than classifying skills, we should simply state the goal of a skill and not try to place it into a specific category, along with other skills. While I tend to agree with this line of thought, I think that it is important that we examine the attempts to classify skills for two reasons. First, the classifications used are a good introduction to the analysis of specific skills. Second, you will come across these classifications in your reading, therefore you need to know to what the writers are referring.

The first classification of skill that I will cover is fine motor versus gross motor skills. *Fine motor skills* are rarely, if ever, found in sport and are skills which require the use of few limbs and are undertaken in limited space (e.g. writing, typing, and sewing). On the other hand, most sports skills are *gross motor skills*. They require the use of several limbs, often the whole body, and tend to take place in a comparatively large amount of space. Despite the fact that sports skills are gross motor skills, much that has been written about skill acquisition comes from research using fine motor skills. Although the American information processing theorist Robert Singer pointed this anomaly out in the 1960s (Singer, 1968), it is only recently that researchers have begun to examine gross motor skills. It is particularly sobering to realize that much of what we teach coaches and physical education teachers, concerning the teaching and learning of sports skills, is based on research with fine motor skills.

Whether fine or gross, skills have been divided into discrete, serial and continuous. *Discrete skills* are those with a definable beginning and end, such as a set shot in basketball, a free-kick in soccer or a pitch in baseball. Discrete skills concern the performance of *one* action in isolation of other actions. On the other hand, *serial skills* are when we join together two or more discrete skills, such as the triple jump. Like discrete skills, they have a definite beginning and end but one component leads into another. So in the triple jump, the hop leads to the step, which leads to the jump. Many gymnastics movements, particularly in floor exercises, are examples of serial skills. On the other hand, *continuous skills* have no recognizable beginning or end. The person can start or stop when they choose. Examples of continuous skills are running, walking, paddling a canoe and swimming. This classification can be useful to us when examining some aspects of practice and learning.

One of the most used classifications of skill, and one which you will definitely come across in your reading, is simple versus complex skills. To me, this is the most controversial of classifications. The notion of simple and complex skills, as used in the motor learning literature, is based on cognitive theories. This is reflected by the fact that *simple skills* are said to be those that require little in the way of information processing demands, while *complex skills* involve much information processing. Simple skills, therefore, would include hitting a golf ball or carrying out a gymnastics routine, where there is little in the nature of decision making and the emphasis is on technique. On the other hand, complex skills would be skills such as passing a basketball. In such a skill, the main factor is not the technical difficulty but the decision of where and when to pass the ball. To call the former skill simple is, in my opinion, to underestimate the neuropsychological demands. Try telling a golfer that it is simple to hit a golf ball accurately!

There is, however, definitely a difference in the demands of skills that require little in the nature of decision making compared to those that require much. Where little information processing is required, technique is the key factor. However, where decision making is important, it is the choice of which technique to use in any given situation that is the major issue. The British psychologist Poulton (1957) did not use the terms simple and complex, but rather open and closed, to distinguish between these kinds of skills. According to Poulton, *open skills* require much in the way of information processing and take place in environments that are rarely, if ever, completely repeated. The change in environment means that every time the skill is performed, the performer must modify his/her technique to achieve the same goal, or even use a different technique to achieve the goal. *Closed skills*, on the other hand, take place in the same or very similar environments,

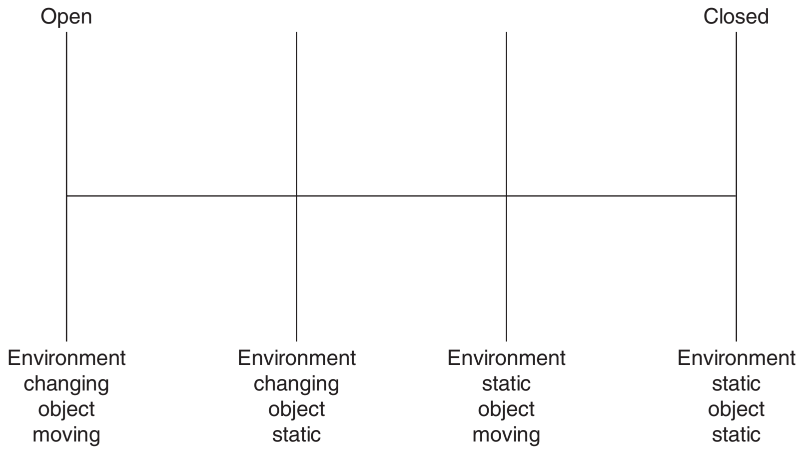

Figure 1.1 Diagrammatic representation of Gentile's open–closed skill classification. Adapted from Gentile, A. M., Higgins, J. R., Miller, E. A. and Rosen, B. M. (1975). The structure of motor tasks. *Mouvement*, 7: 11–28.

therefore the same technique can be used over and over again. Poulton, however, was aware that you could not simply divide skills into *two* categories. Therefore, he claimed that the open-closed classification was best described as being a continuum. Most sports skills will fall nearer to the open end of the continuum than to the closed, although the shot putt is a good example of a closed skill. The size and weight of the shot, the target area and the size of the circle do not alter from one putt to another.

Ann Gentile and colleagues (Gentile et al., 1975) refined Poulton's classification by trying to give some examples of the differences between closed and open situations. The classification does try to take into account some of the neuropsychological differences in tasks, but is still heavily biased towards the importance of decision making and information processing (Figure 1.1).

It is up to readers to decide, for themselves, how much they like or dislike the idea of classifying skills and indeed which type of classification they prefer. Before leaving the subject however, we need to answer the question of whether it is better to simply break the skill down into its component parts rather than placing it into a definitive category. By breaking down a skill, I mean that we should examine the neuropsychological, perceptual and decision-making demands of the skill.

The advantage of breaking down a skill is that you deal with the *specific* skill rather than a generalized concept (e.g. open or closed). Also, you are less likely to focus just on the cognitive aspects of the skill to the detriment of the neuropsychological demands. According to Poulton's classification, making a pass with the inside of the foot, in a soccer game falls well towards the open end of the continuum. Similarly, passing the ball with the outside of the foot and making it swerve also falls close to the open end of the continuum. However, the neuropsychological demands are far greater in the latter, therefore it is a more difficult skill to perform.

Breaking a skill down into its component parts is not as simple as it may seem. Here I will present a breakdown of catching a ball. I will keep it as simple as possible and we will return to it later in the chapter. In order to catch a ball the person must first judge the line and length of flight. They must determine the speed at which the ball is travelling. Then they need to move their hands into the line of flight. They have to decide what style of catch to use, one hand or two, fingers pointing up or down. Immediately prior to hand-ball contact they must ‘give’ (move hands in direction of line of flight), so that the ball does not rebound from a solid surface. They, also, have to close their fingers around the ball at precisely the correct moment. Just a simple skill!

Task 1.1

Choose two skills from any sport and break them down into their component parts, as I have done with catching a ball. Save your answers, as we will return to this later in the chapter.

Ability

The word ability is used in everyday language to describe either the skills we possess or how well we can perform a skill. We may say that someone has the ability to perform a particular task or that another person has great ability in a particular activity. The word ability is used in psychology in exactly the same way, but it is also used in psychology to describe *basic innate actions that underlie skilful performance*. It is easy to confuse these abilities with basic skills, such as walking, running, jumping, and so on. However, as we have seen, those skills are learned while abilities are innate. We naturally acquire these abilities as we develop, although they can be improved by practice. The amount of improvement, however, is limited. It is generally thought that it is the amount and type of abilities that we possess that underpin our proficiency in particular skills. Thus, one person has the necessary abilities to become a gymnast, while another may possess the abilities necessary to become a good rugby player.

The idea that we possess innate abilities that affect how well we acquire and perform sports skills has been with us for some time. This basic premise has, until very recently, gone unchallenged. More recently, Ericsson and co-workers (e.g. Ericsson et al., 1993) have claimed that everyone has the ability to perform *all* skills, if they practise sufficiently. This claim is directly opposed to the notion of abilities underlying skilful performance and the genetic nature of abilities. See Chapter 9 for a more detailed account of Ericsson’s theory.

The notion that we are born with certain natural abilities has intuitive appeal. We only have to observe the people around us to see that different individuals possess different talents. We all know people who ‘have an ear for music’ or are good at skills that require the use of their hands. The idea that people have abilities that predispose them to acquiring many skills in sport led to the notion of a ‘born’ sports person. It was said that such people possess what is called *general motor ability*. Anecdotal evidence supports this claim. Many individuals appear to be good at whatever sport they take up. However, empirical evidence from research tends not to support this claim.

The major researchers into motor ability have been the Americans Franklin Henry (1968) and Edwin Fleishman (1954, 1967). Henry undertook his research with students at the University of California at Berkeley, while Fleishman's research was with American military personnel. Both researchers undertook huge studies examining the abilities possessed by hundreds of people. After carrying out statistical analyses on the data, they both came to the conclusion that there was no such thing as general motor ability. Henry found no evidence of any significant relationships between the abilities he examined. He, therefore, decided that abilities were *specific* and *unique*. Henry explained the 'born' sports person by saying that there were people who possess many specific abilities, therefore they would give the impression of possessing general motor ability. Unlike Henry, Fleishman showed that some abilities were correlated, albeit moderately at best, and could be clustered into groups. The abilities that were related tended to be ones that we might expect, such as static balance, dynamic balance and ballistic balance. Fleishman's theory is known as the *factor analysis hypothesis*, because factor analysis is the statistical procedure he used to determine his clusters. Table 1.1 outlines the clusters identified by Fleishman.

In teaching the nature of ability over a period of more years than I care to remember, I have found very few students who readily accept the findings of Henry and Fleishman. There is a great deal of anecdotal evidence to suggest that there *is* such a thing as general motor ability. We cannot, however, simply write off the findings of Henry and Fleishman. Their research had very large sample sizes and was carried out over a period of many years. One explanation for the anomaly between the research findings and the anecdotal evidence that has been put forward is the notion of *superability*. Superability has been described as a 'weak' general motor ability, which underlies the learning and performance of *all* motor skills. It is the motor equivalent of general intelligence. The amount of superability that each person possesses will vary, just as people's IQ, the measure of

Table 1.1 Fleishman's ability clusters

Psychomotor factors	*Physical factors*
1. Control precision (control over fast, accurate movements that use large areas of the body)	1. Extent (or static) flexibility
2. Multi-limb coordination	2. Dynamic flexibility
3. Response orientation (selection of the appropriate response)	3. Static strength
4. Reaction time.	4. Dynamic strength
5. Speed of arm movement	5. Explosive strength
6. Rate control (coincidence–anticipation)	6. Trunk strength
7. Manual dexterity	7. Gross body coordination
8. Arm–hand steadiness	8. Gross body equilibrium
9. Wrist–finger speed (coordination of fast wrist and finger movements)	9. Stamina (cardiovascular fitness)
10. Aiming	
11. Postural discrimination (coordination when vision is occluded)	
12. Response integration (integration of sensory information to produce a movement)	

Based on Fleishman, E. A. (1967). Development of a behavior taxonomy for human tasks: A correlational-experimental approach. *Journal of Applied Psychology*, 51: 1–10.

general intelligence, does. Individuals with comparatively high levels of superability will be well disposed to learning many skills. However, each person also possesses many specific abilities. The person with low levels of superability but with a strong specific ability, may be good at some skills but weak at others.

Genes

The number of abilities that we possess is determined by our genetic make-up. We inherit sequences of deoxyribonucleic acid (DNA) and stretches of these sequences comprise our genes. For these to be active, however, they must be 'switched on'. This is carried out by a process known as transcription, which results in the formation of messenger ribonucleic acid (mRNA) expression. mRNA expression can be promoted or repressed by proteins called transcription factors. The key issue is that the environment plays a huge role in determining whether transcription be promoted or repressed. We may possess the genes necessary to be a great player in some sport but never have access to participation in that activity. So our potential will be wasted.

The knowledge that genes are essential for abilities to be realized has led to geneticists searching for the genes that facilitate sports performance. This has been almost totally unsuccessful. Some genes have been identified that affect very specific factors, such as alpha-actinin-3 ($ACTN_3$) and muscle strength, but it appears that the complexity of sport means that success is probably determined by the interactions between many clusters of genes. Moreover, as we will see in the next subsection, there are many ways of carrying out the same skills, each way probably requiring different genes.

Research report 1

Haga, M., Pedersen, A. V., and Sigmundsson, H. (2008) Interrelationship among selected measures of motor skills. *Child Care, Health and Development*, 34: 245–248.

Introduction

The purpose of the study was to examine Fleishman's (1966) claims that skills requiring the same or similar abilities will be significantly correlated to one another. Moreover, the authors implied that, if the abilities were similar, the correlations should be high. On the other hand, they stated that, if the abilities are specific, correlations would be low. In fact, Henry (1968) argued that there would be no significant correlations between any abilities.

Method

Participants

Participants were children ($n = 91$), with an almost even split between boys ($n = 46$) and girls ($n = 45$). Mean age for boys was 4.40 (SD = 0.30) years and for girls, 4.40 (SD = 0.29) years.

Test

All participants undertook the Movement Assessment Battery for Children test (Henderson and Sugden, 1992). The test is sub-divided into three sections, each examining a skill that Henderson and Sugden perceived as being inter-related. Section (i) tests manual dexterity using the items posting coins, threading beads and following a trail. Section (ii) examines what the authors call 'ball' skills, with the items catching a bean bag and rolling a ball into a goal. Section (iii) tests balance using balancing on one leg, jumping over a cord and walking with heels raised. The dependent variable (i.e. the method of assessing performance on the test) was a total score for each item, based on both quantitative and qualitative measures. The authors do not provide any information regarding what the quantifiable or qualitative indices were.

Procedure

Children were tested individually in a quiet room, by two assessors.

Results

Correlations between the variables were generally very low and mostly non-significant. There were significant correlations between walking with heels raised and rolling a ball into a goal ($r=0.61$, $p<0.01$); walking with heels raised and catching a bean bag ($r=0.40$, $p<0.01$); jumping over a cord and threading beads ($r=0.35$, $p<0.01$); jumping over a cord and balancing on one leg ($r=0.27$, $p<0.01$); balancing on one leg and catching a bean bag ($r=0.40$, $p<0.01$); balancing on one leg and threading beads ($r=0.36$, $p<0.01$); rolling a ball into a goal and threading beads ($r=0.23$, $p<0.05$); and catching a bean bag and following a trail ($r=0.24$, $p<0.05$). Within each section, there were no significant inter-correlations for manual dexterity or ball skills while, for balance, only jumping over a cord and balancing on one leg ($r=0.27$, $p<0.01$) were significantly related.

Discussion

The authors point out that although there are some significant correlations, they are not between skills requiring the same or similar abilities. It is difficult to see why many of the significant correlations were demonstrated, e.g. why should walking with heels raised and rolling a ball into a goal be related activities? Overall, these results fail to support the idea that there are inter-relations between skills requiring the same or similar abilities. The authors state that the results are similar to those of Drowatsky and Zuccato (1967), who also showed low correlations between tests of static and dynamic balance. The authors go on to examine the implications for learning which is not of interest to us at this moment.

Comment

Here I have focused on the ability aspects of this experiments but it should be noted that the authors were more interested in what this had to tell them about implications for learning. Overall this is a very useful piece of research and shows us that there is more support for Henry's specificity hypothesis than Fleishman's related groupings. However, Fleishman, I am sure, would be critical of the nature of the test used. It is very dubious as to the amount that these items required manual dexterity, ball skills or balance. This is a problem to me.

In understanding the results you need to be aware that in order to see the amount of overlap between two items, you need to square the correlation coefficient (r) and multiply by 100. So the highest correlation, $r = 0.61$, means that 37% of the variation in one task can be explained by the variance in the other.

Also, note that although the authors do not provide any information regarding what the quantifiable or qualitative indices for the dependent variables were, they do provide the reader with a reference for the test. Therefore, the reader can go and find out for themselves.

References

Drowatsky, J. N. and Zuccato, F. C. (1967). Interrelationships between selected measures of static and dynamic balance. *Research Quarterly*, 38: 509–510.

Fleishman, E. A. (1966). Human abilities and the acquisition of skill. In Bilodeau , E. A. (Ed), *Acquisition of skill*. Academic Press, New York, pp. 147–167.

Henderson, S. E. and Sugden, D. (1992). *The Movement Assessment Battery for Children*. The Psychological Corporation, Kent.

Henry, F. M. (1968). Specificity vs. generality in learning motor skill. In Brown, R. C. and Kenyon, G. S. (eds), *Classical studies on physical activity*. Prentice-Hall, Englewood Cliffs, NJ., pp. 331–340.

The ability–skill interaction

In order to understand the ability–skill interaction, we can return to my breakdown of the skill of catching a ball. This time I will attempt to break it down in more detail, using actual abilities. The catcher must use coincidence-anticipation to determine the line, length and speed of flight. They must utilize hand-eye coordination to get their hands into position to catch the ball. If the ball is coming quickly they will need fast dynamic visual reaction time. In order to close their fingers around the ball they will require fast tactile reaction time.

Task 1.2

Rewrite your answers to Task 1.1 but this time naming the abilities that the performer must use.

By breaking down a fairly basic skill, as we have just done, it is possible to see that many abilities can affect performance. In more complex skills even more factors will be involved. As well as the large number of abilities that are involved in performing a skill, we must take into account the nature of the inter-relationship between these abilities.

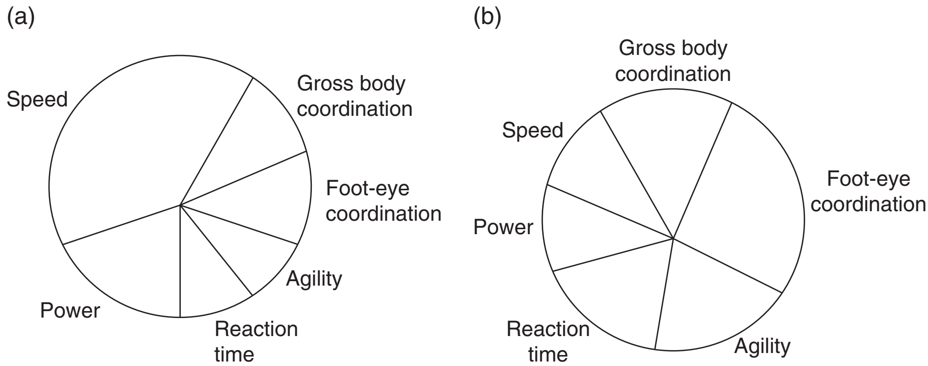

Figure 1.2 Skill–ability interaction: (a) the percentage contribution of different abilities to skilful performance of dribbling by a professional soccer player: (b) demonstration of how the relative importance of each of these abilities differs in its contribution to the performance of another professional player.

In Figure 1.2, I have used a method of diagrammatically describing the relevant importance of different abilities on the performance of a skill. I have taken the skill of dribbling in soccer as my example. In Figure 1.2a, I show the relative importance of specific abilities for one player and in Figure 1.2b their relative importance for another player. These players are real people, both of whom I coached over several years and both of whom became professionals. As can be seen from the two diagrams, the comparative importance of each ability differs, yet both were equally good dribblers. However, the strength of each of their abilities differed, therefore in order to be successful they needed to dribble in different ways. There are many examples of this in top class sport. In soccer, the Stoke City and England player Peter Crouch and the New York Red Bulls and Australia player Tim Cahill are both good headers of the ball, scoring lots of headed goals. However, their height difference (Crouch 2.01 m and Cahill 1.78 m) has led to them using two very different tactics in order to get to the ball before the defenders.

Task 1.3

Choose a skill and draw a diagram, similar to those in Figure 1.2, outlining the relative importance of your own abilities when performing the skill. It would be interesting to ask a friend to also provide you with their interpretation of how you perform. Hopefully this will not end a good friendship.

In order to further examine the ability–skill interaction, we need to be aware that the demands of a task are not necessarily constant. The baseball pitcher or cricket bowler, who can rely solely on speed at lower levels of the game, soon finds this inadequate when he/she steps up to higher levels. Similarly, changes in equipment can lead to the need for different abilities and skills. The change from table tennis racquets covered only by pimpled rubber, with the pimples facing outwards, to racquets with the pimples reversed and layers of sponge between the wood and the rubber, had profound effects on many players. It was the making of some and the end of others. The game changed dramatically with spin service and attacking players taking over from the defensive players. The use of astroturf hockey pitches has also had a major effect on that game. This is called the *changing task model*.

As well as the task changing as individual's step up from one level to another, the people themselves change. These changes may be developmental or due to practice. Examples of the individual changing would be factors like an increase in height or a change in morphology. The *changing person* factor is most noticeable as children go through puberty, but can also occur for other reasons; for example, injuries can cause changes in the range of movement around a joint. This may mean that the individual has to alter the way they perform the skill.

The changing task and changing person factors make the use of testing abilities to predict future performance somewhat unreliable. This is exacerbated by the fact that different individuals use different abilities to produce the same end product. At the height of the Cold War both the Americans and the Soviet Bloc countries tried to use measurement of abilities to identify future stars, but with varying success. Nevertheless, it is still used in some countries.

Summary

It is generally agreed that the performance of a skill is affected by what the individual brings to the task (abilities) and the demands of the task (nature of the skill). Moreover, it is accepted that abilities will change with time. Similarly, the nature of the skill will change when it is placed in a new context: for example playing against better opposition or using better equipment. It is, also, accepted that individuals will perform the same skill in different ways, depending on their own specific abilities. As a result, it is very difficult to use the measurement of abilities to predict performance.

Theories of performance

In this subsection, I will present a very brief overview of the theories of performance and learning that led to the development of information processing theory and the ecological psychology theories. The early theories were based on animal studies and strongly featured the relationship between the stimulus and the response. According to the majority of these theories, when we want to satisfy some need or drive we search for a relevant stimulus and, by trial and error, discover what response will satisfy our need. These theories came from studies, such as those of Skinner (1953), where animals were fed if they acted on a specific stimulus with a certain response. Gradually the relationship between the stimulus and the response was strengthened and the stimulus–response (S-R) bond was formed.

While these theories satisfied the behaviourists, those who tried to explain performance by what they observed, they were unsatisfactory as far as the cognitivists were concerned. The cognitivists were, as the name suggests, interested in the role of the brain in the learning and performance of skills. The first major group of cognitivists was the Gestaltists. The Gestaltists were concerned with the organization of perceptual behaviour into meaningful groups based on their inter-relationships. The individual uses this information to gain the necessary insight to aid problem solving. Problems are often solved by the person thinking through several possibilities before arriving at the correct answer.

Information processing theory

Although Gestalt theorists emphasized the role of cognition in performance, not all cognitivists were satisfied by the Gestaltists' explanation of behavior. It was too vague for many. This lack of satisfaction led to the development of *information processing theory*. This theory was developed at the same time as computers and owes much to the theory of computing technology. The original attempt was as vague, if not more so, than the Gestaltists. It is called the 'Black Box' model (see Figure 1.3). As can be seen from Figure 1.3, it explains very little about how we process information. In fact, it could be argued that it was a behaviourist theory because it concentrated on what happened rather than how it occurred. Information processing theory proper tried to remedy this.

Although there are many information processing models, they are basically the same. The model that can be seen in Figure 1.4 is a simplification of Welford's (1968) model. I will give a brief explanation of the model, and then an outline of the criticisms made of it. It is up to the reader to evaluate the model and the criticisms as he/she reads the rest of this book. In deciding on the chapters of this book, I have followed Welford's divisions of information processing. This is for ease of organization and should not be taken to infer a preference for information processing theory over ecological psychology theories. I have tried throughout the book to present both sides of the picture. It is up to the readers to make up their own minds as to which theory they prefer, if any.

The *input*, to which the information processing theorists refer, is all of the information present in the environment. It is sometimes referred to as the *display*. The display contains a vast amount of information, some relevant to the task and some irrelevant. Relevant information is often referred to as *relevant cues or stimuli*, while irrelevant pieces of information are called *irrelevant cues or stimuli*. This information from the display is relayed to the brain and spinal cord, what we call the *central nervous system* (CNS), by the senses. According to the information processing theorists, the roles in performance, of the brain and spinal cord, are explained by the boxes or divisions shown in the model.

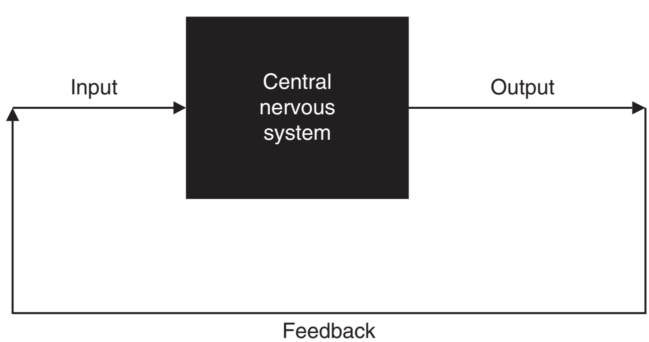

Figure 1.3 The 'Black Box' model of information processing.

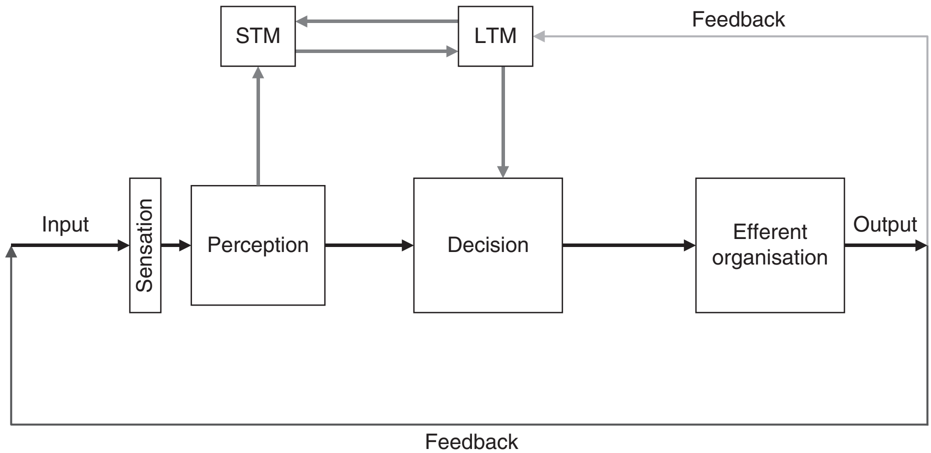

Figure 1.4 Model of information processing. Black arrows represent basic information processing, blue arrows represent working memory activity, red represents feedback for motor control, and green represents feedback for learning. STM short-term memory; LTM long-term memory. Adapted from Welford, A. T. (1968). *Fundamentals of skill*, Methuen, London. For color detail, please see color plate section.

Once the information has been passed to the brain by the senses – *sensation* – the first role of the brain is to interpret the incoming information. If we have normal senses we will all actually see, feel or hear the same things. However, the way in which we interpret them will differ. You only have to hear two people's accounts of the same incident to verify this. How we interpret the incoming information is the role of *perception*. Perhaps the major role of perception is to focus attention to task relevant cues at the expense of irrelevant ones. This is known as *selective attention*. The information processing theorists place great importance on the role of *memory* to aid perception and particularly selective attention.

Perception, according to the information processing theorists, is what we call *indirect* or *inferred* that is it is dependent on our interpretation of the incoming information. This interpretation is based on a comparison between what we hold in *short-term memory* (STM) with what we hold in *long-term memory* (LTM). As you can see from Figure 1.4, there are arrows going from STM to LTM and, also, arrows going the other way. The arrows going from STM to LTM represent the passing of information that we see, hear or feel in the environment to the LTM for future use. The arrows from LTM to STM are concerned with performance rather than learning. The amount of information entering the brain is vast, and therefore we must have some way of selecting the cues to which we will attend. It is thought that this is particularly important, as we are limited in the amount of information with which we can deal at any one moment in time. I am sure that, at this moment in time, some of you are saying, 'You're telling me'. The ability to determine which cues are relevant takes place in the STM. The arrows from the LTM to the STM show how this happens. When people find themselves in a familiar situation, they transfer past experience about such situations from the LTM to the STM. Thus, the STM is forewarned of what is relevant and what is irrelevant, allowing the person to selectively attend to the relevant cues.

This comparison of information, held in the STM and LTM, not only allows the individual to make sense of the incoming information – perception – it also allows the person to decide what action to take in any given situation – *decision making*. These processes together are often referred to as *working memory* (see Chapter 3). Once a decision of what action to make has been taken, the brain has to organize the movement (*efferent organization*). The information, concerning movement organization, is sent from the CNS to the *peripheral nervous system* (PNS), so that the movement can take place. Once we start to move, we begin to process *feedback*. Feedback can be information about the nature of our movements. In Figure 1.4, this is depicted by the bottom feedback arrow. In slow movements, we can use this information to alter or refine our actions as they are being carried out. The top feedback arrow represents information about the success or failure of our actions, and is fed back to memory. This information is stored in the LTM and is responsible for learning.

Regional brain functions and information processing and movement

As with information processing theory itself, in this subsection we will simply outline the main regions of the brain involved in information processing. More detail is given within the individual chapters. Sensation is primarily taken care of by the sensory regions of the brain, the auditory, visual and somatosensory cortices. Perception requires more than simply the sensory regions but also includes input from the prefrontal cortex and the sensory association areas, which are responsible for the organization and interpretation of the sensory information. Decision making is the result of activation of the prefrontal cortex, with the dorsolateral prefrontal region being very important. The anterior cingulate cortex also plays a major role in decision-making processes. However, perception also requires input from information recalled from LTM and this is stored throughout the brain. Efferent organization is under the control of the primary motor cortex, with the premotor cortex and supplementary motor area playing large roles. However, the basal ganglia and cerebellum are also involved. Figure 1.5 shows the major brain regions involved in information processing and movement.

Major criticisms of information processing theory

Throughout this book, we will examine the criticisms of information processing theory. At this stage, it will suffice to outline the major criticisms. The fact that this process is so dependent on memory, in particular the interaction between STM and LTM, means that it must be time consuming. There are many instances in real life that occur much faster than those that can be accounted for by information processing theory. Sport provides many fine examples of this. Normal reaction time, as found in laboratory studies, ranges between 170 ms and 200 ms. This is simple reaction time, when there is only one stimulus and one response. If we increase the numbers of possible stimuli and responses, reaction time increases dramatically. In fast ball games, the player often has very little time in which to respond to a stimulus. There are many examples of this. I will give two here: a cricket batter, facing a bowler bowling at 128 km/h (80 mph), has approximately 500 ms in which to decide what shot to play *and* actually play the shot. Similarly a soccer goalkeeper, facing a penalty kick hit at 88 km/h (55 mph), has only 440 ms in which to save the ball. If information processing theory were correct, it would be impossible

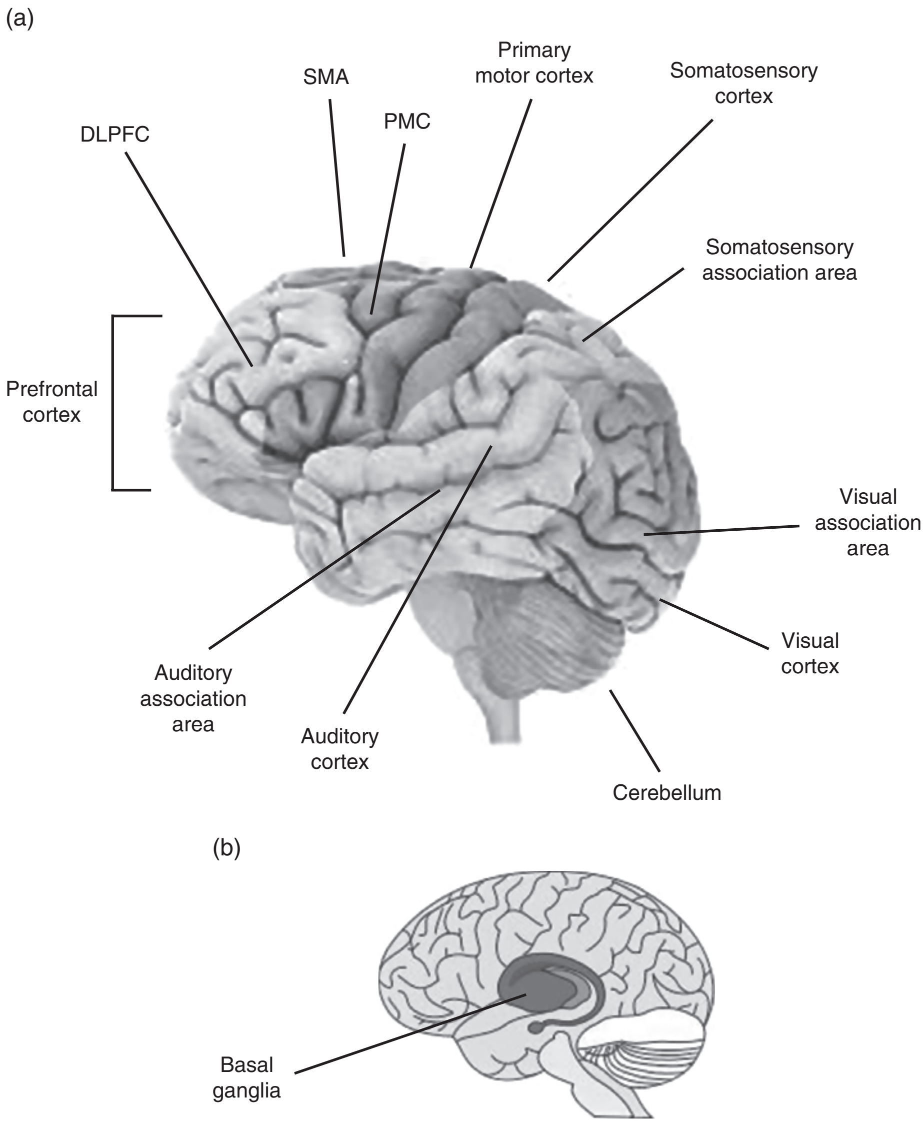

Figure 1.5 Major brain regions involved in information processing and movement (anterior cingulate cortex is not included, see Figure 4.2): (a) a lateral view of the left-hemisphere. The basal ganglia are not visible: their position within the brain is depicted in (b). DLPFC, dorsolateral prefrontal cortex; PMC, premotor cortex; SMA, supplementary motor area.

for a goalkeeper to save a penalty or a batter to hit the ball. The information processing theorists argue that such actions can only take place if the goalkeeper or batter uses *anticipation*. There is some support for this claim (see Chapter 5), nevertheless it does leave some questions unanswered.

Another major criticism that has been made of information processing theory is that, if perception and decision were dependent on the STM–LTM interaction, individuals would only be capable of producing responses for which they have some form of past experience. Thus, the theory cannot account for novel actions. The information processing theorists counter this argument by stating that all the individual needs is experience of a similar, not necessarily the same, situation. The person can then compare the similarities and dissimilarities of the present situation, held in STM, with the past experience, stored in LTM, before deciding how to act. Schmidt's (1975) schema theory (see Chapter 8) attempts to explain this by stating that we do not hold actual past experiences in memory but rather basic rules or *schemas* (sometimes called schemata) concerning our actions.

The third major criticism of information processing theory is concerned with efferent organization. The critics argue that, if the brain were responsible for the organization of all actions that we make, we would need a much larger brain than we have. The information processing theorists claim that, once we have learned a movement, we store what they call a *motor programme* (the efferent organization for the movement) and this motor programme can trigger-off movement with a minimum of effort and organization. Critics counteract this claim by stating that, even if motor programmes require little in the nature of attention and are automatic, we are able to carry out so many skills that we would still need a massive brain to store all the motor programmes. As a result of this criticism, the information processing theorists modified their theory to claim that we do not store each specific motor programme separately but that we store *generalized motor programmes* and are able to modify each general programme for each specific situation. Recently, many information processing theorists have accepted that the brain may only organize the major aspects of the movement and the spinal cord and PNS may be responsible for refining it, to control for the specifics of the situation. We will cover this, and the other major criticisms of information processing theory, in the relevant chapters later in the book.

Ecological psychology theories

The biggest critics of information processing theory have been the ecological psychologists. While information processing theory had its conception in cognitive theories of psychology, the ecological psychologists were concerned with what could be observed rather than what was inferred. As such, they were more based in the behaviourist school. The founding fathers of ecological psychology were the Russian Nikolaï Bernstein and the American J. J. Gibson. Gibson (1979) was concerned with how well we could account for performance based on scientific laws and human interaction with nature. His ideas developed into action systems theory. At the same time that Gibson was developing his beliefs, Bernstein was independently developing his. Bernstein's (1967) ideas were wider in scope than Gibson's but followed the same principle of trying to explain action with as little reference as possible to the role of the brain. We need to remember that this all took place before technological developments such as fMRI and PET. Bernstein and Gibson did not deny that the brain has a role to play in performance but they were concerned that, at the time that they were developing their theories, claims regarding what was happening in the brain were mere speculation and, to them, non-scientific. They believed that we should use scientific principles to explain movement. As far as Bernstein was concerned, these scientific principles could come from physics, Darwinian evolution theory, biology or any other branch of science. What Bernstein and

Gibson would have made of the neuroscientific knowledge that we now possess is impossible to say but I cannot help thinking that there would be some scepticism. Observation of activation of functional areas of the brain does not answer all of our questions regarding the performance and acquisition of skills.

Although there are several ecological psychology theories, the two that have received the greatest amount of attention are action systems theory and dynamical systems theory. These theories complement one another and, therefore, in recent years they have tended to be treated as one or, at least, both are used to explain behaviour by ecological psychologists. Therefore, in this text we will use the term ecological psychology when discussing points that are covered by both theories. If an argument is put forward by only one of the theories we will use the name of the specific theory.

Ecological psychology places great emphasis on the interaction between humans and the environment. The environment dictates what we are allowed to do at any given time in any specific situation. Gibson called these opportunities for action '*affordances*'. Moreover, no two situations are exactly the same, therefore affordances may be similar but never identical. While affordances are present at all times, they will not be acted upon if the individual is unaware of their existence. The person must *actively search* the environment or display for the presence of affordances. A good, though still painful for me, example of this came about when I was coaching a professional soccer team in an important game. The centre-forward had the ball in the centre of the field about 40 m from goal. The right-side midfield player was marked, but the left-side midfield player had a free run to goal. Thus the situation provided an affordance to pass the ball to the left-hand side, allowing the left-side midfielder to head for goal. The centre-forward, however, only looked to the right. He was aware that he could pass the ball to the right-side midfield player. This he did. Unfortunately, this player lost the ball when tackled. The centre-forward was not aware of the affordance to pass the ball to the unmarked left-midfield player because he had not examined the left side of the display. We lost the game one nil. I did not bother explaining to the centre-forward that affordances can only be perceived and acted upon if we actively search for them.

Had the centre-forward searched the display fully, he would have recognized the affordance to pass to the unmarked left midfield player and made the correct response. To the information processing theorists, this would be because he would have recalled similar situations from his LTM and known that this would bring success. The ecological psychologists dispute this. They agree that the centre-forward would have perceived the affordance and made the correct decision but because the information necessary to make the correct decision was present in the display directly. There was *no need for memory*. If the player understood that the aim of soccer is to score, he would perceive the affordance. As long as he searched for it, that is. This is called *direct perception*.

Sport provides many examples of direct perception. As long as you know the aims or goals of the game, the environment provides the necessary opportunities for actions. If you had never played tennis before but saw that your opponent was at one side of the court, you would not need past experience to see the affordance of playing a shot to other side of the court. I am sure that you can provide similar examples from your own sports.

The above account, of direct perception of affordances, may give some readers the impression that the ecological psychologists, like the information processing theorists, believe that perception precedes action. They do not subscribe to such a division, which they see as being arbitrary. According to them, perception and action are linked. This is called *perception–action coupling*. In order to perceive the relevant affordances, the person must act upon the environment. He/she must actively search the environment, using afferent (sensory) and efferent (motor) nerves. Thus perception of the affordance is dependent on movement, as much as receiving sensory information. My centre-forward did not perceive the affordance because he did not move his head, so that he could see the left-hand side of the display. Similarly, once a person begins to act, it is both perception and action that control movement. In other words, as we move we use sensory information to help us control that movement. When running you move your legs and arms but you also look to see where you are going. You are even aware of the feel of your movement.

The ecological psychologists' explanation of the control of movement differs quite markedly from that of the information processing theorists. According to ecological psychologists, the role of the brain is merely to decide what action to take. The brain then provides a very broad set of commands. These commands are said to be *functionally specific*. They are as simple as 'catch the ball' or 'kick the ball'. It is the role of perception–action coupling to determine exactly how the command is carried out – i.e. the way in which we kick the ball, whether it is with the instep, inside or outside of the foot. The perception–action coupling found in any given situation is unique to that situation and will depend on what is required to achieve the chosen goal. Thus, there is no need for motor programmes.

While the theory of motor programmes states that the movement of and interaction between limbs is organized by the brain, dynamical systems theory states that the spinal cord and PNS organize limb movements. This organization is not dependent on memory or detailed instructions from the brain but is the result of the interaction between limbs that are obeying scientific laws. Thus, it is said that the organism is capable of '*self-organization*'. If you lean to your right, your left arm and leg will automatically move outwards to make sure that you do not fall over. Similarly, if you bend your arm, your biceps tense but your triceps relax. If they did not, you would not be able to bend your arm.

The organization of movement is determined by personal and environmental factors. How each person organizes their movements will differ because of their individual strengths and weaknesses. They will, in fact, perform the same skill differently. Venus Williams and Maria Sharapova are both very good servers but have different styles. This is because they are organismically different. Similarly, environmental factors, such as weather conditions, will result in the movement being organized in different ways. It requires different techniques to run uphill or downhill compared to running on the flat.

Two major criticisms of ecological psychology theories have been postulated. The first is that the refusal to accept the role of memory in performance appears to be contradictory to common sense. It is obvious, from observation of individuals that they develop their ability to carry out tasks through practice. If the organism were self-organizing, without recourse to memory or some form of internal representation, the person would be able to perform the task equally as well the first time as subsequent times. This we know is not the case. Very few ecological psychologists now hold the view that some form of internal representation does not take place. They are, however, reluctant to use the word memory; for example, the development of the ability to perceive affordances is called '*attunement to affordances*'.

The second major criticism of ecological psychology is its failure to account for cognitive processes (e.g. decision making). Although ecological psychologists claim that we become attuned to affordances through experience of similar situations, they do not account for how we decide which affordance is the most suitable in any given situation. Anyone involved in sport knows that players often choose an action that is less than optimal. The example that I gave earlier of the centre-forward not passing to the left-side midfield player was due to a failure to perceive the affordance. However, the same player often made incorrect choices even when he had searched the whole display. Ecological psychology makes no attempt to explain how this occurs.

Conclusion

While some psychologists vehemently support their own 'pet' theory, the majority accepts that no theory can totally explain skilled performance. By and large, psychologists can be divided into three camps. Those who believe that the best explanation of behavior is likely to come from the refinement of information processing theory; those who think it lies in the development of ecological psychology; and those who believe in a hybrid theory, taking the best from each school of thought. Many believe that information processing theory provides the best explanation of decision making, while ecological psychology explains movement better. There is, however, less consensus concerning the different explanations of perception – the direct versus inferred debate. The reason that neither theory has been unanimously accepted by psychologists may be due to the fact that *both* provide explanations of how we perform skills. So far psychologists have not been able to find skills that can only be explained by one theory and not the other.

Summary

Skill

- Skill is consistent, goal-oriented, learned and specific to the task.
- Skill may be objectively measured, based on the outcome regardless of the aesthetic merits of the performance.
- Skill may be measured qualitatively, based on what it looks like to the observer.
- Skills may be classified along a continuum from fine (involving few limbs) to gross (involving many limbs).
- Skill may be defined as discrete (having a definite beginning and end), serial (a number of discrete skills linked together) or continuous (having no definite beginning or end).
- Skills may be defined as being simple (containing little in the way of perception and decision making) or complex (drawing heavily on perception and decision making).
- Skills may be classified along a continuum from open (taking place in an ever-changing environment) to closed (taking place in an environment that rarely changes).

Ability

- Abilities are innate.
- Abilities can be improved by practice but only to limited extent.

- The main theories of ability are:
  - general motor ability (determines the individual's prowess at all sports)
  - Henry's specificity hypothesis (abilities are unique and bear no relationship to one another)
  - Fleishman's factor analysis hypothesis (abilities can be grouped into clusters, which have low to moderate correlations with one another)
  - superability (a weak general motor ability underpinning the individuals prowess at sport, but this is also affected by specific abilities).
- The number of abilities we posses is determined by our genetic make-up.
- For genes to be active they must be 'switched on'.
  - Genes are 'switched on' by transcription of DNA sequences to mRNA expression.
- The environment affects the promotion or repression of gene expression.

Ability–skill interaction

- Abilities underpin the performance of skills.
- Different people perform the same skill in different ways because they possess different abilities.
- The relative importance of different abilities changes over time:
  - changing task model (the nature of the skill changes as we move from beginner to elite performer)
  - changing person model (the way in which we perform a skill changes due to changes in our abilities).

Information processing theory

- The information processing theory model (see Figure 1.4) consists of:
  - perception (what we make of the information around us)
  - decision making (what action we decide to take)
  - memory (short- and long-term)
  - efferent organization (the organization of the movements that we wish to make)
  - proprioceptive feedback (aids the control of slow movements)
  - feedback for learning.
- Perception is indirect or inferred and is dependent on memory.
- Decision making is dependent on the comparison of the present situation, held in short-term memory, with similar past experiences stored in long-term memory.
- Perception-memory-decision making form working memory.
- Well learned skills are stored as motor programmes.
- The peripheral nervous system merely relays information to and from the central nervous system.
- The major criticisms of the theory are:
  - the process described would be very time consuming and would take longer than the time taken to perform many skills
  - it does not account for the performance of novel skills
  - our brains are not large enough to store all the motor programs we would need.

Ecological psychology theories

- The major ecological psychology theories are action systems theory and dynamical systems theory.
- The brain is responsible for deciding our goal (what we wish to do) in any given situation.
  - This decision is very general and is said to be functionally specific, e. g., catch the ball, kick the ball.
- We actively search the environment for affordances (opportunities to achieve our goal).
- Perception is direct; it does not require memory, all of the information necessary is present in the environment.
- Perception and action are coupled (both work together to help us perceive and act upon the affordances).
- Movement is controlled by the peripheral nervous system.
  - It is self-organizing (muscles, joints and nerves interact with one another to create the movement).

Test your knowledge

(Answers in Appendix 2)

Part one

Choose which phrase, a, b, c or d, is the most accurate. There is only *one* correct answer for each problem.

1. An example of a serial skill is:
   a) putting the shot
   b) the triple jump
   c) the front crawl
   d) kicking a soccer ball

2. The basketball set shot is an example of a:
   a) discrete skill
   b) serial skill
   c) continuous skill
   d) perceptual skill.

3. According to Henry, reaction time is a:
   a) general ability
   b) specific ability
   c) continuous skill
   d) technique

4. Abilities:
   a) can not be improved by practice
   b) are hereditary
   c) are not affected by age
   d) can be improved dramatically by practice

5. Superability is:
   a) an ability that is better than the person's general ability level
   b) an ability that allows the person to become a top class athlete
   c) a strong general motor ability
   d) a weak general motor ability

6. As children develop physically, the way in which they perform a skill may change because:
   a) their abilities alter
   b) the task alters
   c) they learn faster
   d) they become more motivated

7. According to information processing theory, perception is dependent on:
   a) short-term memory only
   b) long-term memory only
   c) both short- and long-term memory
   d) attunement to affordances

8. According to information processing theory, efferent organization:
   a) is responsible for controlling movement
   b) is controlled by the peripheral nervous system
   c) provides feedback
   d) aids decision making

9. Which of the following is not accounted for by information processing theory?
   a) performing skills automatically
   b) the production of novel responses
   c) performing more than one skill at a time
   d) performing skills without recourse to feedback

10. According to ecological psychology, movement is:
    a) organized by efferent organization in the central nervous system
    b) organized by the muscles and joints
    c) dependent on motor memory
    d) dependent on working memory

11. According to ecological psychology, perception is not possible without:
    a) action
    b) experience
    c) knowledge
    d) working memory

12. Which of the following is not well explained by ecological psychology theories?
    a) how we can perform very fast movements
    b) how we can perform skills that require a great deal of co-ordination
    c) how we can perform different variations of the same skill
    d) how we make decisions

Part two

Which of the following statements are true (T) and which false (F)?

1. Skill must be learned explicitly. T F
2. A skill does not have to be aesthetically pleasing. T F
3. The performance of a skill must be measured quantitatively. T F
4. Passing a ball, in a basketball game, is a complex skill. T F
5. Passing a ball, in a basketball game, is a discrete skill. T F
6. A person can have a relatively weak superability but still be good at a particular sport. T F
7. The relative importance of different abilities, when performing a skill, can change as we move from one level of competition to another. T F
8. Having good technique does not necessarily mean that we are skilful. T F
9. By measuring the ability levels of children, we can easily predict who will be good at different sports when they become adults. T F
10. Working memory consists of perception, short-term memory, decision making and recall from long-term memory. T F
11. According to information processing theory, efferent organization is responsible for every part of a movement. T F
12. Simple reaction time is between 170 ms and 200 ms. T F
13. Information processing theory is good at explaining how we can perform movements of less than one reaction time. T F
14. According to information processing theory, motor programmes are the result of lots of practice. T F
15. According to ecological psychology theories, instructions from the central nervous system, concerning what action to take, are detailed. T F
16. According to ecological psychology theories, perception is passive. T F
17. Action systems theorists say that perception is direct because it does not require memory. T F
18. According to dynamical systems theory, perception precedes action. T F
19. According to dynamical systems theory, the peripheral nervous system plays little role in the organization of movement. T F
20. According to dynamical systems theory, movement is self-organized. T F

Additional reading

Gentile, A. M. (1972). A working model of skill acquisition with application to teaching. *Quest*, 17: 3–23.

Hrysomallis, C. (2011). Balance ability and athlete performance. *Sport Medicine*, 41: 221–232.