*Physical Education and Sport Pedagogy*
*Vol. 12, No. 1, February 2007, pp. 1–22*

## DISCUSSION

# Think SMART, not hard—a review of teaching decision making in sport from an ecological rationality perspective

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*Background:* Recent developments of theories for teaching decision making in sport offer a large variety of applications for the context of physical education.
*Purpose:* This review of current models of teaching tactical skills concludes that most models incorporate different cognitive learning mechanisms, such as implicit and explicit learning, and are either domain specific or domain general. Yet, most models ignore the structure of the environment when defining in which situation a specific cognitive process will be beneficial and in which situations it will fail.
*Findings:* From an ecological rationality perspective the experimentally validated SMART (Situation Model of Anticipated Response consequences of Tactical training) model is presented; this model identifies in which situation a particular learning mechanism should be beneficial.
*Conclusions:* It is crucial to acknowledge that no one model of teaching decision making is the best but rather that choosing the appropriate model depends on the task and persons involved. The SMART model provides selection criteria for models of teaching decision making used in the domain of sport.

Teaching decision making in sport has seen a resurgence of interest in the past few years. The reasons lie partly in the belief that teaching games in school can be improved if techniques and tactics are connected more appropriately, and partly in the belief in the importance of teaching games in school. Strategic and tactical knowledge orient decision making and are essential components of teaching games (Gréhaigne *et al.*, 2001). Strategic knowledge reflects the competence to plan ahead and therefore influence decisions within a situation. Tactical knowledge is the situation-specific information accumulated through past experience that guides the decision making about the selection of movements and their execution (Gréhaigne *et al.*, 1999). There are two main concerns in most frameworks presenting concepts

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ISSN 1740-8989 (print); ISSN 1742-5786 (online)/07/010001–22
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DOI: 10.1080/17408980601060184

of teaching decision making in sport: What is learned? How is something learned? The first question involves what content needs to be learned and the level of domain specificity of the strategic and tactical knowledge components of decision making. For instance, whereas some frameworks indicate a very game-specific approach, in which it is assumed that 'fundamental knowledge is likely to vary considerably from sport to sport' (French & Thomas, 1987, p. 31), others argue for a high level of transfer between strategic and tactical components of games, at least within related games (Mitchell & Oslin, 1999). To address the second question some have proposed making a distinction between implicit and explicit learning strategies (e.g. Williams & Grant, 1999), with different approaches focusing more on implicitly learned strategies (e.g. Gréhaigne *et al.*, 2001, p. 63) or accentuating more explicitly learned strategies (e.g. Bunker & Thorpe, 1982).

I will present four models that share this argument that technical and tactical training needs to be connected more appropriately, but they differ in at least the two dimensions of learning and domain described below. This review provides an analysis of evidence in favor of these existing models, which include two more recently developed ones, and contributes to the rules in the literature governing model selection based on the situation at hand and the experience of the learner. One model, the Situation Model of Anticipated Response consequences of Tactical training (SMART), allows teachers and coaches to select between different types of learning and to choose the specificity of training from an ecological rationality perspective. This model incorporates features of the player, the task and the situation and seems advantageous over other models proposed to date.

## Learning dimension

On the dimension of learning, a distinction is made at the level of training method in how much explicit information is given to the learner (i.e. implicit vs. explicit learning dimension). The concepts of implicit and explicit learning may be best explained by looking at the learning situation itself. Situations in which actions are incidental in nature engender implicit learning, whereas situations in which actions are intentional in nature engender explicit learning.

Incidental learning (Thorndike & Rock, 1934, p. 1; Perrig, 1996) is learning in a situation without the intention to learn, or without explicit knowledge about the underlying rule structure of the situation. For instance, tactical decisions learned through playing pick-up games in basketball may result in good but nonverbalizable individual decisions about when to pass and when to shoot to the basket. The acquisition of so-called if–then rules, whereby a learner performs in specific situations (if) with specific actions (then), relies mainly on implicit learning if such rules are not explicitly taught (McPherson & Thomas, 1989). However, if a player is introduced to an attack situation by a coach using a blackboard demonstration and skill-like training, repeating the same movement in one context, then he/she will likely produce *verbalizable* knowledge of these if–then rules and will rely more on explicit learning. The learning distinction is a well-known differentiation in sport used mostly for learning movement production (Masters, 2000) and less for movement selection. However, recently (McMorris, 1998; Gréhaigne *et al.*, 2001; Raab, 2003) this distinction has been extended to tactical training and seems to serve both theoretically to classify different models of tactical training or perceptual training (Williams & Grant, 1999; Farrow & Abernethy, 2002), as well as practically to define how to learn decision making in sport. Yet, the advantage of one learning style over the other in decision making (see Raab, 2003, for an overview) or perceptual training (see Farrow & Abernethy, 2002, for an overview) is rarely empirically investigated.

## Domain dimension

The other dimension is how learning is applied to teaching games. On this dimension, concepts can be differentiated theoretically as either domain specific or domain general. In practice, this distinction results in recommendations that are very situation specific, that is, they apply to a specific sport or to a specific situation in a sport, or more generally, so they can be used in different situations and in different sports. An example of a domain-specific situation would be a volleyball game in which players have to learn to choose between spiking beside an opponent block or lobbing the ball with their fingers over the opponent block. How one acts in this specific situation can be only marginally applied to other situations in other sports. However, if a training set-up presents a small-field game in which a ball can be caught and thrown over the net to find a gap between the positions of the opponent team, then this small-field game can be applied to many sports, such as hockey, volleyball or soccer, even though situation factors such as using a stick, a hand or a foot are varied. This kind of approach represents a more domain-general view of tactical training. Direct evidence about the cognitive transfer of tactical concepts (Mitchell & Oslin, 1999) or the transfer of strategic knowledge (Jones & Farrow, 1999) between related net games such as badminton and volleyball is quite rare and experimental control is mostly absent.

Note that both dimensions are defined on a continuum: implicit learning and explicit learning on a continuum of intentionality, and domain general and domain specific on a continuum of transferability.

For the continuum of intentionality it is important to stress that in real sports situations, behavior usually depends on both implicit and explicit learning and tactical training approaches rely on both situation-specific and situation-general components. Nevertheless, the magnitude to which they are positioned toward the poles of each continuum can be distinguished; coaches or physical education teachers consider this when selecting among different models at hand. The perspective (explicit vs. implicit) on learning that underpins tactical training seems undiscovered. Researchers have not yet been able to define the learning perspective, as Kirk and MacPhail (2002) have argued, and I would like to add that no one knows exactly what learning perspective underlies the decision-making process in sport (e.g. Poplu *et al.*, 2003).

For the continuum of transferability it is important to note that transfer of learning generally describes the influence of previous experiences on performing a skill in a new context (Magill, 2001). For the teaching of decision making, however, transferability refers to the ability to transfer 'tactical understanding' between games (Mitchell & Oslin, 1999; Dodds *et al.*, 2001; Mandigo & Anderson, 2003).

Drawing on empirical evidence from laboratory and applied research, I will extend our current understanding of the teaching of decision making in sport by integrating several teaching models in a framework of ecological rationality. Such a framework would allow coaches and educators to choose among the various teaching methods based on the situation at hand. The SMART model will be presented, which defines the interaction of implicit and explicit learning as well as specific and general knowledge applicable to the situation of interest.

## Ecological rationality of decision making in sport

The notion of ecological rationality refers to the study of how cognitive strategies exploit the representation and structure of information in the environment to make reasonable judgments and decisions (Gigerenzer, 2000). In sport, ecological rationality describes the match between a decision-making strategy and the environment in which it is used (Raab & Gigerenzer, 2005). For instance, in basketball, ignoring the opponent's defense structure when defining an attack strategy in most cases will be ineffective. Therefore, a specific attack strategy is not good or bad per se but depends on the strengths and weaknesses of one's own and the opponent's team. The same is true for decision-making strategies in general. What information, how much information and how information is used to decide among a set of possible options depends on the structure of the environment.

What does structure of the environment mean? This can be defined as the information available to the person acting in this environment. The number of predictors (cues) pointing toward one option (criterion), and the specific predictor–predictor and predictor–criterion correlations, constitute essential information that can inform people which option to choose (Hammond & Stewart, 2001). For instance, a goalkeeper in soccer may use different cues such as the approaching attacker's hip or foot position with respect to the ball to decide whether to jump to the left or right corner of his goal. Different distributions of the cues in the environment therefore can be used to decide which information, that is, how many cues and how such cues are used, to apply to derive a choice.

In sport, the ecological rationality perspective is present in approaches of action theory. Action theory defines the three fundamental components of situation, task and person to describe every action (Newell, 1991; Nitsch, 1994, 2004). The action theory transferred to teaching games calls for the definition of personal constraints, situation components and task components. The benefits of describing the environment, the tasks and the abilities of the persons to make a choice between different approaches to teaching tactics in sport seem plausible, however this is often only realized within a specific approach at a broad level (e.g. classification of games and tactical problems, see Griffin *et al.*, 1997). Within the same game of basketball, the task of shooting the ball to the basket is easy or difficult depending on the person's experience and the situational variables such as the activity of the defenders. For instance, on a broad level the classification of different games, such as invasion games (e.g. soccer, rugby), net/wall games (e.g. volleyball, squash), striking/fielding games (e.g. baseball, cricket) or target games (e.g. golf, curling), is often used to differentiate tasks and situations. This classification (Werner *et al.*, 1996) is intended to show levels of complexity; for instance, target games are less complex than invasion games.

On a more specific level, game complexity can be differentiated for tactical situations within each sport. For instance, Mitchell (2000) defined three levels of complexity for attacking. In this differentiation, in basketball, simply to shoot is less complex than to shoot, feign and change speed and this is less complex than to use a target forward, shoot, feign, change speed and move with the ball.

To bridge the various levels differentiating the environment, Raab (2002a) used a measure of complexity to define between-sports and within-sports situations based on the number of players, number of options and their interconnectivity to define a 'cyclomatic number of complexity' (McCabe, 1976, p. 302) quantitatively for different situations. From this perspective the decision-making strategy that is mapped on a specific structure of the environment is domain specific. A classification of complexity on the level of games (e.g. target games are less complex than invasion games) does not seem to be an appropriate level at which to train and transfer decision-making strategies. For instance, in volleyball the information available, the time pressure present and the options available are very different if a player wants to serve or to spike. However, an allocation decision of a midfield player in soccer (invasion game) and an allocation decision of a playmaker in volleyball (net game) may use much more related strategies based on previous performance of players in their respective teams.

If we apply this ecological rationality approach to decision making in sport two conclusions can be drawn that present the benefits of such an approach. First, none of the strategies proposed by models of teaching decision making in games is always superior to other strategies because, depending on the situation and the task, one strategy may fit the constraints of the environment and the person better than another and vice versa in another environmental and personal match. Differentiating models of teaching decision making along the continuum of implicit and explicit learning strategies allows comparison of their efficiency when applied to different sports or different situations within the same sport. Second, because the ecological approach proposes domain-specific strategies, transfer of strategies between different environments should be reduced. That is, transfer between related environments should exist whereas transfer between unrelated environments should be absent. Again, differentiating models of teaching decision making in sport along the continuum of domain specific and domain general enables one to judge the models against the evidence accumulated.

## Models of teaching decision making

The number of models of teaching decision making has been growing recently. Wilson (2002) summarized models that introduce skills first and then tactics (Rink, 1998), tactics first and then skill (Bunker & Thorpe, 1982) and tactical game models that mostly extend the original idea of the Bunker and Thorpe approach (Griffin *et al.*, 1997). Metzler (2000) argued in a similar vein that there are a number of instructional models in physical education. More recently, Kirk and MacPhail (2002) emphasized that we need to know more about how teachers and coaches use models. This current debate should also consider that an important aspect is to select among different models known by a coach or teacher depending on the situation at hand, as indicated in general by action theory, or by an ecological rationality perspective as indicated above.

Four models will be reviewed here that share the combination of skill and tactics in teaching decision making: the Teaching Games For Understanding (TGFU) approach (Bunker & Thorpe, 1982), the Decision Training (DT) approach (Vickers, 2003), a mostly German-published approach called the Ball School (BS) model (Kröger & Roth, 1999) and the SMART model (Raab, 2003). The models can be classified such that the TGFU and the DT lie more toward the explicit pole on the learning dimension, whereas the SMART and the BS will lie more toward the implicit learning pole (Table 1). Furthermore the BS and TGFU seem to be more situation general and the SMART and the DT more situation specific on the domain dimension (Table 1).

### *Teaching Games For Understanding (TGFU) approach*

The TGFU approach, one of the most cited and validated approaches to tactical training (see Griffin *et al.*, 1997; Butler *et al.*, 2003, for overviews), goes beyond more technique-led approaches such as isolating techniques first before integrating them into game-like training (Allison & Thorpe, 1997). TGFU refers to earlier work of Bunker and Thorpe (1982), which indicated that tactical awareness results in making appropriate decisions in skill execution (how to do it) and skill selection (what to do). Game performance in TGFU broadens the perspective of what should be learned in a game to decision making and non-skill behavior, such as court or field coverage from a base position (Griffin *et al.*, 1997). The crucial component of the approach is the use of playing actual games or modified games. Through exposure to the full game or a reduced version, learners come to appreciate the game concept, develop tactical awareness resulting in appropriate decisions that help them in skill execution, enhance their performance and in the end combine

Table 1. Models of tactical training grouped by dimensions of learning and domain

| | Implicit learning | Explicit learning |
|---|---|---|
| Domain specific | SMART | Decision Training |
| Domain general | Ball School | Teaching Games for Understanding |

technical and tactical components (see Kirk & MacPhail, 2002, for a detailed description). Studies to test the validity of the TGFU approach were conducted (Turner & Martinek, 1999), and the TGFU approach has been extended (Holt *et al.*, 2002), modified (Kirk & MacPhail, 2002) and criticized (McMorris, 1998; Dokas *et al.*, 2002).

*Learning dimension.* In the TGFU approach, teaching is mostly done in an explicit way. As McMorris (1998) stated, the TGFU is a cognition-to-technique approach that starts with instructions and understanding of the tactical problems. Turner and Martinek (1999, p. 295) further elucidated the facets of the approach to include 'explaining why a tactic is needed' and 'teaching rules and tactics early in the learning process to enhance each player's understanding' by acquiring declarative or explicit knowledge. However Turner and Martinek (1999) also stated that teaching procedural knowledge that is based on if–then knowledge for appropriate actions is beneficial.

*Domain dimension.* The TGFU approach includes statements about both situation-specific training and situation-general training. Previous work on TGFU states that tactical knowledge will transfer across games that share key characteristics in their tactics (Thorpe & Bunker, 1989). For instance, basketball, netball and hockey are categorized as invasion games because of the use of common features of a target/goal or invading territory to make or defend space in attack or defense. One application of such a TGFU approach is the use of Go through Go To (GtGT) games. GtGT games are small-field, small-group games organized according to tactical problems. This approach does not isolate games for specific sports but rather builds a curriculum around tactical problems because, as Thorpe and Bunker (1989) argue, the tactical nature of games is essentially the same across different sports (Mitchell, 2000).

More recently Jones and Farrow (1999), Mitchell and Oslin (1999) and Turner *et al.* (2001) published empirical investigations mainly on the transfer level of games within the same category (e.g. invasion games, net games) and tentatively supported such transfer. For instance, Jones and Farrow (1999) used a design in which transfer of tactical knowledge from volleyball to badminton was proposed. The treatment group first had a four-week training course of volleyball and then badminton, whereas the control group received before the badminton training a four-week rugby unit. Transfer of knowledge and decision-making speed or accuracy was assumed to transfer from the volleyball to the badminton knowledge because they belong to the same category of net games with similar tactical features to be learned, whereas the rugby unit should not enhance decision making in badminton. Results indicate that knowledge about effective court formations of players assessed in a badminton multiple-choice test was enhanced in the treatment group by 26% from the pre-test knowledge. In addition, decision accuracy in game-play scenarios in badminton presented on video was superior in the treatment group compared to the control group, whereas no differences were found for decision speed.

Mitchell and Oslin (1999) were able to show transfer of tactical understanding from badminton to pickleball (indoor version of tennis), both net games. Ten lessons of badminton, learning strokes and setting up an attack by the creation of space on the opponent's side of the net, were followed by five lessons of pickleball among students from the ninth grade. Decision-making ability was assessed by the Game Performance Assessment Instrument (Oslin *et al.*, 1998). Decision making in pickleball was better than in badminton, suggesting 'that students might have retained some of the tactical learning' (Mitchell & Oslin, 1999, p. 168). An alternative explanation for this result is that pickleball is just easier in respect to decision making and therefore higher scores could be obtained. This is an open and experimental question and the number as well as the experimental control of the previous studies does not allow at this moment to determine the amount of transferability of tactical understanding between games.

It should be noted that one extension of TGFU (Kirk & MacPhail, 2002) also stressed that instructional models such as TGFU should be based on learning theory, and little is known about how students learn decision making in games. Kirk and MacPhail (2002) extended the TGFU model from Bunker and Thorpe (1982) with situated learning that uses as one feature domain-specific knowledge for tactical decisions. Situated learning defines, for instance, the relation between prior experience of the learner, the game's forms, and the context in which these games are played, and therefore extends the understanding of situated performance.

### *Decision Training (DT) approach*

Decision Training describes a coaching approach that allows athletes to make decisions in training similar to those encountered in competition (Vickers, 2003). The Decision Training approach is opposed to a skill-oriented approach, where the same skill is repeated over and over again. DT is usually more variable, includes a number of skills within the same lesson and uses tactically oriented instructions. Including tactically oriented instructions emphasizes the training of cognitive aspects involved in decisions rather than only movement execution.

The DT approach (Vickers, 2000, 2003) consists of seven decision-training tools that incorporate information about practice, feedback, instruction and learning. The tools are 'variable practice,' which uses variations of the situation when teaching within a single class of skills; 'random practice,' which uses variations of the situation when teaching different classes of skills; 'bandwidth feedback,' which delays and reduces feedback for the athlete; 'questioning,' which probes the understanding of the decision making by the athlete; 'video feedback,' for self-analysis of the athlete's performance; 'hard-first tactical instruction,' which teaches technical and tactical concepts early in the learning process or season; and finally 'modeling,' to demonstrate skill or tactic using skilled models to enhance performance.

*Learning dimension.* Vickers *et al.* (1999) differentiate bottom-up behavioral training, such as teaching sub-skills, and top-down decision training, such as teaching techniques as a whole and tactics in their context. Both bottom-up and top-down training of baseball hitting have their merits over the learning course; however, Vickers *et al.* (1999) argue that for long-term improvements decision training is more effective, at least for intermediate and advanced learners, and is as good as behavioral training for novices' acquisition and for transfer tasks such as hitting the baseball with different ball speeds. An explanation for the long-term advantage of DT compared to behavioral training is that learning processes in DT can use higher quality information, because decisions are required during the acquisition. In addition, DT involves the training of complex whole skills that allow easier transfer to related but new situations, such as hitting balls with different speed or spin.

I classify the DT approach more toward the pole of explicit learning than implicit learning because although bottom-up and top-down training can both be learned in an implicit or explicit manner, the method of the DT approach seems to rely more on explicit learning. For instance, instructions concentrate on 'high levels of cognitive effort in learning' (Vickers *et al.*, 1999, p. 366) because coaches provide the learner with strategies and concepts for sport-specific situations. Furthermore, the DT approach uses 'questioning' to probe the understanding of tactical situations by an explicit learning procedure.

*Domain dimension.* The DT approach is domain specific because the concept proposes that each decision highlights a specific cognitive skill that is defined within the context of the sport (Vickers *et al.*, 2004). These cognitive skills are for example how and where to direct attention in a specific situation to specific cues. Furthermore how to anticipate a specific event or to retrieve from memory correct solutions under conditions of limited time (see Vickers *et al.*, 2004, for examples and empirical evidence). Yet it seems that there are some domain-general training procedures as well, such as perceptual training and gaze control, but these are implemented less often and if used are still mostly introduced in a sport-specific manner.

### *Ball School (BS) model*

The BS model concentrates on an ability perspective on non-sport-specific training for small games (Kröger & Roth, 1999). This approach prefers broad training over an early sport-specific specialization and assumes that early sport-specific specialization does not result later in better performance, compared to teaching tactical tools and enhancing levels of coordination. Three pillars represent the concept of BS. The training is ability oriented, playful-situation oriented and skill oriented. Ability-oriented training in BS refers to coordination abilities such as rhythm, balance or orientation. Playful situation refers to the notion that skills are learned through play. Therefore the concept starts with a reduced game form that allows players to explore situations even when they have not yet been trained on technical skills. Skill oriented means that a set of tactical tools is learned, such as 'hitting a target' or 'avoiding defenders.' A list of tactical tools is experimentally validated in net games such as volleyball, for instance (Hossner & Kortmann, 1997).

*Learning dimension.* BS is classified toward the implicit learning pole because training concentrates mostly on small games (playful-situation oriented) without introducing the cognitive structure of how to decide within these games and without introducing regular sport games such as soccer, basketball or volleyball (ability oriented). Evidence that BS training results in improvements in games is presented mostly in German-published journals and coaching manuals (see Kröger & Roth, 1999, for an overview).

*Domain dimension.* The BS model is domain general because it uses games that are introduced as non-sport specific and can be played using hand, foot or bat (Memmert, 2000). In addition, as mentioned above, the ability perspective of BS assumes a high transferability of technical and tactical performance. There are, however, applications of this approach to more specific games such as wall/net games (Roth *et al.*, 2002). However, in applications of the BS training to net games it is assumed that tactical components should transfer between games from the same category, as described in the TGFU approach.

### *Situation Model of Anticipated Response consequences of Tactical training (SMART)*

SMART is a model that defines the use of implicit and explicit learning processes depending on the complexity of the situation, and it is domain specific. Unlike the other models of tactical training, this model describes the underlying processes of tactical decisions linking instructional strategies in a learning theory as previously proposed for other models (Metzler, 2000; Kirk & MacPhail, 2002). Furthermore, SMART defines situations in which one process should lead to better outcomes than another process and enables research-based selection between models of teaching decision making in games. For instance, implicit learning procedures that allow learners to acquire tactical knowledge without the ability to verbalize it, are predicted to be beneficial only in low complex situations (Raab, 2003). In addition the model predicts that transfer from tactical knowledge is only effective in situations in which the same underlying if–then rule structure is present. The general theoretical background of SMART is that decisions in sport are learned through mapping between a situation, the movement and its effect in the environment. For instance, in tennis, a player can learn to return a service cross-court with the effect of hitting the anticipated side of the court and in such a way that the opponent can or cannot reach this return. A number of experiences in sequence will enable one to differentiate the situation (e.g. if the server serves with or without spin), the movement (e.g. the angle of the tennis racket approaching the ball) and the anticipated effect (e.g. hitting the boundary line after hitting a number of times cross-court). Recognizing a situation that is either implicitly or explicitly learned enables one to select an effect that itself generates the movement connected to it (cf. Elsner & Hommel, 2001; Raab, 2003).

In Figure 1 the general scheme is described as progressing from either an implicitly or explicitly learned recognition of the situation, to option generation, choice and perception of the effect of the decisions in the environment. In turn perceiving the

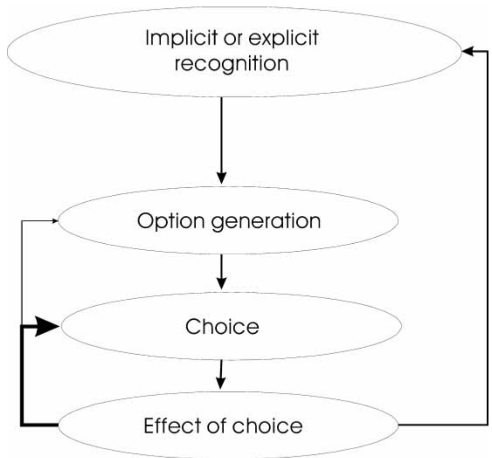


Figure 1. SMART: Situation Model for Anticipated Response consequences of Tactical training. Feedback from the effect of a decision can change processes within the components to different degrees (represented by the different weights of the arrows)

effect of the player's own decisions results in feedback of different magnitudes (indicated by the weights of the arrows) to the above-mentioned components, such as choice or option generation. These processes underlying the components of recognition (Raab, 2002a), option generation (Johnson & Raab, 2003), choice (Raab, 2003) and the effects of choices on further choices (Raab, 2002b; Raab & Johnson, 2004) are presented elsewhere and are not essential for the argument presented next.

*Learning dimension.* Implicit and explicit learning are differentiated by the use of instruction in the teaching process. If if–then rules are verbalized explicitly by coaches or if athletes are themselves using verbalizable information to make decisions, then this is intentional training that leads to explicit knowledge. However, if if–then rules are acquired through incidental training, such as that based on experience, no verbalization of the recognition of the situation is generated, leading to implicit knowledge. Of course in the field both types of training are present and knowledge about situations can be partly verbalized to guide decisions. In a number of lab experiments in sports such as basketball, handball and volleyball, Raab (2003) showed that incidental training results in implicit learning of if–then rules, whereas intentional training results in explicit learning of if–then rules. These data were also replicated in field studies (Raab, 2002a) and extended to possible interactions of implicit and explicit learning (Raab, 2002b). The main finding of four experiments in Raab (2003) was that implicit learning results in faster and better decisions in low-complexity situations whereas explicit learning results in better decisions in high-complexity situations. This finding can be replicated in different sports and does not depend on the level of complexity or whether the complexity of the situations was manipulated by the perceptual (e.g. number of players and distance between them) or the cognitive (e.g. number of options and number of cues) component.

*Domain dimension*. SMART is domain specific because the model requires either implicit or explicit recognition of specific situations to enable option generation and choices. Consequently, better situation-specific recognition results in better decisions, as is known in cognitive science (Klein *et al*., 1995). More precisely, option generation by experts results in better choices (e.g. in a complex attacking situation in ball games) because the options experts generate are mapped to the given situation (e.g. structure of the defense and attack players). Johnson and Raab (2003) found evidence for situation-specific option-generation performance of handball experts, whether options are laid out or to be generated by athletes themselves. Experts generate only those options with a high success rate in this situation.

## The present and the future of decision making in sport

It can be concluded from this review that coaches and teachers use a variety of models for training or teaching games. The ecological rationality approach proposes that teachers should map the structure of the task, the environment and the person to decide between different concepts of teaching decision making in sport. It is clear that following one or another model results in a different kind of learning that is more or less sport specific. Because of the skewed distribution of empirical evidence for or against these models it is difficult to say what model results in greater long-term improvement of players' performance. However, it is also notable that most of these models are difficult to reject on first hand or to evaluate based on given descriptions and owing to a lack of direct comparison between them. The research strategy of comparing skill-led to tactical approaches does not seem to help to discriminate between a variety of different and mostly accepted approaches that combine technical and tactical training. From this review there are at least two developments that seem necessary to improve this field of research and to judge the practical implications of the different models.

First, models that rely on a number of assumptions need to be described in an experimentally (lab-based and field-based research) testable way. For instance, for models at the domain-general pole, assumptions on what can be transferred to which other sports or situations need to be stated more precisely. The domain-specific models, however, need to define the specific situations in which a decision-making strategy works there and only there. Furthermore, the models at the implicit or explicit learning poles need to describe when these learning modes result in better decisions and how we can match a specific teaching procedure to a specific learning process.

Second, in addition to gathering evidence to describe the models precisely, direct comparisons need to be made between the different approaches. To my knowledge none of these comparisons exists. Yet merely comparing the effectiveness of models in a specific situation in a specific sport does not tell us which model is the appropriate choice for a given situation. From an ecological rationality approach it needs to be defined a priori in which situations a particular kind of approach should perform better. One way to avoid having to perform all possible empirical tests for a specific model in a number of different environments is therefore to elucidate the theoretical underpinning of the models, the proposed learning mechanisms, how domain specific these mechanisms are and finally what processes are involved in decision making in a specific situation in a specific game. SMART does propose that approaches at the implicit learning pole are effective in low-complexity situations whereas the approaches from the more explicit learning pole are more effective if situations are more complex. Decision-making strategies that are acquired in one situation or sport may only be transferable to situations in which a similar information structure is present, independent of the classification of the game or tactical problem.

Third, the present review judges approaches only on the dimension of effectiveness of decision making in tactical situations. However, it is clear from the debate on the models described that other criteria need to be validated as well, such as when and how these approaches can be combined on the road to learning games, the learning of the movement production aside from the movement selection itself, the motivational aspects of these approaches and many other criteria that have been discussed for individual models (McMorris, 1998; Holt *et al.*, 2002). It should be noted that although this future avenue can be explored, it does not diminish the necessity of comparing the different models on the criterion they were built for, that is, on how well they teach playing games.

## Acknowledgements

This work was supported by a grant from the Federal German Institute for Sport Science (BISp VF 0407/06/16/95 and VF 0407/06/13/96). The author is grateful to Anita Todd, Joe Johnson and Fabienne Buck for their assistance with the English version.

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# Response to 'Think SMART'—some elements of perception/decision/action in team sports

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The 'Think SMART' paper raises serious concerns about some elements of perception, decision and action in team sports. The purpose of the present contribution is to present another view on certain concepts and frames of reference used in this paper.

From our point of view, a player's game-play intelligence results from a combination of flair, resourcefulness, vigilant attention, sense of opportunity and so on. Based on this description, emphasis is always put on being 'practical' in order to attain success during game play. A player's practical efficiency must be flexible in order to respond appropriately to constantly varying game situations. It has also been recommended that perception and action be coupled for the analysis of expert performance (Chamberlain & Coelho, 1993; Williams *et al.*, 1993; Williams & Grant, 1999). This suggests that when considering the development of decision-making skills, anticipation, decision making and effective action should be associated whenever reflection on action is sought.

## Perception

Any decision, with regard to the context and theory of play, becomes interesting only if it can be efficiently translated into action. This implies that the player actually has at his or her disposal the range of corresponding responses (i.e. individual and collective technical skills and tactics). However, players tend to favour, among accessible answers, those valued by the group to which they belong. Reciprocally, the mastering of technical and tactical skills reinforces motivation. Thus, although tactics make up the context that justifies the use of particular technical skills, these skills should not be perceived as secondary. Technical skills constitute the tools for tactics (Mahlo, 1969). In the visual domain, to perceive implies decoding, putting different perceptions in order and organizing information. In this

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sense, perception represents a critical moment for decision making. It provides for a simplified model of reality but, at the same time, it reveals which clues the player gives priority to over reality (Bouthier, 1989; Gréhaigne & Godbout, 1995; Gréhaigne, 1997).

The problem for a player is to succeed in encompassing the entire complexity of the game within a system made of the smallest possible number of fundamental action axes interrelated in a strong logical and functional unit. Tactics are based on successive decisions, taken according to the evolution of the action. The development of tactical capacity implies the development of a capacity for deciding fast. In turn, this capacity relies on one's capacity for conceiving solutions. In a word, the development of a capacity for choosing requires the development of knowledge and routines. Consequently, the player, through cumulative experience, builds up an actual action matrix, by always assimilating and refining the data collected into a personal mental action picture which allows him or her to act and react faster. More stable elements, such as the competency network, the force ratio, the cognitive map, part of the tactical knowledge or the action plan profile, and part of the player's resources (e.g. motor skills), constitute a meshed background that filters the perception-interpretation-anticipation-decision sequence. As the play action unfolds, more changing elements such as the player's location and posture, the level of one's fatigue and motivation, and the current event profile add their weight and ultimately determine a more or less stable chain of relevant and/or irrelevant decisions.

The whole set of elements can only come into play at a superior cognitive level where one can make choices, face unexpected events and find solutions for new situations. At this point, cognitive processes serve to extract information from play, to make up an adequate representation of the situation, to assess potential events and to draw up action scenarios.

## Configuration of play: anticipation source for decision making

In a broad sense, a configuration is a list or a schema providing the nature and the main characteristics of all elements of a given system. In sport the notion of configuration of play refers to the relative positioning of players in both teams in relation to the possession and the location of the ball (or any object fought for) and in relation with the various players' moves. At times, it is also referred to as patterns of play (Ali & Farraly, 1990) or situations of play (McPherson, 1993).

During the game, a configuration of play evolves as long as the ball remains in play. There are two ways of looking at this. First, as in a picture, the static configuration of play may be defined by the positions of the players at a moment M (Gréhaigne *et al.*, 1997). However, another way of considering the problem in a more dynamic manner consists of defining the micro-state of the attack/defence system on the basis of location, direction and possible speed of all players and the ball involved in the confrontation system at this moment. Considering such a dynamic configuration of play represents a more elaborate answer for describing the reality of the game.

In connection with perceptual and decisional skills, the construct of configuration of play appears crucial because it makes it possible for the players to optimize their activity during play in movement. In this case, one can hypothesize that:

> the perceptual learning consists in extracting configuration schemata from pertinent and typical clues whose covariance or co-presence, in a given situation, makes it possible to reduce the time of analysis and of evolution of the informational context through the choice of favored indicators that are predictive of the global situation. (Paillard, 1987, p. 1422)

Exploiting adequately a configuration of play sends one back to one or many pertinent analyses of its properties. As the opposition evolves, new relations are created between elements of the game and others are destroyed, thus the production of an endless series of instantaneous but temporary balance states. From the point of view of the player's activity, all these relations that constitute the whole set of configurations are not equally interesting. Some are not at stake and the player can ignore them; others must imperatively be recognized because they are the ones that will prompt the production of an adequate response in the shortest possible time. Frequently, there might be different answers that could solve the task at hand but the more pertinent and reliable will quite often be the simplest and the most economical. A good answer involves the selection of some features of the configuration of play, an actual ordering of elements that gathers together all indispensable relationships and only these ones. Ochanine (1978) calls this actual ordering of elements 'operative structure' and calls its representation in the player's mind 'operative picture'. It is an economical picture reduced to the indispensable elements. Its properties are: adaptation to the opposition, laconism, plasticity and an intentional character. This picture will be constructed by and for player activity. In favouring, a priori, certain game-play elements, the player treats these data faster when they appear in a configuration of play. But at the same time, the player is dependent on the frame of reference that allows him or her to seek this information. These elements are at the interface of perception and decision.

Another indication of this decision-making conception is that perception and decision of action are strongly interwoven. Consequently a transfer of this singular process entails problems. The learning process, from a constructivist perspective, implies constant interactions between the subject and the environment. This model emphasizes the contributions of perception and decision to the action. Such a dynamic model reflects the reality of a game played under strong time constraints. One functioning hypothesis is to consider that the player's analysis of play action under strong time constraints is conducted with reference to a few typical configurations of play and related forerunner cues (allowing anticipation). Knowing the essentials of appropriate responses to a given kind of configuration of play facilitates fast decision making (Bouthier, 1986).

## Transfer

The measured effects of prior training on the performance of a subsequent task define the transfer of psychomotor learning. Although it may be similar, this task usually differs measurably from that originally practised. In laboratory tasks, the amount and direction of transfer effects are accurately predicted. In practical skills, transfer is more likely to take place between tennis and badminton, for example, than between swimming and soccer. Similarity is not the only correlate of transfer that can predict such a phenomenon; empirical studies must take account of factors such as the amount of practice and the sequence of events in previous training.

Transfer effects may be positive, negative or zero; learning one task may facilitate, hinder or have no observable influence upon performance of the next task. The degree and amount of transfer are contingent upon such factors as the number of common elements or principles, the stimulus and response similarity, the amount of pre-differentiation training, the variety of learning-to-learn experiences, the part–whole relationships, the differences in inter-task complexity, the use of mnemonic aids and the extent of proactive or retroactive interference. Game-play complexity does not allow simple transfer but frequently confronts the player with a reconstruction of prior learning. In fact, an 'operative picture' is created and strictly interwoven with a particular team sport.

However, the actual research on transfer does not confirm the transferability of previous learning from one game to another. Hence, the transfer of tactics across games within the same category is worthy of examination, particularly given the lack of research on this topic. As is most often the case, research design flaws are difficult to overcome. The studies reviewed by the author of the Think SMART paper (i.e. Jones & Farrow, 1999; Mitchell & Oslin, 1999) present some problems. For instance, how can one observe a transfer of tactical knowledge from badminton to pickleball following five lessons? In fact, recent studies have shown that a minimum of 12 to 14 lessons of two hours each are necessary to obtain true learning in team sports (see Turner & Martinek, 1999; Gréhaigne *et al.*, 2005).

## Discussion

On the road leading to the beginnings of expertise, the connections between perception and action are crucial. But it seems also that the reciprocal link between the various elements underlying perception, decision making and action evolves during a player's development. Particularly, the acquisition of routines related to the perception of useful cues should strongly influence the player's treatment of configurations of play. Knowledge about the rules of the game and action rules is another matter to be considered.

Intuition and 'shortcuts' are ways through which some expert players find adequate tactics without making an inventory of all possible solutions and comparing them. This heuristic functioning intervenes when logic and computation of responses, in an algorithmic sense, are too slow and cannot take incoming information into account.

Once a player has constructed an inadequate game-play solution, it is difficult to inhibit it. The concept of inhibition comes from cognitive psychology and is related to Piaget's thoughts (1974) on the development of intelligence through a coordination mechanism. Hence, cognitive development is not only conceived as the progressive acquisition of knowledge, competencies and routines but must also be related to the capacities to inhibit contradictory reactions of knowledge in resolving game-play problems brought forward by different configurations of play. In addition it is important to take into account a player's adaptability (i.e. flexibility) which seems to characterize the mental activity a player faces in the complexity of game play.

In conclusion, we have discussed the models and some studies proposed in the 'Think SMART' paper because we feel that it has been based on an incomplete frame of reference in team sport modelling and didactics. We hope to carry on this discussion with the authors in an international meeting on Teaching Games for Understanding.

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# Response to the critique: 'Response to "Think SMART"—some elements of perception/decision/action in team sports'

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The critique from the authors provides another view on concepts such as perception, decision and action. The main argument seems to be that they complete an incomplete frame of reference in team sport modelling and didactics as summarized in their conclusion.

Let me respond to similarities and differences between the approaches taken by myself and by the authors. I will concentrate on the three main aspects: the concepts of perception, configuration of play, and transfer. In summary the models presented in my article seem to incorporate the concepts mentioned in the critique and I will try to demonstrate where conceptually and empirically improvements and discussions are most fruitful.

The authors state that decisions made in a dynamic environment require a model that represents the dynamic process rather than a static picture. I agree and indeed support this stance as evidenced by the models proposed in my article. For example the SMART model assumes a sequential selection of the most important cues (perception; Raab & Gigerenzer, 2005) the dynamic configuration of the play (Raab, 1999) and specific aspects of transfer in similar environments (Raab, 2007).

Assumption 1: 'The development of a capacity for choosing requires the development of knowledge and routines.' I agree and the purpose of SMART is precisely to define under which conditions this knowledge should be implicit and when it should be beneficial to present information (e.g. via instructions, feedback) to enable players to verbalize their knowledge explicitly.

Assumption 2: 'Considering such a dynamic configuration of play represents a more elaborate answer for describing the reality of the game.' I agree that for the

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decision-making process these configurations (I call them implicit and explicit recognition) are essential and SMART assumes that they play a crucial role. However, I provide a probabilistic answer on how these configurations are important for an individual decision when time pressure is present (e.g. Raab, 2002; Raab & Johnson, 2004). I provide deterministic answers, too, when a general heuristic should explain decision-making phenomena (Raab & Gigerenzer, 2005).

Assumption 3: 'A good answer involves the selection of some features of the configuration of play, an actual ordering of elements that gathers together all indispensable relationships and only these ones.' Again my approach defines the attributes which allow deciding between given options and how they are ordered (see Johnson & Raab, 2003, for an example). I can't see any controversy here unless on a more specific level a constructivist approach would define how decisions and decision time are predicted.

Assumption 4: 'However, the actual research on transfer does not confirm the transferability of previous learning from one game to another.' I agree, SMART assumes only low transferability of strategies because the ecological rationality approach is domain specific. However this approach goes beyond a taxonomy of different sports to assume potential transfer between games but compares the structure of the information within and between games to predict the amount of transferability.

In sum I am optimistic that there will opportunities to compare the theoretical underpinnings and practical consequences of these models more directly.

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