Anatomy of agility

Anatomy of Agility
movement analysis in sport

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Introduction

Scientific ideas about movement

Over the past fifty years, scientific theories about coordination have become increasingly complex. Ideas about motor control have evolved; and, over time, more and more factors have come to play a part in how movements will eventually turn out. In the course of this process, theory kept reaching a point at which it was (cautiously) concluded that the overall structure had at last been identified, and all that remained was to fill in the details. This assumption was repeatedly revealed as premature by 'zooming out' from the structure and including the surrounding context – and again and again it was shown that theory was still imperfect.

The original ideas about movement were open- and closed-loop models, turning motor into sensorimotor function. Outside the laboratories where they were tested, i.e. closer to the real world, sensorimotor loops proved not to be isolated incidents. They can be interrelated, which in turn means they can influence each other – for a skilled tennis player can do well at other ball sports involving strokes (field hockey, badminton, baseball and so on). The term 'specificity' was now coined, and open- and closed-loop models had to be expanded to take account of it. The specificity matrix in which similarities between patterns of movement are determined is the product of cognitive processes, with the brain as the super-computer. As a result, the field of cognitive psychology had to be integrated to reveal the underlying mechanisms of specificity.

For decades, motor control theories were held in a stranglehold by cognitive psychology. Finally, they were released from this one-sided cognitive approach by – among other things – a new theory of information processing. Cognitive theory assumed that the environment contains nothing but meaningless information which, just as with a computer, needs all kinds of calculation processes in the brain to allow perception (meaningful observation). The alternative direct-perception theory showed that this notion is untenable in a complex world. Perception – the meaning of observation – is part and parcel of the environment. The brain thus lost its monopoly on perception; and understanding how perception arises therefore meant 'zooming out' even further to the meaningful environment.

And this was not just a matter of sensory function. Cognition also lost its monopoly on thinking about how motor function is organized. In the chaos of the real world, for instance in ball sports or when moving over unstructured terrain, the assumption that the central nervous system can determine and control all movements was no longer tenable. Motor control without direct interaction between the body (and its properties) and the environment cannot suffice. Dynamic systems theory, developing out of Nikolai Bernstein's legacy, revealed the necessary framework for that interaction.

This 'zooming out' and putting sensorimotor function in a broader perspective did not always go down well in the scientific world, and today there is still by no means any ultimate consensus on how motor function is controlled in a complex context. There are still several schools which each claim they can cover a great deal of the total surface of the movement landscape – often without even feeling the need to define which areas do and do not fall within the range of the theory. There are sometimes exaggerated depictions of the 'adversary', just as supporters of ecological theories do when they present certain cognitive theories as a 'hamburger model': a hamburger in which all the nutritive parts are in the middle (the brain) and the body and environment (the halves of the bun) do not apparently play any part. There are also peacemakers who, somewhat pretentiously, proclaim a unification theory in which all the schools can be brought together. The 'constraints-led approach' and 'optimal feedback control theory (OFCT)' have such implicit ambitions or pretentions.

Of course, 'zooming out' will continue, and so current opinion on motor control will also lose its established status; and people studying motor control will have to keep looking for a model that will accommodate the even greater complexity of the subject matter. Indeed, we may eventually have to abandon the idea that we can ever find a single comprehensive theory to describe reality. We will then have to accept that there is a whole series of motor control processes that differ from each other, operate more or less independently and each only apply within certain contexts. Scientific articles will then have to indicate in detail which patterns of movement and contexts the measured effects and underlying explanations do –and do not – apply to. Publications in which certain patterns of movement and contexts are excluded can still be counted on the fingers of one hand; but in the future this may become essential. And it is just as essential in this book, especially because it focuses on the translation from to theory to practice. The analysis in this book is confined to agility in sport and deals with all the high-intensity varieties of the running movement that occur in open situations, from running straight ahead to sidesteps and single-leg jumping with a run-up. This allows a deep analysis, with logical implications for practice.

The book includes a theoretical section and a practical section. The first three (theoretical) chapters mark out the field of high-intensity movement and the context in which agility in sport takes place. This is followed by the more practical chapters, which attempt to provide a coherent, manageable overview within that field of what science has identified so far. In addition to logical reasoning, this should provide an overview with many practical implications – theory and practice of movement analysis in a single book, hopefully without any unbridgeable gaps.

The need for context: Chapter 1

Chapter 1 is not in fact about agility. It begins by outlining a theoretical framework for the analysis of agility. The book aims to map out the complexity of movement in a context, setting out from the concept of 'dexterity' and the four levels of motor control described by Nikolai Bernstein. This model describes the part played by coordination in the overall context of movement. The concept of dexterity points to the body-intrinsic nature of movement. Patterns of movement must not only be designed to ensure a workable link with our environment, but must also cater to what the body needs to ensure its movements are not only effective but also take place with low energy costs and sufficient self-protection. From this we may conclude that coordination mediates between potentially conflicting interests: those that are 'body-intrinsic' and 'environment-intrinsic'.

It is obvious that the environment tends to be variable and changing. What is rather less obvious is that our bodies are also variable. Yet increasing fatigue, changing motivation and so forth have a major impact on what is body-intrinsic, and make the overall context even more complex. This increases pressure on motor control.

The mediating function of coordination is thus very complex. The combined demands from the environment and the body mean that control of movement cannot choose the shortest path between planning and execution, but must make it more robust by using corrective 'what-if' scenarios and even taking less-than-obvious detours.

This should make things clear: complexity must be acknowledged, and simplifying motor control processes soon leads to distortion of reality. The complexity which may make this first chapter rather tough reading will be somewhat reduced in the chapters that describe translation into practice; but the goal is not simplicity, but a balance between manageability and coping with the complexity of reality.

The context of high-intensity movement (in sport and elsewhere): Chapter 2

This book is basically about movement analysis. The complexity of non-linear control makes analysis difficult. Constant changes in the influences on the intention of the movement, the body and the environment make it almost impossible to identify an underlying structure. Approaching the influence of these three components on movement in terms of the 'constraints' each of them imposes on possibilities for movement already gives us a clearer picture of movement analysis. Methods that fail to take account of the constraints imposed by the task, environment and organism can then be judged inadequate.

However, it is highly questionable whether the generally accepted framework as in the theory of the constraints-led approach can suffice for a clear translation into practice. The constraints may need to be further specified in order to make the complexity manageable and prevent it from getting bogged down in abstraction. In order to focus on practicality, this book has therefore opted for a number of restrictions on movement and context:

- *The task: agility in sport based on the running pattern*. Agility may at first sight seem too incoherent for clear constraints to be identified. However, there are good arguments in favour of the idea that all forms of agility are simply variations on the running pattern. The basic running pattern does not change in the various forms of agility.
- *The organism: high-intensity movement*. In high-intensity movement, influences from the body (constraints) are clearer than in low-intensity movement – there are more ways of waltzing than there are of sprinting. In high-intensity movement, many subsystems are overloaded to the point of what is acceptable. This restricts variability in the body (the body becomes less unpredictable), and so the constraints are clearer than in low-intensity movement. That is why it is easier to analyse high-intensity than low-intensity movement.
- *The environment: the playing field and the opponents*. In sports in which agility plays a part there is always standardization of the environment, in which opponents may be the most unpredictable factor. The size and characteristics of playing fields are predetermined, and in organized sports the influence of opponents is constrained by the rules of the game.

Opting for 'high-intensity agility in sports' with such specific constraints allowed analysis of movement that was specific enough to have practical consequences. The aim was to structure agility, seen as varieties of the running pattern, so that the coherence between its various manifestations became clear and strategies for finding and assessing relevant components could be formulated.

The remarkable finding was that there is indeed a relatively simply underlying structure for all the forms of agility based on running, and that all the various sports are in fact structured in the same way. The analysis of agility in this book can serve as a model for analysing all kinds of other families of movement, such as throwing.

Organization and control of agility: Chapter 3

To make a usable analysis of agility, it is important to understand how its various components – all the derivatives of the running pattern – are interconnected. This interconnection, or specificity, is so to speak the supporting tissue of movement. It gives structure to the seemingly chaotic patterns of movement, and makes them controllable and manageable. There are various dimensions of specificity among forms of agility. The most obvious dimension is motor specificity, in which patterns of movement are outwardly similar. Then there is the sensory dimension, especially because agility usually involves a lot of improvisation and the reactive aspect of it (responding to situations as they arise) is important. This book will only discuss the sensory dimension to a limited extent; and this may be criticized. To begin with, the distinction between motor and sensory function is somewhat dubious, for without each other these two aspects of movement become meaningless. At the same time, research shows that truly top-flight athletes particularly stand out in the reactive aspect of agility.

However, the fact that this book mainly focuses on the motor aspect of agility does not mean the sensorimotor dimension has no value. Although meaningful movement depends on sensory function, the reverse is also true: movement filters perception. In a physical posture in which certain actions cannot be performed well or at all – such as suddenly braking when having to change direction abruptly – the relevant information from the environment is rapidly filtered out and no longer perceived. Analysis of motor function is therefore crucial to decision-making. Other literature can be consulted in order to learn about the sensory aspects of agility, without any risk of the interrelationship between motor and sensory function being overlooked.

Besides its motor and sensory dimensions, specificity also has dimensions based on energy, intention and dominant control. The latter, which concerns the level in the organism where the movement is mainly controlled (the brain? the spinal cord? the muscles?), is crucial in order to bring the constraints from the body and the constraints from the environment together. Peripheral self-organization is needed to control the multiplicity of variable components and make high-intensity movement controllable in the context of the environment. This brings us into the arena of dynamic systems theory. In the imminent chaos of explosive agility in an unpredictable world – with opponents and arbitrary ball trajectories –a number of components have to be stabilized so that the situation can become controllable. These stable components of movement ('attractors') turn out to be identical in all forms of agility, and this provides a solid basis for analysis. Control depends on this stability. Stability matters more than perfection, and controlling forces matters more than controlling posture.

Self-organization in agility: Chapter 4

Stability of movement is of course above all necessary where loss of stability can mean failure of motor control and risk of injury. Identifying these critical components is a key step in movement analysis. There has so far been very little research into stable components of movement. This has so far been a matter of logical reasoning based on knowledge of anatomy, neurophysiology and so on, allowing initial distinctions to be made in the multiplicity of possible attractors. In the light of such phenomena as degrees of freedom, degrees of constraints and phase transitions, attractors can ultimately be divided into three categories: passive, active inefficient and active efficient attractors. This localization and classification of attractors is a meaningful intermediate step towards detailed analysis of movements in terms of agility. Such an approach is suitable when analysing not only agility but also all kinds of other high-intensity movements.

Stable components in agility: Chapter 5

Analysis of agility on the basis of the need for stability is built up from the bottom by means of building blocks. Self-organization of the smallest components of the movement creates a series of building blocks that can be used to compose bigger self-stabilizing units. The starting point is the stability, i.e. the attractor state, of individual muscles. If science had accurately mapped out the attractor state of each muscle under a variety of conditions, we would prefer to rely on that information. Unfortunately, scientists seem to be mainly interested in variability – the more, the better – and the stability of muscle contractions has scarcely been studied. The stability of muscle contractions has scarcely been studied. What remains is logical reasoning based on anatomy and the resulting opportunities for self-organization of stability. Which muscle groups are vulnerable and have to be as stable as possible when exposed to major forces, and hence contribute as attractors to the greater whole? The most obvious examples are hamstrings.

Larger clusters of cooperating muscles can be created from the attractor building blocks at intramuscular level. In agility, the quality of movement is dominated by different clusters in each overall pattern. They are self-protecting, appropriate for transporting energy from one part of the body to the other, and for absorbing impinging forces. These clusters can never be properly described by mapping joint positions. Joint positions are too specific, and hence cannot be universal enough for open skills. The principles must be more abstract, such as the joint coupling principle, which is about how joints behave in relation to one another. Each joint has its own latitude for the joint position, and only the way in which joint positions are coordinated is fixed.

The clusters of cooperating muscles are in turn parts of larger units that are ultimately combined into contextual patterns, or overall movements in agility: stop-and-go, sidesteps, spins, running bends, single-leg jumping with a run-up and so on. Clusters of cooperating muscles may be antagonistic within such an overall contextual movement. Such antagonism is one of the most interesting and most limiting aspects of agility, and in many sports determines people's athletic movements.

Examples of analysis: Chapter 6

Translation of the theoretical framework to the manifestations of agility leads to assessment of specific execution. It is here that 'science becomes art'. A subjective, intuitive and experience-based assessment of the quality of movement is inevitable. In contrast to the more black and white descriptions of the earlier stages of movement analysis presented in this book, when we reach this level, things become mainly grey. Obvious errors (passive and active inefficient attractors) may still be black-and-white, but are still only part of the analysis. They are also the simplest to identify. Assessing the quality of active efficient attractors is the most difficult challenge, and when observing high performers, it is the most interesting one. When is achieving improvement still worthwhile, and where it is simply a matter of additional frills that will have little or no impact on overall performance? The answer to such questions will greatly depend on the context.

In a book as a visual vehicle that can only include series of photographs, it is very difficult to present analyses of errors clearly. A good deal of valuable, high-quality information is lost when video recordings and series of images are used for the analysis instead of real-life observation. That is why this book contains only a small number of series of images as examples – especially tennis movements, for the context there is so clear that enough information is preserved. The series are of course only a start – an initial introduction to learning how to look at high-intensity movement for the inexperienced observer. And, for the more experienced coach, the series are a starting point for more structured use of existing observation skills.

Motor learning and the context of agility: Chapter 7

In the first six chapters the constraints-led approach has continually been used to describe the context in which agility takes place. How does this context influence the quality of agility in the long term – in other words, what part does context play in the learning process?

If the context is a rich learning environment, we can best opt for 'whole practice', training in a competition setting; if this setting is less suitable for learning, agility should be trained for in separate practice materials ('part practice').

Central to the learning process is how sensory function is processed. What matters to the learning system is not the *quantity* but the *quality* of sensory function. This means that more sensory information is not necessarily better. By identifying reafferent proprioceptive sensory function (information from the body) and environmental sensory function (information from the context) and comparing these with known learning mechanisms (such as the role of results and variation in learning), we can identify all kinds of organized sports in which agility plays a part. Some sports, such as tennis, turn out by nature to have a rich learning environment; and others, such as soccer, do not. Translated into the constraints-led approach, this means we can draw up rules for interaction between constraints in order to create a powerful learning environment.

Fields not discussed here

Logically, the next stage in the process should be to work out how agility should be taught in practice. However, this means introducing and elaborating an additional, very extensive field of research: motor learning. To take account of what has already been discovered in this area, however, the book would have to be a lot thicker than is necessary in order to analyse movement. Instead, I have chosen not to include such details here, especially as they would detract from the importance of movement analysis to the training process. Movement analysis deserves a book of its own, partly because it is so crucial to the training process, and partly because it is so often overlooked in that process. Even wealthy professional sports organizations seldom make detailed, individualized movement analyses. For details of motor learning and agility, including smart methodologies focusing on types of intrinsic learning and effective feedback processing, you can consult the extensive available literature; but you will largely have to make the conversion to practice yourself. Just as in movement analysis, supporting research has so far provided very little practical guidance.

The approach to movement analysis in this book is strongly focused on the operation of anatomy and the resulting motor control: the 'bio' side of biomechanics. This book therefore pays little attention to the classic, and still customary, biomechanical approach with its emphasis on (external) kinematics and kinetics. It may be useful to seek additional information on this and attempt to link it to the contents of this book. Further support from such fields of knowledge as anatomy of the movement apparatus, neurophysiology, perception-action coupling and so on is useful for a deeper understanding of the subject. Broad knowledge can thus encourage a 'holistic' approach to high-intensity movement in sports.

The structure of movement analysis in this book is so extensive because analysis of agility can then serve as a model for describing the overall principles of movement analysis. Putting together small and large building blocks can also be used to analyse such things as baseball pitching, fast bowling in cricket, hurdling and so on. A remarkably large number of the building blocks in these patterns will be identical to those in agility. For a better understanding of the subject it is therefore advisable to seek less obvious interconnections between the various patterns of movements. Soccer coaches, in particular, should take a closer look at other sports in order to get a better grasp of their own. The structure of high-intensity movement will then prove surprisingly simple.

Once we have successfully analysed high-intensity movement, we can venture into moderate- and low-intensity movement. Analysis of these is significantly more difficult, for the constraints are far less clear than in high-intensity movement. This means that far fewer options for effective movement are ruled out than in high-intensity movement. Science thus makes its research particularly difficult by almost always focusing on moderate- and low-intensity movement. This may help explain why findings are so poorly translated into practice – and hence why people doing practical work are not so very interested in what scientists have to say.

In conclusion

This book also includes boxed text, a terminology list and a bibliography. The purpose of the terminology list and the boxes is to explain various terms with brief descriptions if these make things easier for the reader. They can also provide additional information that is not directly necessary for a basic description. The descriptions are of course not exhaustive, and it may be useful to look for further information elsewhere.

The bibliography is also intended as an aid, although such a list is nowadays rather problematic. A printed bibliography is a rather old-fashioned search engine. Enter a term in an online scientific search engine, and a multitude of sources will pop up – far more than what this book contains. So, the bibliography does not claim to provide a full overview of what research has brought to light. Nor does it claim to back up the contents of the book with fully conclusive scientific evidence. Much of this book is speculative, and ahead of its academic time. Research is far too slow for those who need to do practical work – and it suffers from serious gaps. Scientists bandy terms like 'self-organization' about, and seem not to understand that self-organization depends on self-stabilization. Self-stabilization – of muscle contractions, for instance – is hardly studied, or at least too little to do practical work. The main focus is on variability, which is only the run-up to stability.

If you want sports practice to be evidence-based, the existing scientific evidence will not even give you a part-time job. If you now want to do anything useful in practice, you will have to try your luck with as yet unproven models and experiences with a successful approach. So, the best thing you can probably do is use the terminology list and the bibliography in conjunction with a search for interconnections between research, the concepts in this book, best practices, and the context in which you yourself are working. Interconnections give a better idea of reality than in-depth details; and, for the time being, implicit knowledge will remain a key factor in practical work.