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Chapter 11

EXTENDING THE RATHER UNNOTICED GIBSONIAN VIEW THAT 'PERCEPTION IS COGNITIVE': DEVELOPMENT OF THE ENACTIVE APPROACH TO PERCEPTUAL-COGNITIVE EXPERTISE

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ABSTRACT

In this chapter, we present the foundations of an enactive approach to cognitive expertise. We first discuss the dichotomy between classical cognitive approaches to expertise and ecological approaches to motor behaviour. The limits of classical cognitive approaches are related to the empirical study of experts on very derived tasks based on the study of memory in laboratory and to the symbols storing problem in continuous and uncertain environments. The limit of the ecological approach is related to the reduction of human complexity to the two-dimensional perception-action system. We propose an alternate framework in which basic cognitive functions such as categorization are taken into account in their links to visual search processes. We report some published experimental data which tend to show that visual perception embody higher-level demands. This shall involves redefining the role of cognition as a teleological constraint for perceptive systems rather than as a mere enrichment process of a poor stimulation, and redefining the ecology of perception as a multiform (i.e., biological, cognitive, physical) and demanding environment rather than as mere array of external light.

INTRODUCTION

> "Often nowadays when I talk to an audience about the ecological approach to perception, I am asked whether this approach has anything to say about cognition, or whether there must be a firm line drawn between perception and cognition with different principles applying. The first answer to this question is that perception *is* cognitive. Cognition has to do with knowing. The number one definition of cognition in my favorite dictionary (Random House) is 'The act or process of knowing: perception'."
>
> E. J. Gibson, 1991 (p. 493)

> "I feel that perception relies on very fine clues that do not appear to everybody, and there is something automatic that virtually reacts at our own place". Bruno Martini (French handball goalkeeper, twice world champion)
>
> In Ripoll, 2008 (p. 80)

The above (second) statement, relying on empirical experience of an expert player highlights the theoretical need for characterising clues that are critical for reducing uncertainty and for regulating one's own behaviour. For about three decades, research in psychology has brought evidence for the existence and use of such critical clues in memory and perception. However, the above statement also supports research endeavours directed towards the building of a theory of automatic and invasive processes in expert perception. The latter aspect is rather poorly understood and little is known about the ability of experts to spontaneously 'couple' to those predictive clues, especially under time pressure. On what basis do they select picked up information? In the present chapter, we advocate for the development of an enactive approach to expertise that should account for both perceptual sensitisation to predictive stimuli *and its relations to usual task goals*. In the course of our development we should contribute to fill in the gap found in the literature between mnemonic and perceptual adaptations. Both processes have been envisaged as a system, which allows linking perceptual behaviour to task demands on the basis of a memory trace which is embodied in the coupling between the variables.

Our approach builds on recent experimental evidence, which demonstrates that: 1) expert visual search behaviours are rather global in nature thereby reflecting and embodying the nature of their *global-and-structural* domain-specific cognition, 2) categorization is a basic phenomenon in expert enhanced perceptual performance, 3) perceptual expertise relies on tight coupling between perception and categorization.

From the 70's, research on expertise has developed in sport and other contexts such as chess, medical diagnosis or music. Chess was certainly the most influential domain with seminal works of de Groot (1946/1978) and Chase and Simon (1973) having dramatic impact on the definition of research protocols on memory, which were imported in sport psychology. Globally, these studies showed that experts are better than novices at recalling familiar material pertaining to chess game. Moreover, Chase and Simon, in 1973, showed that this advantage is mediated by a chunking process by which experts recall sequences of multiple pieces, whereas novices organize information in a more elementary way. From the first moments of experimental research on cognitive expertise, memory and perception were considered together. What we propose here is *to strengthen the fruitful study of the links between perception and cognition*.

In sport, since the 80's, a first trend of research involved a series of authors who proposed laboratory protocols, building on chess literature or memory tasks derived from cognitive psychology (Abernethy, Neal, and Koning, 1994; Allard, Graham, and Paarsalu, 1980; Chiesi, Spilich, and Voss, 1979; Deakin and Allard, 1991; Didierjean and Marmèche, 2005; Garland and Barry, 1991; Starkes, 1987; Werner and Thies, 2000; Williams, Davids, Burwitz, and Williams, 1993). This research corpus demonstrated: i) enhanced recall and recognition skills, ii) decreased change blindness for 'semantic' changes, iii) increased automatic anticipatory abilities for extrapolating future scenarios (even from static displays), iv) the specificity of the expert advantage, the latter rising when the material used is coherently organized, that is structured according to the rules of the game, and according to adaptive principles of players' organisation. The research trend, relying on classical concepts of cognitive psychology, has contributed to the importation of the information processing approach in sport psychology. This participated in revealing cognitive characteristics of expert adaptation in sports while emphasising the role of memory in performance. During the same period, several authors reported research on perceptual aspects of expertise in sport (Abernethy, 1987; Bard and Fleury, 1976; Helsen and Pauwels, 1993; Ripoll, 1988; 1991; Ripoll, Kerlirzin, Stein, and Reine, 1995; Williams and Burwitz, 1998; Williams, Davids, Burwitz, and Williams, 1994). Visual parameters have been studied mainly either in relation to motor control or in relation to decision making in uncertain environments, though, on the field, both aspects of visual function (i.e., 'sensorimotor', 'semantic') interact (see Ripoll, 1991, for examples of studies of the interaction between both functions). The synthesis of the results is not fairly easy because of the diversity of the protocols employed by authors. Fixation duration and number during visual search were sometimes taken as discriminating between expert and novice populations. In several studies, fixation duration was longer and number of fixations was less important in experts than in novices (Helsen and Pauwels, 1993; Ripoll, 1988). However contradictory results were obtained, with experts having more and shorter fixations (Williams *et al.*, 1994). More recently, Martell and Starkes (2004) provided evidence that both behaviours could occur during the same task. For instance, in a live defensive zone task, the visual strategy consisted in elite ice-hockey players of both early and rapid fixations followed by a late fixation of long duration prior to the final execution. Actually, it appears that there is no such thing as a basic change of visual search that would be independent from task nature/progress or cognitive constraints. We believe that understanding perceptual expertise implies giving an account for the multiple coupling between perception, action, cognition and diverse task variables. This is motivated by the will of describing the dynamics of expertise and not only mnemonic performance obtained on very derived tasks. In that, we are sympathetic with the "expert performance approach" – initiated by Ericsson and colleagues (Ericsson and Williams, 2007; Williams and Ericsson, 2005) – which may contribute to "capture" exceptional performance and mediating psychological processes. However, we stress the need to know about the inner nature of the psychological processes involved rather than stressing the need for simulating 'more and more' actual performance. What we propose here is to focus on cognition-perception couplings. We think that capturing the inner psychological constraints also involves understanding the basic relationships between psychological processes, beyond describing patterns of differences in accuracy performance in more and more realistic experimental protocols. In the end, we aim at exemplifying a theoretical-driven approach to expertise, in which perceptual expertise can be conceived as an emergent property of the coupling between usual cognitive tasks encountered on a daily basis (e.g., linguistic labelling of game scenes in expert basketball players when they are working on game systems and tactics with their coach) and visual search parameters (e.g., oculomotor behaviours). This will imply to briefly recall basic principles of the ecological approach to visual perception and to extend its systemic framework to higher-level processes.

It is nowadays traditional and convenient to present an opposition between 'ecological' approaches to perception and action and 'cognitive' approaches to motor control or decision making. In the first framework (J. J. Gibson, 1979), a two-dimensional system is conceived, in which action is specified by perception and perceptual events are created by action (figure 1). It excludes representational concepts because of the 'knowing character' of senses.

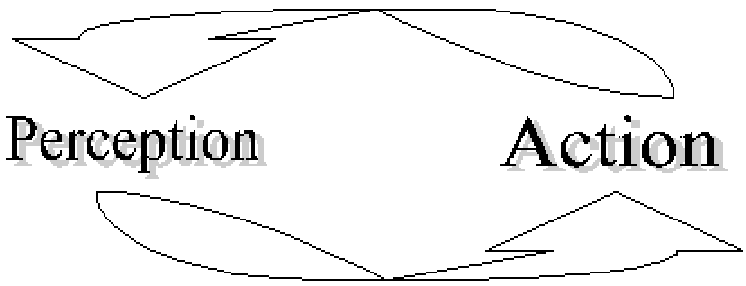

Figure 1. The perception-action cycle in the ecological approach to perception.

Information is significant: there is no need to produce mental representation in order to enrich and interpret incoming stimulation. The approach has been applied with success in 'movement science' for explaining a series of motor behaviours like catching a ball or driving a car, and more generally for explaining the direct perception and the use of optical variables like time-to-collision or vertical optical acceleration (Bootsma and Oudejans, 1993; Lee, 1976; McLeod and Dienes, 1996; McLeod, Reed, and Dienes, 2002). From the other side, there is no such thing as an intelligible 'system' that would account for the determinants of expert performance. Building on both the ecological approach to visual perception (J. J. Gibson, 1979) and the theoretical trend of enaction (Varela, Thomson, and Rosch, 1991), we will be considering cognitive constraints as 'ecological constraints' of perception. In contrast with the usual role attributed to cognition by sport scientists, which would restrict to a support system in charge of the enrichment of initial stimulation, we see cognition as a 'teleological constraint' that weighs on perceptual systems. By 'teleological', we understand the *final* dimension of a process. That is, in a systemic theory, perception and eye movements are seen as embodying higher level cognitive *demands,* which are largely dependent on both the cognitive task at hand and expertise. The perceptual systems are constrained by their ecology, which is not only the external and 'visible' environment – as in the Gibsonian theory –, but also a *dynamic psychological environment.* Behavioural constraints such as categorisation or diverse verbal descriptions of the game imply that search for information is in relation with cognition, not for its symbolic enrichment function, but rather because of its 'output', teleological status. As a consequence, cognition as conceived here may be one term of a two-dimensional coupling with perception. *Cognition, in our chapter is not conceived as an interpretation tool, but rather as a directional force that drives search towards information that has 'historically' or ontogenetically been found to be diagnostic for the satisfaction of* *cognitive-like outputs*. Moreover, the effect of cognition on perception will be considered as a rather straightforward influence which can let perception embody the teleological dimension of usual cognitive outputs (e.g., labelling the category of a defensive organisation in basketball) (figure 2). This does not imply that *symbolic* structures 'pilot' perception or that perception is 'indirect' as suggested by Rock and others (see Rock, 1996).

Note that in our proposal, symbolic structures are not required for getting influence from higher-level functions on perception-action cycles. For example, it is because a given part within a visual scene usually affords a player a given categorisation that he or she will become sensitized to the parts diagnostic of the categorisation. In the remaining part of the present chapter we gather data collected both in the general psychology literature and in our laboratories, which tend to give support for the embodiment view of high-level processes in perceptual systems.

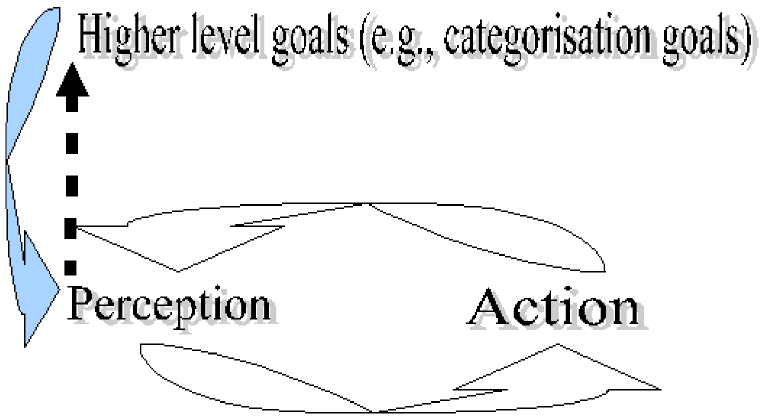

Figure 2. The perception-action cycle and the embodiment of psychological constraints in perception.

THE EMBODIMENT OF CATEGORISATION IN PERCEPTION AS A DIMENSION OF THE PSYCHOLOGICAL ECOLOGY OF PERCEPTION

We first suggest bringing together the domain of perceptual-cognitive expertise in sport and a recent paradigmatic trend in psychology that deals with the interaction between perceptual and conceptual processes (Goldstone, 1994; 2001; Goldstone and Barsalou, 1998; Goldstone, Steyvers, Spencer-Smith and Kersten, 1996; Harnad, 1987; Laurent, 2002; Livingston, Andrews, and Harnad, 1998). Though it is recent, the systematic study of conceptual learning influences on perception has strong experimental and theoretical bases in an earlier "New Look" psychology initiated during the 1940's. The role of 'complexity' in perceptual judgment might date back to those times when Jerome S. Bruner and Cecile C. Goodman published their very amazing data on the organizing role of value and need in perception (1947). In their paper (p. 33), the authors themselves quote Thurstone (1944): "For, as Professor Thurstone has put it, 'In these days when we insist so frequently on the interdependence of all aspects of personality, it would be difficult to maintain that any of these functions, such as perception, is isolated from the rest of the dynamical system that constitutes the person". We think that the fashion of the 'non-cognitive' approach to motor behaviour has conducted to a new reductionism in sport science[1], which paradoxically, in the same time, is associated to a noisy defence of models of 'complexity'. The perception-action couple is a system, but can not afford *alone* satisfactory explanations for other factors than strictly motor ones. Nevertheless, an individual engaged in a sport task is submitted to constraints that do not restrict to the 'realm' of coordination between body segments or to the catching of mobiles. We argue here that sport context is not only a field for the application of psychological concepts but also an ideal field to help building a real theory of complexity. Because on the field players are submitted to a wide variety of constraints (i.e., decisional, emotional, motor, physiological) and because sport science is an 'interdisciplinary field', reducing a theory of behaviour to the motor dimension would be especially misleading and uninspired. In our laboratories, we have developed an experimental program to work on the interaction between perceptual performance and higher-level cognition, such as categorisation. We have been working with expert basketball players which have been known to use schematic diagrams – such as those that are presented on figure 3 – on a daily basis. We hypothesised that expert perception could be sensitised to critical visual features on the basis of their conceptual activity which consists in describing game situations, for example in order to subsequently reproduce an offensive or a defensive plan on the real field. This type of routines has been thought to promote an attunement of search process to visual features that are critical to a given categorisation. Therefore, we set up a series of experiments in which expert and novice basketball players had to discriminate between schematic basketball configurations under severe time pressure (Laurent, 2003*a*; Laurent and Ripoll, 2002). In a 'same-different' judgment task, two coherent basketball configurations were presented sequentially, each during 1200 ms, the first on the left part and the second on the right part of a screen and were projected by a video beamer. Given both the complexity of the scenes, and time constraints, the task was very challenging for the participants. The configurations could be identical or different. When different, they varied either physically, within the same defensive category, or both physically and categorically. That is to say that a physical change could produce or not a categorical change (see figure 3 for an overview of the procedure used for creating stimuli).

After the 1200 ms presentation time period of the second configuration, participants had 1000 ms more, during which they still could give their answer. During this last period, a grid mask was presented on the screen and served as a signal since participants were informed that if their response was not given before the mask had vanished, then their answer would be recorded as "incorrect". Responses were given by pressing two keys of a computer keyboard corresponding to "identical" and "different" responses. Analysis of variance and subsequent post-hoc (all $p < .05$) showed that experts were better than novices at discriminating patterns of game only when a category boundary was straddled between the base and the target (figure 4).

[1] Sometimes non-arbitrarily called 'human movement science'

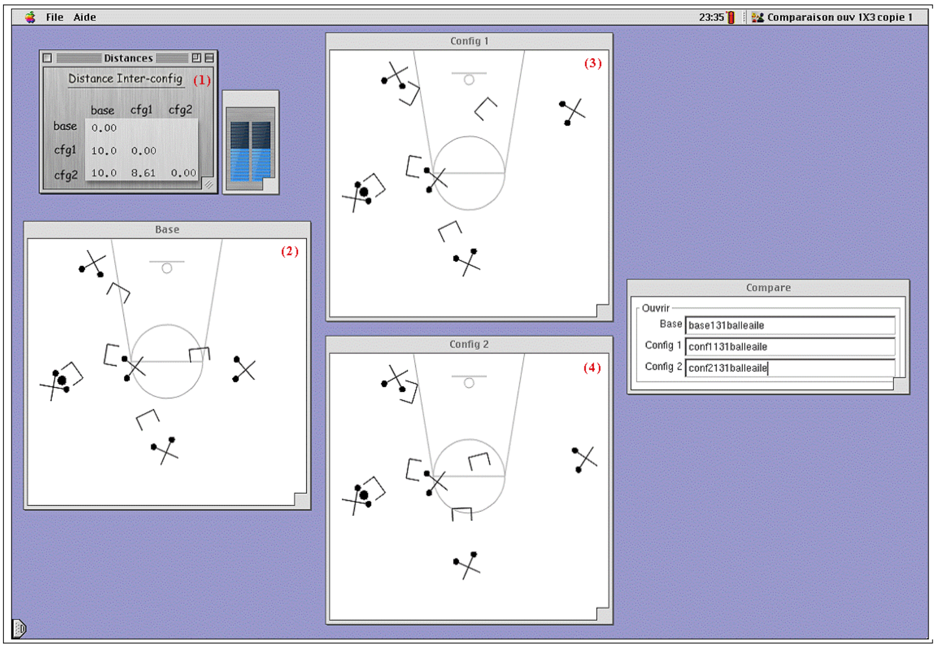

Figure 3. Procedure used for controlling and equating the physical distortion index in both ‘between-category’ and ‘within-category’ conditions (adapted from the cluster encoding method validated by Courrieu, 2001, first method). On the left (box 1), a matrix affords the numerical coding of physical distances between the three configurations. In this example, the source (box 2) belongs to the ‘1-3-1’ category. On the right, the between-category configuration (box 3) belongs to the ‘1-2-2’ category. The ‘within-category’ configuration (box 4) belongs to the ‘1-3-1’ category, like the source. Offensive players are represented by crosses and defensive players are represented by half squares.

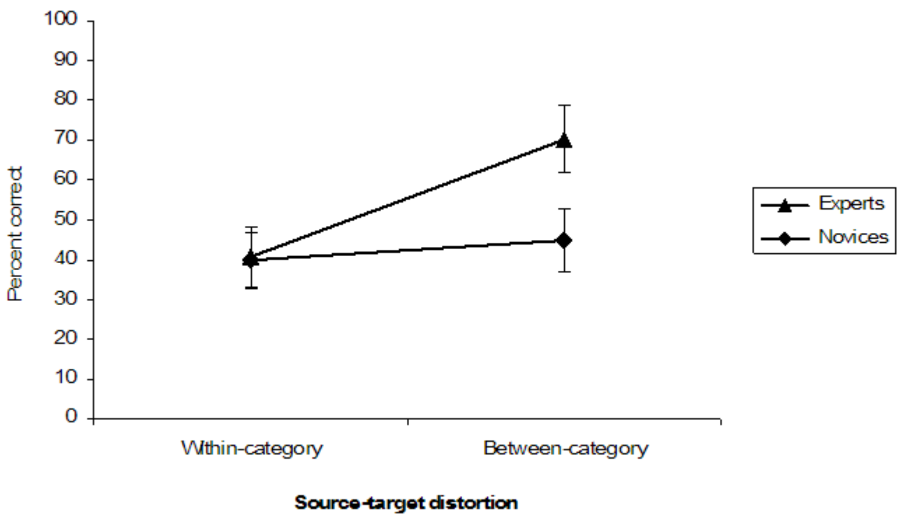

Figure 4. Response accuracy as a function of source-target distortion (within-category, between-category).

In the present study, it is shown that experts can be as weak as novices for discriminating two coherently organised patterns of play. In the literature it has been commonly admitted, since the first studies in sport in the 80's, that coherence was the critical factor for predicting expert performance in laboratory tasks. In our speeded perceptual task, what are critical are the categorical relationships that are established between both configurations. For a similar amount of physical distortion in both ''within-category" and "between-category" distortion conditions, expert perceptual abilities are differentiated. The differentiated pattern is due to the sensitivity of the perceptual system to visual features that are diagnostic of the categorisation. Several arguments tend to favour an early access to categorical features in vision: i) no within-category compression effect was found; it is likely that if a verbal labelling process mediated expert response, then they would have considered different members of the same category as being 'identical'; however experts were not found to be weaker than novices in finding within-category differences; ii) given the complexity of the scenes and the comparison to do, the task placed strong temporal constraints on the psychological mechanisms, which make us privilege a low-level perceptual hypothesis rather than a double perceptual and linguistic labelling process; iii) none of the experts reported to be aware of such a mechanism during the debriefing of the experiment; at most they reported to be aware of some pieces of game organisation. Then, it seems that conceptual categorisation can influence perception, but this influence might not require a conceptual representation to be elaborated during such perceptual tasks. We can conceive that extended practice constrains search and sensitise perceptual systems to visual features that are usually diagnostic of task success. Those features generally afford the player to be successful, so that it becomes highly adaptive for players to search for them when they are dealing with such stimuli. Perceptual discrimination abilities in expert basketball players are dependent on the sensitisation of vision that occurs as a result of a daily coupling between vision and conceptual outputs. In the enactive framework proposed here, we can say that visual expertise is the embodied history of couplings between different organism search components (e.g., vision) and the behavioural or cognitive outputs of the action in which the individual is engaged on a daily basis (e.g., production of categorical labels denoting game configurations).

THE RELIANCE OF PERCEPTUAL EXPERTISE ON PERCEPTION-ACTION CYCLES: EMBODIMENT OF COGNITIVE CONSTRAINTS

The perception-action cycles play a major role in ecological approaches to perception (J. J. Gibson, 1966; 1979). These cycles allow the individual to modify his or her relationship to the world by the regulation of behaviour as a function of perceptual information. Traditionally, the reliance on such cycles is evoked in the framework of motor coordination. In order to get evidence of the embodiment of *cognitive* constraints on perceptual-motor processes, we (Laurent, Ward, Williams and Ripoll, 2006) analysed eye movements of experts and novices in a discrimination task. Basketball experts and novices had to judge whether two configurations were the same or different. The configurations were presented subsequently in the following sequence: first configuration (during 4 seconds) – mask (during 2 seconds) – second configuration (until the answer). The number of elements displaced between the first one and the second one was varied (i.e., 0, 1, 2, and 3). Results mainly indicated that during the perception of the second configuration, novices had their number of eye fixations varied linearly as a function of the number of displaced elements. The greater the number of elements displaced, the fewer the number of eye fixations. This relation was well described by a linear equation of the type $y = -.5236x + 6.8613$ ($p < .05$, $R^2 = .89$). In contrast, experts had their number of eye fixations unchanged across discrepant similarity conditions (figure 5). We have interpreted this as evidence for the embodiment of teleological constraints of cognition in perception and action. The object and the dynamics of visual search are dependent upon the history of couplings between the stimulation (i.e., game scenes) and usual cognitive demands (i.e., verbally describing schematic patterns of games). As far as novices are concerned, they have got no historic coupling between their search process, schematic basketball configurations, and conceptual outputs. It seems then that the information picked up by them involves entities of the visual display; the greater the number of figured entities manipulated, the greater the likelihood to find quickly a local distortion of the display. On the opposite, experts have coupled for years the invariants concerning alignments of players (provided by visual stimulation) with conceptual labels (see the preceding section for examples of labels). Therefore, their search is not sensitive to local manipulation of the display. Their eye movement number is rather constant in this experiment (figure 5).

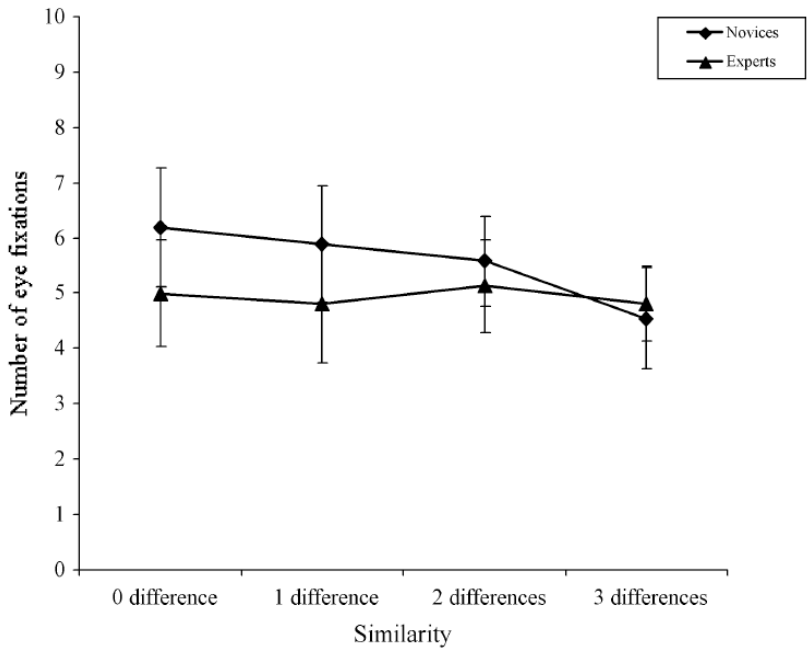

Figure 5. Mean number of fixations (and standard deviations) in experts and novices in the various source-target similarity conditions [reproduced with permission of the Psychology Press, Taylor and Francis Group (http://www.informaworld.com), from Laurent *et al.*, 2006, Experiment 1].

Together with our results obtained when categorical relations between displays were manipulated, this indicates that expertise penetrates vision ability and search, as soon as the eye movement stage, but *most important*, the perceptual sensitization is dependent upon teleological constraints relative to higher-order cognitive goals. A daily conceptual behaviour relying on relational invariants of the visual array generates a search for information that is embodied in specific motor patterns of the eyes.

CONCLUSION

In the theory and experiments discussed in the chapter, perception and discrimination abilities were conceived as: i) being dependent upon the manipulation of categorical features of the visual display, ii) relying on eye movements that embody the task goals usually associated to the processing of such stimuli (i.e., the production of a conceptual response). It is then possible to see cognitive expertise (including sport expertise) as a process that penetrates perceptual systems. A good candidate for explaining the acquisition of a skill subject to give rise to such a pattern of result is ‘‘learned differentiation’’ of visual stimulation (Gibson and Gibson, 1955). Actually, we do not think that symbolic models that have been developed for chess expertise can be applied directly to sport expertise. Some earlier studies in chess reported that experts could decrease the number of their eye fixations, fixate between related pieces, and increase their perceptual span (Reingold and Charness, 2005). This might be interpreted in the mainstream expertise framework. Since the pioneering work of Chase and Simon (1973), it is proposed that experts distinguish from less skilled people in the way they ‘‘chunk’’ visual stimulation in their domain of expertise. These pieces of encoded visual stimulation have been variably estimated in chess (see Reingold and Charness, 2005) to be between 10 000-100 000 (Simon and Gilmartin, 1973), 50 000 (Simon and Chase, 1973) or 300 000 (Gobet and Simon, 2000). However, as Varela and colleagues (1991) put it, chess is like a ‘‘crystalline’’ world. There are particular positions, with a finite number of possible moves. Sport scientists have been tempted by the importation of chunking models in sport, envisaging for example, the programming of eye movements on the basis of abstract knowledge bases (see Williams, Davids and Williams, 1999): “Traditionally, it has been assumed that visual search strategies are determined by task-specific knowledge structures stored symbolically in long-term memory. It is argued that through learning a performer builds up an immense knowledge base of experience which can be used to interpret events encountered in circumstances similar to those previously experienced. These knowledge structures direct the performer’s visual search strategy towards more important areas of the display based on past experience and contextual information” (p. 153). However, if symbolic knowledge bases are made of such a huge amount of chunks and higher-level knowledge like templates (Gobet and Simon, 1996), and that such a modelling is *ad-hoc* for sport, how many chunks and other symbols do experts should *store* whereas their environment of expertise is not ‘‘crystalline’’? If their environment does not include discrete spaces but rather continuous spaces (e.g., a basketball field)? Since any given situation is not strictly the same as another, would an expert have an infinite number of chunks to elaborate? A computational explosion could then occur! We think that perceptual sensitisation to relevant parts of stimuli (such as perceptual zones corresponding to empty parts, between entities) occurs but we do not envisage symbolic storing of ‘‘chunks’’ in memory. We showed earlier that categorisation could be put forward in order to account for perceptual expertise while taking into consideration the bounded character of human resources, and that perceptual systems are themselves constrained to select invariants relevant to usual task goals. In that, we join to the declaration of E. J. Gibson (1991, p. 493): "*Many psychologists think of cognition exclusively as problem solving, reasoning, remembering, and so on, however. I like to point out that these processes begin with and depend on knowledge that is obtained through perception, which extracts information through arrays of stimulation that specify the events, layout, and objects of the world. The ecological approach holds that this process is a direct one, in that the information is picked up without the intermediary of secondary sources, like inference from past experience or from premises that are somehow inherited*" (E. J. Gibson, p. 493). We do not state here that mental representations do not exist or that they are not useful, but their functional role can be questioned and might be even limited to a mental simulation of affordances (see Laurent, 2003*b*, for such a proposal), giving rise to conscious experience. That is, mental representations can be thought of as subjective, emergent, and synthetic end products and serve as a cognitive basis for the conscious experience of the state of subject-environment relationships. Though we cannot formally exclude symbolic computational models of expertise from our empirical results, we show that we need to understand both categorization-perceptual abilities and cognition-eye movements couplings as cases of coordinative structures within a larger psychological system. Furthermore, our conception based on dynamic couplings is more parsimonious in terms of constraints that weigh on the storage of information. Instead of postulating the existence of an infinite number of symbolic chunks (or at least a great number of "classes of chunks", and/or schemas or templates) in memory, we define an enactment process by which the *coordination* – such as the ones evoked in the empirical studies reported in this chapter – allows the pick-up process and potentially, as a non-mandatory consequence, the emergence of a mental representation.

On the other hand, the Gibsonian approach has not been very powerful in describing how expertise emerges. The non-specific concept of "attention" (a disembodied one) has been repeatedly used by the Gibsonian tenants for explaining the psychological adaptation underlying expertise. Alternatively, authors have employed an "ecological approach" to expertise in order to model the progressive attunement of experts to task constraints (Vicente and Wang, 1998). Our approach is slightly different and complementary, in that we try to focus on a new type of ecology: the ecology of psychological processes, at a microscopic scale, can be made of other psychological, physiological or behavioural processes themselves, and the attunement can concern the dynamic coupling *between* these processes in addition to the coupling between the subject and the environmental structure, at the macroscopic scale. We would like to extend the "ecological" frame of perception to other contexts than strictly motor ones. In our enactive view, we defend the idea that historic couplings between perception and cognition can actively modulate the detection of invariants that are predictive of adaptive behaviour. Indeed, beyond the 'realm' of motor production, the adaptive behavioural output of experts can be 'cognitive-like' (e.g., concept production describing the game). Furthermore, each teleological dimension that has got an adaptive value for the human being, including physiological factors (e.g., thirst, see Changizi and Hall, 2001, for an illustration of basic needs effects on perception), can weighs on the attunement of the perceptual system to some invariants in order to get information that specify the state of subject-environment relations with regards to the adaptive needs. These multiple needs have been embodied possibly at different periods of phylogenesis and certainly at different moments of the ontogenesis and at different time scales (from learning during the first months of childhood to the present of physiological variations, and from the macrodynamic scale of learning to the microdynamic scale of physiological changes). This is the reason why sport behaviour, with its composite characteristics, including a wide panel of active determinants (i.e., biochemical, biomechanical, neurological, psychological, etc.), might be a privileged field for the development of this paradigm of enaction, which should prove to be fruitful for people 'truly' interested by complexity. By 'complexity' we understand multiple components that potentially can interact and assemble in different coordinative patterns within a system. Hence we do not state that disembodied symbolic functions such as hypothetic schemas, templates or chunks 'pilot' an enslaved embodied sensorimotor system. Neither do we hypothesize that sensorimotor loops are sufficient to give an account for expertise, as if all adaptive behaviours could be restricted to the range of movement and to perception-action coupling. We suggest adopting the enactive perspective for improving our knowledge of interactions between cognitive and sensorimotor dynamics, as well as in order to better understand the multiple factors underlying expert behaviour in the framework of a single theoretical system.

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