Attention Alters Appearances and Solves the 'Many-Many Problem': Implications for the Research in Skill Acquisition

Raúl Sánchez García[1] & Miguel Ángel Sebastían[2]

(1) Universidad Europea de Madrid; (2) Universidad Nacional Autónoma de México

Raúl Sánchez García, Depto. Teoría, Recreación y Organización del Deporte, UEM.

Miguel Ángel Sebastián, Facultad de Filosofía y Letras, UNAM

Correspondence concerning this article should be addressed to Raúl Sánchez García, Departamento de Teoría, Recreación y Organización del Deporte (CAFYD),Universidad Europea de Madrid, Edificio D, planta 1(sala profesores), C/ Tajo s/n, 28670 Villaviciosa de Odón, Madrid. E-mail: raul.sanchez@uem.es

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Abstract

In this article we argue that research in skill acquisition has underestimate the relevance of some features of attention. We present and theoretically discuss two essential features of attention that have been systematically ignored in the research of skill acquisition, both at a sub-personal and a personal level: attention alters in an essential way the perceived stimuli; and attention is crucial for solving 'the many-many problem'. We also propose new lines of research and implications for training within skill acquisition that take these ideas into consideration.

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What is Attention? An Intuitive Approach

An interesting way of approaching the problem of attention is by an intuitive and pre-theoretic conception. William James (2007) presents it as follows:

> Every one knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration, of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others, and is a condition which has a real opposite in the confused, dazed, scatter-brained state which in French is called *distraction*, and *Zerstreutheit* in German. (ibid. pp. 403-404).

Attention is a constitutive part of our pre-theoretical understanding of other's cognition and behaviour; in other words, a constitutive part of our folk-psychology. We make use of the notion of attention (as of the notions of belief, desire, or intention) to make sense of other's actions and predict their behaviour on that basis. We speak of *focusing attention* in the coming ball to return a serve in tennis or to shoot and score in football or in the opponent's balance in order to apply a winning technique in judo. If one concentrates attention on a certain part—e.g. the tennis ball—one might not hear the sound of the crowd or notice the presence of the judges (Chabris and Simons, 1999). Furthermore, it is clear that one plays better tennis when one does it attentively than when distracted by trivial thoughts or by the sound in the stands. Some skills—like driving—are likely to be deployed in the (nearly) absence of attention, while engaging with other activities: listening to the music, a phone conversation or our own private thoughts. This is true, but only if the driving task is easy enough. It is doubtful that you could do that while driving a F-1 at 300 km/h!

Furthermore, as James pointed out, attention seems to be related to our conscious experiences and the way things seem to us: *what-it-is-like* for us to perceive things (Block, 2002; Nagel, 2002). There is something it is like for you to focus attention on this paper instead of in the music that sounds in the background and switching attention from the music changes the character of your experience.

These kind of considerations bring Watzl (2011) to characterize attention more recently as "the selective or contrastive aspect of the mind: when you are attending to something you are contrasting what you pick out with what remains in the background." (ibid. p.845). Nonetheless, it is very difficult to go beyond this intuitive definition and provide a more detailed characterization of what attention is; in part because it is a complex neuropsychological function. Already in 1959, Moray (1959) founded more than 12 different definitions for the term attention and nowadays there is no complete agreement about what attention is and what is not. A complete definition of it should not only incorporate the aspect relative to the selection of stimuli in the environment but also to the selection of plans directed to goals (Tirapu-Ustárroz et al., 2011, ch. 6). From a neuropsychological perspective, Luria (1975) made use of this idea an defined attention as selection process for the necessary information, the consolidation of the elegible action programs and the maintainance of a permant control over them.

This paper highlights two essential features of attention that have been systematically ignored in the research of skill acquisition, both at subpersonal and personal levels.[1] First,

[1] In order to clarify such differentiation in the conceptualization of levels, we subscribe the following distinction proposed by Hurley (1998):

> When we conceive of intentional agents at the personal level, we think about the relations between what they perceive and intend, what they believe and desire, and try to make sense of them as acting for reasons, though of course allowing for irrationality and mistakes. By contrast, causal explanations in neurophysiological or computational terms describe subpersonal mechanisms and functions. The personal level contents of mental states can be seen as carried by such subpersonal processes, or vehicles of content. But the properties of subpersonal processes, of vehicles of content, cannot simply be projected into personal level mental content, or vice versa. These different ways of looking at and describing an organic system need not display isomorphisms or map onto one another in any simple way. As with emergent properties of dynamic feedback systems in general: Significant qualitative differences at one level may depend on minor quantitative differences at the other level. Discontinuities, intricate or salient structure at one level may be invisible at the other. (pp. 2-3).

attention alters in an essential way the perceived stimuli. We support this claim by reviewing empirical evidence showing the crucial implications of attention in the way things appear to us and suggesting that attention modulates the perception of all prothetic properties—those with a gradable scale—,such as speed or strength, paramount features of almost any sport. Second, following Wu (2011a,b), we show the relevance of attention in solving what he dubbed ’the many-many problems’: in order to be able to act, to do something, we have to solve the problem posed by being potentially influenced by several inputs with several outputs. Attention allows us precisely to solve this kind of situation.

In the next section (§2) we present the novel findings of two features of attention ignored in the literature: the modification of appearances and its role in solving the many-many problems. §3 reviews the skill acquisition literature on attention within the field of sport (where the information processing and the expertise approach are the predominant paradigms), showing that the features of attention described in the previous section have been ignored in this field. §4 presents the relevance of these novel findings for the specific field of skill acquisition in sport. The last section (§5) analyzes the implications that such novel proposals could have in developing new lines of research and new ways of training in sport skill acquisition.

Novel Findings in the Study of Attention

This section introduces relevant aspects of attention, which have not been covered in the existing studies. First (2.1) attention is not a mere filter of stimulus but it actively modifies the features of the percibed objects. We present the empirical evidence collected by Carrasco and colleagues that support this claim. Second (2.2), Wu’s argument on the ’many many problem’ shows the paramount importance of attention as selection for action.

Attention Modifies Appearances

Attention improves performance by increasing the accuracy and reducing the reaction time in tasks such as detection, discrimination, visual search, etc. Attentional mechanisms allow sensory systems to prioritize relevant information. For example, we can dinamically concentrate processing resources at a certain spatial location. This spatial attention typically coincides with foveation, but one can also *covertly* attend to locations in the periphery in the absence of eye movements (Posner, 1980). Covert attention has both an endogenous (voluntary) and an exogenous (automatic) component (Lyon, 1991; Jonides and Yantis, 1988; Nakayama and Mackeben, 1989; Posner, 1980).

There is a particular feature of attention that is especially relevant for skill acquisition: attention alters the way in which we perceive our surrounding environment. Carrasco and colleagues have shown that attention alters how things appear to us. It alters percieved speed, saturation, contrast, spatial frequency, flickering rate, etc (Anton-Erxleben et al., 2007; Carrasco, 2006; Fuller and Carrasco, 2006; Turatto et al., 2007).

In a brilliant paradigm, Carrasco (2006) tested the subjective contrast perceived by the subject without asking the subject to rate their subjective experience, avoiding bias in the response while measuring the effect of attention in appearances and performance.

In the experiment we are going to present, Carrasco used a common stimulus in psychophysics: a *gabor patch*—an oriented grating whose luminance profile is a sinus. These gabor patches can be seen in fig.1, which illustrates the set up of the experiment. Subjects in the experiment are asked to fixate their gaze and attend to a point in the center. Two gabor patches will then appear. One of them has a fixed contrast and the other's contrast is modified randomly. The orientation varies randomly for both gabor patches.

In a first condition, researchers asked subjects to press a key with the orientation of the most salient gabor patch. If the more salient gabor is the one on the right, they have to use the keys on the right to indicate its orientation as shown in fig.1. The answer of the subject in this condition is compared to the answer of the subject in a second condition (see fig.1) where a cue appears and automatically captures attention. The cue can be neutral, and so it coincides with the fixation point, or peripheral. When the cue is peripheral, it automatically captures the attention to the side where it appears. This cue is uninformative: the relation between the position of the cue and the most salient gabor patch is random.

Figure 2 presents some of the results for high and low contrast. For example in the high contrast condition (b in fig.2) an attended gabor with a contrast of 22% looks like a gabor with a contrast of 28%. As a result of this experiment, Carrasco et al. showed that subjects tend to perceive the cued gabor as more salient. Attention modifies how objects appear to us—the phenomenal character of experience.

Attention modifies perceived properties, thereby, facilitating discrimination tasks. Nonetheless, attention seems to modify only prothetic properties. Prothetic properties are properties with a meaningful zero value and inherent directionality such as saturation, contrast, spatial frequency, speed, etc. For prothetic properties there is a gradable scale and it makes sense to talk about an increase in the information: no (zero) contrast, more or less contrast, more or less saturation, etc. On the other hand, there is no such a gradable scale for metathetic properties, like hue. Attention does not modify non-prothetic (metathetic) properties such as hue (Fuller and Carrasco, 2006).

Attention as Selection for Action

In the previous section we have seen that attention modifies the way things appear to us; it changes the kind of experience we undergo when we perceive objects. This will affect every decision process that we make at conscious level (in contrast with automatic decisions), which, at least partially, depends on how things appear to us; i.e. the kind of experience we undergo. In Carrasco et al's experiements, attention is bottom-up and represents an involuntary process where the cue captures the subjects attention. We have seen how such involuntary attention modifies our perception and in § we will stress the relevance of these findings for the study of the role of attention in skill acquisition.

In this section we would like to focus on voluntary, top-down attention, starting from an understanding of this cognitive capacity of the subject at a conceptual level. We want to stress (i) the relation between attention and action and not merely between perception and action; and (ii) the role of voluntary attention in skill acquisition. Serious consideration of these issues should lead us to new research programs in the study of skill acquisition

Our theoretical and folk psychological notion of attention is tied up to that of selectivity. Attention, as a voluntary capacity, is not a mere pasive filter which let some information and no other go through but, at the very least, a flexible one that pipes some information to serve certain purposes, to do something, to act in the environment. Attention serves action, understood both as bodily and mental behaviors (i.e. thinking, reasoning, imagining etc.). This has lead some author to maintain that attention is selection for action (Wu, 2011a).

Voluntary attention serves a purpose, which depends on the subjects' intentions and motivational states—what she wants to do. In performing an action the subject is *attuned*[2] to relevant information, which guides the subject's response. If, for example, you want to open the door, you will focus on—attend—the door's handler shape while ignoring other information such as the bumpy texture of the door or the color of the handler. The motivational state—to open the door—plays a causal role in the generation of the action; first by selecting a colection of stimuli and movements directed to the satisfaction of the motivational state and second by keeping these movements *attuned* by means of the relevant information.

Very recently and following ideas previously voiced by Alan Allport and Odmar Neumann (see for example Allport (1987); Neumann (1987)), Wu (2011a) has convincingly

[2]The term *attunement* is also common to the ecological literature. Nevertheless, selection for action approach differs from ecological usage in the level of attribution. Whereas the ecological paradigm uses attunement at a subpersonal level (via physical properties of environment and neural circuits in the brain), selection for action uses attunement at a personal level, where motivation and intention play a paramount role for the subject.

argued that we should understand attention as *selection for action* and that voluntary attention helps solving what he calls 'the Many-Many Poblem' (Wu, 2011b), which is roughly the problem of generating a coherent behaviour by examining many *inputs* and many potential *outputs*. As the author claims: "[t]he agent must be selective in the face of this problem on pain of failing to act: she must select a specific input to inform a specific output" (ibid. pp. 50-51). Wu uses the following toy example to illustrate the problem—as he notes, the demand for selection is much greater in real life situations:

> Consider the following scenario. Two objects are in your field of view: a football and a basketball. Focus also on the possible use of your two legs to kick either ball, the left or right leg. We can then consider what I shall call a (restricted) behavioral space for the agent at that time that is constituted by a mapping that links "many" possible inputs to which the subject can respond and "many" possible outputs that count as the relevant responses. In the current case, the behavioral space is constituted in this way: for each of the two objects, two responses at a given time are available, namely kicking with the left leg or kicking with the right[...] In this scenario, you can only do one such action at a time. The Many-Many Problem is illustrated by noting that to do anything at all at a time, selection of one among the four behavioral possibilities must take place within the behavioral space at that time. If selection does not happen, then nothing does. Thus, if there is to be action at this time, the Many-Many Problem must be solved: appropriate selections must be made where an input informs a specific output. (Wu, 2011a, pp.100-101).

Selection for action depends on the subjects' intentions and goals ans doesn't seem to be a merely subpersonal process. Wu himself considers and rejoins such possibility. We could argue against the consistency of this position by *reductio* assuming that the input selection for action as presented in the Many-Many Problem is a subpersonal process and does not require an agent (S). In this case, the subject would not be attending certain features of the environment to guide accurate bodily movements. Rather some subpersonal cognitive system (C) is what performs the required selection. If that were so, C would be sufficient for guiding the intentional action, namely, kicking the ball. S's performing a bodily movement in a certain particular way would be the result of perceptual attunement that does not involve her because, *ex hypothesi,* being C a subpersonal process does not constitute nor suffice for S (for having an agent). The agent's action would not be guided by her perceiving relevant features but rather something else that tracks information. This statement implies that it is not her tracking certain information, forcing the rejection of the platitude that an agent acts guided by the 'how she perceives the world'. Nonetheless, C is not identical to S nor sufficient for her perceiving how things are. C is a part of S, a subsystem of her contributing to her shooting the ball. As C is a part of the agent S, what we have is a part of S contributing to S's reaching and grasping. If we are not willing to deny the platitude that S performs the action in virtue of her attunement to the relevant features, then, given that the selection performed by C is sufficient for S's attunement, we have the ground for S's attending to the relevant spatial properties and as Wu maintains "selection within the Many-Many Problem is or suffices for a subject level phenomenon of selection and thus of attention" (ibid. p.103).

Before moving into the implications of these features of attention for skill acquisition, it would be useful to review the literature about the role of attention in skill acquisition to justify our vindications.

The Study of Attention in Skill Acquisition

The existing literature in the study of attention within skill acquisition in sport come mostly from an information processing paradigm (Janelle et al., 2004). Traditionally, these studies have been[3] focused on topics such as *selective attention, divided attention* and

[3] The information processing paradigm has been advanced and specifically applied to sport skills thanks to an "expertise approach", placing special importance on the comparison of the differences between novices-expert and on how strategies and knowledge of experts are acquired in real-life sport domains (Summer, 2004, p.13). Nonetheless, we argue that such "expertise approach" remains in the same reductionist ground

alertness as attention (Posner and Boies, 1971). Due to the fact that the two first topics are the most interesting ones for the aims and discussion of the present paper, the following subsections (4.1, 4.2) present a review of studies on selective attention and divided attention.[4] In subsection 4.3 we deal specifically with novel strategies—based on psycho-physiological measures of attention.

Selective Attention

This model's roots are to be found in the proposals of Broadbent (1958). It understands attention as "the preferential detection, identification, and recognition of selected stimulation" (Woods, 1990, p.178). As several inputs from different sensorial modalities (visual, haptic, auditory...) are constantly reaching the subject, attention allows certain information to be processed while other is just ignored.

Selective attention has been often measured through indirect indexes as reaction time (RT) differences as a function of cue availability. Experiments presenting cue availability have used spatial and/or temporal occlusion as research strategies (Starkes et al., 2001). Also, search patterns have been registered and verbal reports analyzed in order to infer areas or aspects that are attended. The main accepted hypothesis places a strong relation between level of expertise and ability to allocate attentional focus. The more expert the subject becomes, the better her ability to attend correctly to significant cues for the skill at

as its previous paradigm and should be treated as pertaining to the same kind for the arguments presented in this paper. It is also worth to mention that witin the field of skill acquisition, ecological psychology has extensively treated the issue of attention as well. Gibson (1966) considered attention as a process for selecting information. He explained the "education of attention" as a gradual "attunement of perception" to the invariants offered by the environment and a progressive detection of specifying sources of information (Jacobs and Michaels, 2002; Müller and Abernethy, 2006; Cañal-Bruland et al., 2010; Shafizadeh et al., 2011). However, there are potential problems in Gibson's treatment of attention and many times the concept is confused or collapsed into the concept of perception: the education of attention can be understood mostly as an education of perception. In this paper we are not dealing explicitly with the ecological paradigm. Nevertheless, some of the critics against other theoretical frameworks target also, *mutatis mutandi,* the ecological one. When required we will make these critiques explicit in footnotes.

[4]This term refers to our state of alertness or preparedness for action. Such state is related to levels of arousal, emotions, stress, "choke under pressure". A sample of recent work on that field can be found in: Eysenck et al. (2007); Janelle and Hatfield (2008); Coombes et al. (2009); Barnes et al. (2010). In these studies EEG/ERPG are used as indirect indexes.

hand.

A vast range of research has been devoted so far to the suitable *focus of attention*, dealing with the area, sensation, effect, etc. where the subject should be oriented during performance. Basically, the debate surrounding such issue deals with the comparison of internal (own movements)/external (effects of movements or implements) focus of attention.

According to the recent literature,instructions and feedback that direct the learner to an external focus of attention while performing are more beneficial than those directing him to have an internal focus. Such hypothesis has been successfully tested in a balance task (Wulf et al., 1998); golf putting Wulf and Su (2007); tennis backhand and striking accuracy (Maddox et al., 2000); volleyball serves (Wulf et al., 2002), soccer kicks (Wulf et al., 2003) basketball free throws (Zachry et al., 2005), discus throwing(Zarghami et al., 2012) or swimming crawl stroke (Stoate and Wulf, 2011). A punctualization to these studies is offered by the results of Castaneda and Gray (2007);Uehara et al. (2008); and Lawrence et al. (2011). They show how the differences of using external or internal focus of attention depend highly on the level of expertise of subjects.

Apart from the *focus of attention* topic, there is other vast group of researches centered on the study of differences between *novice/expert search patterns*. The predominant measures used in the studies were summary gaze fixations and associated gaze behavior characteristics such as relative location, duration and frequency of occurrence (see Button et al. (2011) for a review of the literature on visual search in sport). Such patterns are useful to infer the attentional strategies used by the subjects in order to select crucial cues for the skill to be performed. E.g., Causer et al. (2010) concluded how a longer quiet eye (final fixation or tracking gaze that is located on a specific location/object in the visual display for a minimum of 100 ms) duration seem critical to a successful performance in shotgun shooting disciplines. They recorded visual search behaviors (point of gaze and eye fixations) of elite and sub-elite shooters in shotgun shooting disciplines (skeet, trap, and double trap events). Elite shooters demonstrated both an earlier onset and a longer relative duration of quiet eye. Also, in all three disciplines, quiet eye duration was longer and onset earlier during successful compared with unsuccessful trials for elite and sub-elite shooters.

Divided Attention

Performers can regulate their mental resources across different actions implied in the performance of a certain skill. As expertise develops, there is a shift from *declarative* to *procedural* control of the movements(Anderson, 1982, 1983, 1993; Fitts and Posner, 1967; Proctor and Dutta, 1995). Declarative, step-by-step conscious control of the action through working memory is slow and very attention demanding. On the other hand, procedural, automatic and unconscious control of the actions is fast and does not produce so much burden in the attentional resources that can be used in other requirements of the situation (e.g. decision making in a complex situation). It seems that due to prolonged practice some processing activities do not need the same amount of attentional demand, acted and controlled unconsciously.

One classical strategy to assess automaticity in sport has been the use of a dual-task paradigm where the performer has to divide his attentional demands between different tasks performed simultaneously. Comparing the performances of single-task condition (e.g soccer dribbling) with dual-task condition (e.g soccer dribbling while doing some basic arithmetical problems) the researches obtain indirect indications about attentional demands of the primary task (the soccer dribbling). Specific researches has been conducted by Parker (1981) examining ball catching/throwing as a primary task and peripheral vision detection as secondary task; and Tenenbaum et al. (1994) examining the recall of structured game situations as primary task and handball bouncing as secondary task.

Dual task paradigm has been used also to assess the attentional demand during different stages of performance (Rose and Christina, 1990; Davids, 1988), suggesting that attentional demands are greater at the beginning and at the end of the movement, being the middle portion more prone to be controlled automatically. Also, dual task paradigm has been applied to equally important tasks, the core issue being the flexibility of performers to switch attention from one to the other. Leavitt (1979) compared experienced and novice ice hockey players' ability to complete a hockey task while performing a secondary visual shape-identification task. Leavitt found that the performance of the experienced hockey players was not affected by the secondary task as they were able to switch attention from one task to the other. That was not possible for novice players, whose performances were negatively affected to a great extent.

Other studies where dual task paradigm was related to different levels of expertise are: Allport et al. (1972); Smith and Chamberlin (1992). More recently, Beilock et al. (2002) compared a group of novice and expert soccer players using a dual-task paradigm in order to measure the attentional demands involved in a soccer dribbling task. Players had to dribble trough a series of posts while simultaneously performing a secondary auditory monitoring task. In the monitoring task, individuals listened to a series of words for a specified target word and, when hearing it, repeated it out loud. Secondary auditory task impaired the performance of less novices either when performing with the right or left foot. Nonetheless, auditory task only impaired the performance of experts when using their non predominant foot. These results supports the hypothesis that attentional demand decreases in high levels of execution due to the automatized control that experts gain over their performances.

The Psycho-physiological Strategy in the Study of the Properties of Attention

Although not new, recent research of attention is beginning to examine in a much more systematic way the relationship between attentional states and physiological measures being electroencephalograph (EEG) and event-related potentials (ERPs) the most used indexes (Janelle et al., 2004). The rationale behind this is to get access to the neural substrates of behavioral activity observed during sport performance. Most common sport modalities for this kind of study have been marksmanship, archery or golf as their stillness during the action allows to place the required technological equipment to get the desired physiological indexes.

In the comparison between elite and novice marksmen, several studies concluded that both groups use different strategies for controlling attention: the EEG of experts showed cortical lateral asymmetry during the shooting, something lacking in the case of novices (Hatfield et al., 1984; Haufler et al., 2000; Hillman et al., 2000; Janelle et al., 2000; Landers et al., 1994). Such difference in cortical asymmetry between groups of different level of expertise (the asymmetry being greater the more expert the group) was also found in archery (Salazar et al., 1990) and golf (Crews and Landers, 1993). This and the fact that more expert subjects present greater task-related alpha synchronization in left hemisphere (Hatfield et al., 1984), represent the two most accepted evidences of the different attentional strategies used by different skill level subjects.

The measurement of ERPs (derived from temporally indexed EEG data) has been used also as an indirect measurement of attention, as it enables us to infer changes in the brain's electrical activity due to the different processing patterns implied. The greatest limitation in the use of ERPs data is the 'noise' introduced by the motor requirements of dynamic tasks normally used in sport (Janelle et al., 2004, p.298). Nonetheless, ERPs can be useful for inferring attentional states in the preparation phase of the movement execution. Zani and Rossi (1991) studied ERPs of clay-pigeon shooters in two modalities: skeet and trap. They found several differences which led to the conclusion that attentional strategies—at least in experts—are very sport specific. It is unclear, as the experiments by Czigler et al. (1998) showed, whether such strategies are transferable to novel motor tasks.

As a reminder of the potential limitations of such research approaches, Lawton et al. (1998) and Janelle et al. (2004) warned that findings using EEG measures in sport should be interpreted with caution. As this paper attempt to show, such limitations are not only due just to complexity of method and procedure in the registration and calculation of data.

The Relevance of (Other Features of) Attention for Skill Acquisition

In this last section we specifically show the relevance of the findings discussed so far in relation to the field of skill acquisition in sport—which, as shown in the previous section, have not been explored. We then (5.1) present possible new lines of research—based on these new findings—and implications for training.

As showed in §3, there are some features of attention that have been neglected, both in the general study of attention and in the skill acquisition literature: Carrasco et al.'s finding on the importance of attention modiying appearance and Wu's analysis of attention as selection for action. This section presents the specific implications that both features of attention have for the world of sport.

The relevance of the findings of Carrasco et al's for skill acquisition and sport dwells in the fact that modification of appearance due to attention applies to prothetic properties such as force or speed. In fact, the paradigm presented in these findings has been used specifically to test the influence of attention in the perception of speed (Fuller et al., 2009; Turatto et al., 2007). For these purpose, Gabor patches were used but this time the changing paramenter was the moving speed of the Gabor instead of its salience. The study revealed that participants overestimated the motion speed of the attended Gabor by approximately 10% (Turatto et al., 2007), regardless of adaptation effect (Anton-Erxleben et al., 2011).

Generally speaking, such results have important implications for any kind of interceptive action in sport: imagine the importance of a correct speed estimation for a tennis players or a baseball batter and the possible disruptive effect that covert attention may cast into the situation. Speed is a property which is present in almost any sport, where moving targets—objects or humans—are ubiquitous. It may be the case that expert players use different attentional strategies and/or compensating actions in order to avoid the overestimation of speed effect. Such relevant topics has been neglected so far in sport. The present paper points precisely at such blind spot whose research may lead to a better understanding and improvement of expertise, enhancing instruction and training programs as well. In the section *New lines of research* we will developed further this issue.

The relevance of Wu's argument on "attention as selection for action" referred us to the so-called Many-Many Poblem: the problem of generating a coherent behaviour by examining many "inputs" and many potential "outputs". Players in the sport ground have to face and deal with this kind of problem constantly. Consider this situation during a soccer match: a forward player is close to the goal. The goal keeper is in front of him, a bit far from the goal line; the defender is next to the player, trying to take the ball away; there is a team partner on the player's right side. In this particular situation, these three can be considered the relevant inputs within the behavioral space of the player. Following Wu's argumentation, there are also many possible outputs counting as relevant responses. The player can try to score flickering the ball or making a direct shoot; he can face the defender trying to dribble him or protecting the ball; and alternatively he can pass the ball to the partner to the foot or to an advanced position in the field. Thus, six possible actions at a time, defined by specific input-output linkages, constitute the behavioral space available to the agent at that time. Attention offers the selection mechanisms to link specific inputs with possible outputs required for the player to act. Such selection produces a specific path in the behavioral space: the player does something. That action would not happen (the player would not do anything) if the many-many problem was not solved.

In this simple example above, we are only considering vision in order to act, selecting object, location, color etc. In a real situation, there is a bunch of other possible inputs coming through multiple exteroceptive and interoceptive channels. Having said that, it is easy to understand why within real playing conditions of the game, the many-many problem is more significant than ever. Furthermore, managing such many-many problems represents a crucial role in the learning process. Skill acquisition in sport implies a lenghtly learning process in order to reach certain degree of expertise and the many-many problem could be a decisive factor to discriminate expert player from intermediate or beginners.

New Lines of Research and Implications for Training

After showing the relevance of other features of attention through the proposals of Carrasco and Wu respectively, we aim at (a) proposing possible research applied specifically to the field of sport and (b) discuss some implications for training derived from the new proposals presented along the paper.

(a) Carrasco stated that attention modifies appearances but only in the case of prothetic properties (those with a gradable scale) such as speed and force. If we take a close look to sport activities we may find a number of cases where such prothetic properties are paramount. Imagine the importance of correct speed estimation for a tennis players or a baseball batter; for intercepting a ball pass in basketball; for a goalkeeper's save in football; for the reception of the far coming ball for a touchdown; or for a definitive spike in volleyball. Also, think about the importance of correctly estimating the force applied in the grip of the jacket of a judo player or in the front line of a rugby scrum. Both speed and force are prothetic properties; thus, our perception of them, at least at the conscious level, is affected in an essential way due to attention. These properties are crucial in many other sports so we must research precisely how attention is affecting them. In order to advance in this direction, instead of Gabor patches—as in Carrasco's original proposal—experimental protocols could use sports related stimulus,closer to domain specific situations. So to say, tennis balls could be used in computer simulation programs but also real balls in a conditioned experimental room adapted to generate measurable distracting cues.

These type of experiments could shed interesting results, as distracting stimuli (from other players or from spectators) abound among the game in many sports and the potential disruption of attention would affect perception. This effect would be even more perturbing in the case of stressing or threatening situations. According to attentional control theory (ACT; Eysenck et al., 2007), under high threat conditions, participants display an attentional bias toward threat-related distracting stimuli. Such predictions were corroborated by Wood and Wilson (2010): by manipulating the saliency of the goalkeeper in a penalty shoot (by waving hresearches have been applied tois arms in order to distract the penalty taker) they achieved a significantly greater number of saved penalties when compared to non distractive condition.

Wu's proposal shows how volition modulates attention, understood as an active filter (non passive, as in classical filter models) that allows pertinent selection for action. Taking it into account, it would be interesting to introduce some variations in Carrasco's experiment (in normal skills, as when using Gabor patches or in sport skills, as when using balls coming in the screen) in order to assess the influence of voluntary top-down attentional strategies upon bottom-up processes of attention. Carrasco's condition in the experiment took into account how appearances are altered due to changes in attention in normal subjects. The study showed a clear bottom-up effect regardless of subjects' voluntary control. Nonetheless, we could introduce other conditions with subjects that were previously trained in specific attentional strategies. Significant differences between conditions would have profound implications: we would be able to discriminate more effective attentional strategies from others. It might be the case that attentional strategies are task specific (better attentional strategies in soccer goalies might not be the most suitable in tennis) so the experiment should be replicated in different sports.

(b) Although the design of training programs to enhance attentional abilities of players has been a paramount issue in the field of skill acquisition in sport, we suggest that some blind spots in the area still remain. We have already presented the different implications of directing the subject towards an internal or external focus of attention. Besides, observational learning approaches in sport stress the importance of directing attentional cueing.

Most studies have focused on enhancing the anticipation skills. These studies have been conducted by highlighting important information cues. Janelle et al. (2003) tested the effectiveness of different cueing conditions during observational learning of a soccer accuracy pass. They conclude that the use of video modelling with visual and verbal cues collectively improved performance as verbal information combined with visual cues enhanced perceptual representation and retention of modelled activities. Williams et al. (2003) used video simulation training in field-hockey goalkeepers in penalty-flick situation and concluded that the group who received the perceptual training improved their response times significantly (when compared to control and placebo groups). They also concluded that such training effect on anticipation skills had transference from the laboratory to the field, highlighting the practical application of the program.[5]

Not denying the important findings achieved so far, at least one step further is needed. In our view, the new implications for training should be focused in the development of voluntary strategies for attentional control. In this vein, Wood and Wilson (2011) presented a quiet-eye training program for penalty kicks. Their aim was "to align gaze with aiming intention to optimal scoring zones", avoiding the bias effect produced by anxiety on visual attention. Vickers (2007) had already shown how gaze was influential on visual attention and Land (2009) how gaze was driven by voluntary (top-down) attentional control. According to Wilson et al. (2009) anxiet —pressure under threatening situations—was responsible for disrupting the goal-driven attentional control in penalty kick. Nonetheless, a quiet-eye program was a suitable voluntary (top-down) strategy to try to overcome such non desired bias. Results showed how the group under the quiet-eye program obtained a more effective visual attentional control, were more accurate and score more goals than the placebo group. Nonetheless, differences between groups were not significant when competed in a penalty shootout. This circumstance seems to point out that the anxiety of the situation generated an attentional bias that was not sufficiently controlled by the voluntary strategies learned through the quiet-eye program.

Despite the degree of success of such training program—also positively tested in other

[5] It is worth to mention that from the ecological paradigm, several studies have signaled the difference in the use of information variables of novice players and experts in cricket (Müller and Abernethy (2006) or in field-hockey goalkeepers Cañal-Bruland et al. (2010). See Ibáñez-Gijón et al. (2011) for a review of this kind of studies). Such results are crucial in order to start to understand the development of training programs based upon the "education of attention".

activities such as golf-putting (Moore et al., 2012)—, what is important is the direction it signals. This direction is perfectly aligned with the contributions we have brought forth in this paper. Carrasco's experiments showed that attention alters perception in an essential way and Wu's theorization at a personal level opens the possibility for attention to be voluntarily trained and modulated in order to affect action. The control of attention is an utmost demand for every player—maybe more for defenders of goalkeepers—in order to do a good performance and do not get disturbed—by anxiety—or distracted (e.g., avoiding tricks, feints, dribbling).

Based on these novel approaches to attention, our proposal aims not only to signal points or areas where to look at or to attend. This does not suffice. What is important is to be able to develop what we call an "attentional state": to attend to with the intention of.[6] Thus, we refer to attention affected by volition (volition used as a synonym of intention to act); attention voluntarily modulated by the subject. Intentions can be generic (e.g. go for the attack or defending mode) or more specific (e.g. overtake the car in the next turn).[7]

Imagine an already planned play in a corner kick. Every player of the team knows the pre-arranged pattern of play in order to score. Nonetheless, every player is attending to the game with different specific intentions: the player kicking the ball from the corner wants to pass the ball over the penalty area for player number 9 to head the ball; player number 9 attends the play with the intention to set himself free from the defenders in order to head the ball; his team mates attend the play with the intention of dragging the defenders out of the selected zone for player number 9 to be able to head the ball and score. For the moment, this kind of voluntary attentional training has been applied only to simple, closed, controlled skills, such as penalty kicks in the research of Wood and Wilson (2011). Nonetheless, we claim that this is just the first step for a real and practical

[6] From the ecological perspective, an "education of intention" (Jacobs and Michaels, 2002, 2007) has not been combined with the "education of attention". Therefore, they keep separated what we want to bring together in our proposal.

[7] Translating it to the language of dynamic systems approach, such intentions would act as goal constraints for the whole system.

application to game situations.

The possibility for voluntary attentional training in real, dynamic sport settings is still to be researched. This paper has tried to call attention to this underdeveloped field of study in skill acquisition from a theoretical perspective and to highlight the need and importance of empirical researches in this area that would end up in the implementation of suitable voluntary attentional training programs.

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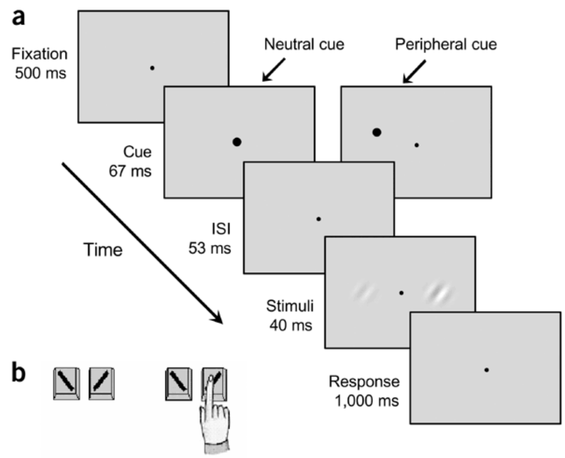

Figure 1. Carrascos' Paradigm for Measuring the Influence of Attention in Phenomenal Character.

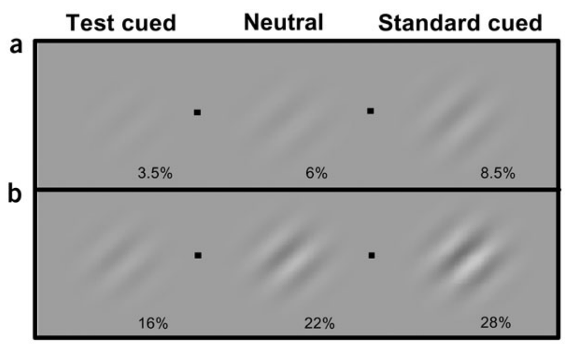

Figure 2. Attention Effect on Phenomenal Character