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The Tennis SensoriMotor Synchronisation Paradigm

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Abstract

The author proposes a new Paradigm for both research and practice regarding tennis. Sensorimotor Synchronisation (SMS) is the scientific field studying how people may synchronise their actions to an external stimulus (a pacer). SMS provides the most relevant set of concepts to tennis because synchronisation with both the ball and the opponent is the most decisive factor for performance: ball directionality, early preparation and economy of movement are all affected by good synchronisation skills but not so much by reaction time. In martial arts schools, synchronisation is the golden chalice of superior performance, which leaves many questions about the choices that have been made in tennis. Here, after a mini-review of SMS-related concepts and terms, an SMS application to tennis will be proposed and some drills will be described for the first time. Not all questions will or can be answered here, however a new Research Programme should be emerging: as is the case in all Programmes and Paradigms, they cannot be directly tested but they offer the background for specific experiments to follow. Tennis SMS is also compatible with bioinformatics since expert systems may be developed to both monitor and improve synchronicity.

Keywords: bioinformatics, distal method, motor skills.

1. Introduction

The Distal Method is a broader Paradigm (in the classic sense of Kuhn's Scientific Paradigms) about expertise attainment. It combines western scientific knowledge, epistemology and traditional School[*] insights. This means, its methodology is superior – (see for example Papageorgiou and Lekkas, 2020) while its applicability is maximised; in other words, while its theory is general, its applications (e.g. as guidelines and methods) are specific, practical and oftentimes deceptively simple.

The main application of the Distal Method has been in tennis and indeed, the main volume of publications concerning the Method, is about tennis (Papageorgiou, 2016; Papageorgiou, 2019; Papageorgiou, 2020; Papageorgiou, Papadopoulos, 2018). With this paper, a new Paradigm will be introduced; one that should have already been the main focus for researchers in tennis: The Sensory-Motor Synchronisation (SMS) Paradigm for Tennis (tSMS). Why SMS? Because it is what we mostly do in tennis: synchronise (not react) with an external pacer (both the opponent and the ball) – not to mention internal coordination themes (such as the kinetic chain). The SMS

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* A School is any system that aims at, and provides tools for, spiritual growth. Such schools are Aikido, Yoga, Vajrayana, Tantra, Mathematics (in the classical Greek sense), Art (various forms) etc. School methods and structures have not been adequately studied by western science; indeed, such a subject is often considered a *taboo*.

Paradigm resonates well with the Distal Method but is also an independent Paradigm for researchers to follow from now on in tennis (and even other sports).

This paper has three parts. In the first part I will select and present the most relevant SMS findings for tennis, along with some implications for practice. The second part consists of practical applications. There is an increasing cost along this path, since it cannot be crossed *salva veritate*: the most relevant theoretical and experimental findings are selected based on, and limited by, my own knowledge, perception and criteria. However, they accurately reflect the literature findings. One step further are the implications for practice. These implications are even more affected by my own judgment, previous experience and understanding; other researchers could propose different implications for practice – and this is fine. Taking the farthest step, we find the applications for practice. This step requires an even more catastrophic (for truth) process than the previous one (implications for practice). Catastrophic, save necessary. It is like proposing a Research Programme[*]; everything I propose may be a subject for various experiments, no matter how reasonable and plausible it may sound. This is my goal after all: to initiate a Paradigm, not to exhaust its implications and applications by myself in a single paper. The third part will propose ways for bioinformatics to be applied to tSMS.

2. Results and discussion

From SMS to tSMS

Under the broader SMS Paradigm all relevant research takes place which has to do with the coordination of rhythmic movement with an external pacer. The basic mathematical discipline which deals with periodicity is the theory of music (but not the western one). The basic axiomatic foundation of this theory is the Fourier Analysis. The focus of the researchers in SMS spans all the way from the classic finger-tapping and metronome coordination, to interpersonal coordination of "hyper-followers", and to music ensemble performance. Two excellent reviews covered the most important aspects of research in the SMS until 2013 (Repp, 2005; Repp, Su, 2013). By no means is this an attempt to *repeat* the findings presented in greater detail in these two reviews. I refer the reader to these reviews as I consider them to be essential reading on this subject.

One relevant finding which should be stressed early on, to demonstrate the importance of SMS for tennis, comes from both visual occlusion and moving-target interception studies. Many such studies support that the opponent (in tennis and other sports) is a valuable source of information in the "prediction" of where the ball will go (Müller et al., 2006; Rowe et al., 2009; Müller et al., 2010; Goulet et al., 2016). It is not just the ball's trajectory; crucial fragments of information are revealed from the movement of the opponent's body (this is why bluffs and disguise happen in tennis). That is to say, we do not just coordinate – or even react – to the incoming ball which "appears" out of thin air; the coordination sequence starts before we get to see the ball, from kinematically relevant sources of information taken from the way the opponent moves; this skill to take advantage of contextual information is an hallmark of expertise (Murphy et al., 2018). It is a sort of "dance" between us and the opponent, not just a coordinated intercepting action against a moving target (the tennis ball).

Basic terms

When referring to coordination, we usually mean *intentional coordination* which happens in cases where actions are intentionally coordinated with referents. Research (and common experience) has shown that SMS behaviour can also spontaneously emerge (relative coordination), especially in cases where we interact with a periodic phenomenon (Repp, 2005). In reality, there is a *continuum* between the two extreme consciousness states, not just a flip-flop between being fully aware or unaware of our coordination activity; coordinating with stimuli happens with various degrees of intentionality. There is a constant transition from intentional to unintentional coordination (and *vice versa*), exactly the way our control of breathing is constantly drifting from intentional to unintentional. This happens even in tennis: contrary to what we may believe, automaticity soon takes over and our intention to coordinate gradually vanishes until we discover we have "lost our focus", we have been hypnotised i.e. we have lost our intention, but alas, we only realise it too late. On the other hand, being too intentional (if we may say so), makes us rigid and

[*] I am referring to Imre Lakatos' Research Programmes.

anxious. The only real solution is to train our automaticity consciously, create reliable patterns, anchors and subdivision strategies (as we shall see in the process).

The external pacer has a rhythm; the minimum period between two reference points (such as the clicks of a metronome) is called *Inter-Onset Interval* (IOI). In theory (maths), we can have just one periodic phenomenon (one IOI so to speak) with an infinitely long period. The biggest known period in the universe is from the Big Bang to the next Big Bang. Below many orders of magnitude are the periodic phenomena occurring in, say, tennis. In tennis too, we can have a unique IOI and consider it periodical (it is a matter of using a suitable approximation theory which will help us decide how to treat each IOI in relation to others). The *Inter-Tap Interval* (ITI) is the period between two successive actions of an individual who is coordinating *somehow* with the IOI: indeed, an individual's ITI may coordinate in many ways with the external IOI. The IOI and the ITI may be *in phase* (even number of periods spanned by IOI and ITI) or antiphase (π rad difference between IOI and ITI) – see Figure 1. Other phase relationships are possible, but pose greater difficulties for the individuals (Mechsner et al., 2001). Moreover, there can be many IOIs for each ITI (1:*n*, meaning that 1 ITI is divided by *n* IOIs), or many ITIs for each IOI (*n*:1, meaning that 1 IOI is divided by many ITIs). When synchronising with the IOI, what we choose as the rhythmic pattern is called *tactus*, or the "preferred rhythm" (e.g. the "beat" of the music).

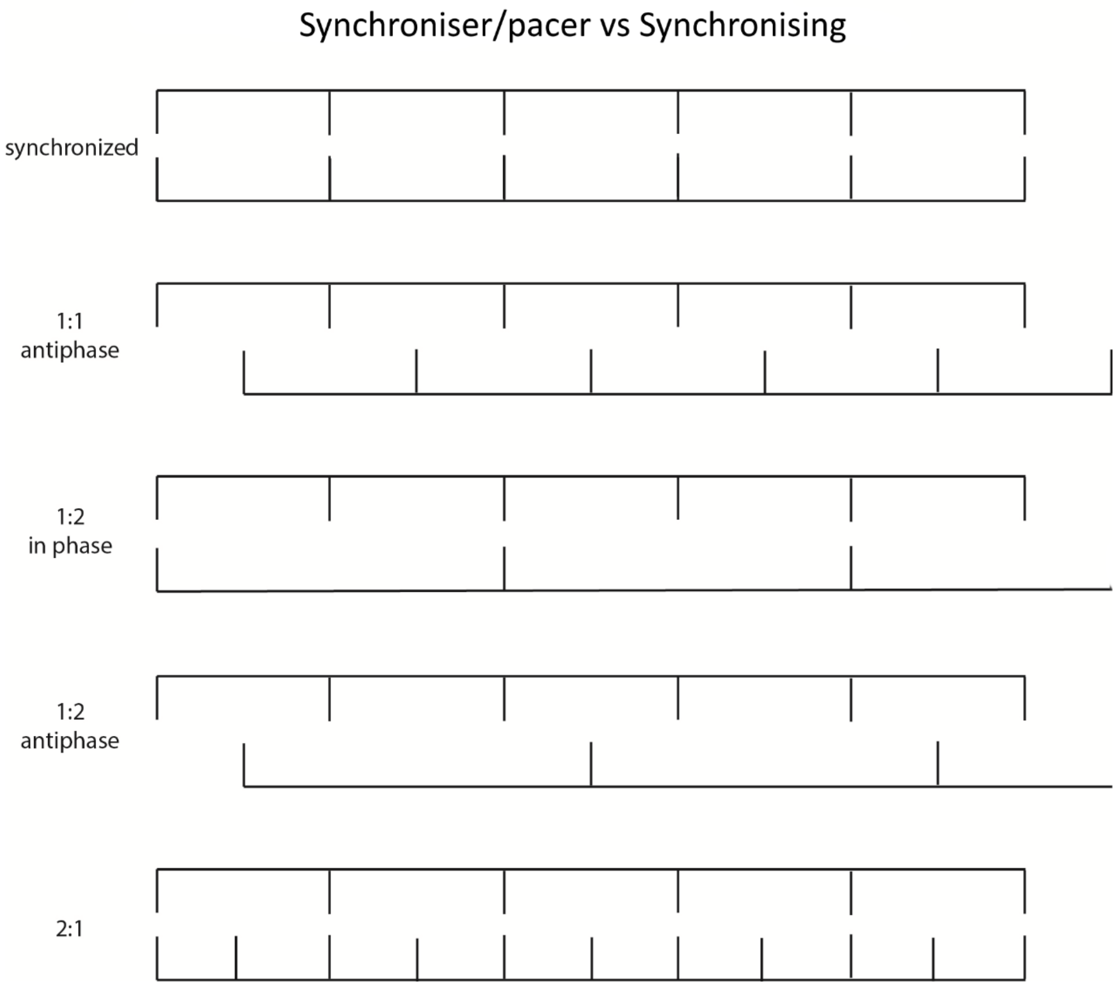

Fig. 1. Various synchronization cases between the pacer (IOI, always on top in the graph) and the synchronising (ITI, always on bottom in the graph)

For tennis, a good fit would be to consider as IOI the period between contact point (opponent's racket) and ball bounce on our court. Two IOIs would be: from the opponent's contact point until our own contact point (if the second IOI is of the same time-length as the first one).

Hitting on the rise, or hitting a second volley, would be hitting in antiphase. If we considered only phase and antiphase, all other strikes should be reducible to these two cases.* How would we decide which stroke is reducible to hitting in phase or in antiphase since many strokes clearly do not coincide with either (e.g. half-volleys)? A theory of approximations is needed, not only for tSMS or SMS but for the whole of western science. An epistemologically intense theory that helps us categorise the measured (ITI) in terms of the measure (IOI); the approximating (ITI) in terms of the approximated (IOI). Until then, we shall just use our common sense and best-guess what is *what* (e.g. smashes would be in-phase, while second volleys would be antiphase).

Negative Mean Asynchrony (NMA). A universally occurring phenomenon in SMS is that actions tend to precede signals: we tend to act too soon instead of in time or too late (Repp, Su, 2013). NMA also shows we *anticipate*, rather than *react*, to pacing stimuli – a difference detectable on the neurophysiological level as well (Pollok et al., 2008). NMA is of course an error, and the reduction in synchronicity errors is the focus of the emerging tSMS Paradigm.

Synchronicity themes

IOI limits.

Are there limits to IOIs – and what is meant by that? Limits to the IOI perception have long been identified (Fraisse, 1982). The IOI can be too long or too short and this could disrupt our coordination, but for different reasons. When the IOI is too short, there are two consecutive limits. The first one is the biomechanical limit. For example, in the tapping research protocols, it occurs when the participants cannot physically move their fingers any faster. In such instances the biomechanical limit is about 200 ms (Truman, Hammond, 1990). For tennis it should be much higher, since moving the lower arm-racket system is more difficult (in terms of inertia) than moving a single finger. But, even 200 ms is not our perceptual limit. Using two fingers instead of one, we are able to bypass the biomechanical limit and reach the perceptual limit where loss of SMS perception takes place. For expert participants (e.g. musicians), this limit is a bit more than 100ms (Repp, 2003). The upper limit is slightly less than 2s (1800 ms). What happens after that? SMS, which is based on anticipation and prediction, becomes reaction-time-dependent and participants' ITI tends to lag behind the IOI.

Several possible solutions exist in tennis for the problems posed by the IOI limits. As we move towards the lower limit, the stroke's kinetic chain could also start shifting from serial to one-unit (biomechanical adaptations). A form of subdivision benefit may be used in both types of limits, both as an anchoring method (long IOIs) and as a coordination enhancer (short IOIs). Metrical accents could also provide better coordination in both cases.

Types of stimuli.

What do we tune to? There are many possible types of rhythmic stimuli (at least as many as our senses). Three specific cases are of special interest for us: auditory, static visual and moving visual. Static visual pacers (flashes) are far worse pacers than auditory ones, that is, they are more difficult to follow (Repp, 2003; Lorås et al., 2012). Moving visual pacers fall in between being worse pacers than auditory, still far better than static ones (Repp, 2003; Hove et al., 2010). These differences may be of neurophysiological origin (Ruspantini et al., 2011). Auditory pacers are the easiest to follow, maybe due to the strong auditory-motor coupling on the neurophysiological level (Grahn et al., 2011).

Now, when it comes to coordinating with others, we do not need to put a lot of thought into it: coupled participants mutually and unconsciously adjust their ITI's, becoming a sort of "hyper-followers" (Konvalinka et al., 2010; Nowicki et al., 2013). They even synchronise their brainwaves (Lindenberger et al., 2009)! The human mirror neuron system seems to be responsible for this ability to coordinate with our opponents (Denis et al., 2017). Coordinating our actions with others increases positive feelings towards the other person and bonding, especially when the pairing synchronisations becomes more accurate (Hove, Risen, 2009; Kleinspehn-Ammerlahn et al., 2011). Coaches should stress and train the shared intentionality, which leads to better mutual coordination. They should also try to explain to their athletes, what "chemistry" between two players is all about and how to intentionally achieve joint attention as a common goal.

* There are many other ways to divide IOIs and that could be the subject of another article.

Source of errors.

Two main sources of errors may be recognised: central timekeeper, related to perceptual/behavioural aspects, and peripheral, related to motor centres (Repp, 2005). The first type is more error-prone than the second one – and this is a good thing since peripheral sources of errors is more difficult to address as they are related to *abilities* and not *skills*, hence they are stable and change-resistant. On the other hand, there are plenty of strategies to improve our perceptual skills, such as the *conscious automatization process* (Papageorgiou, 2014; Papageorgiou, 2016)*: train automaticity consciously, do not just "let it happen". To that extent, the Performance Spiral is a suitable method (Papageorgiou, 2019).

Before we get too excited, however, we should first confirm that SMS is trainable – and to what extent? In SMS studies, when untrained individuals are compared to expert musicians for example, the asynchronies are twice as large for the novices (Repp, Penel, 2002). This sounds as an impressive feat but how early can we reap the benefits of such an improvement? Even though SMS takes years to develop, reliable SMS is already achieved from three or four years of age; almost adult-level SMS is achieved by seven or eight years of age (McAuley et al., 2006; Kirschner, Tomasello, 2009). Having in mind that mature motor skills of all types (manipulation, ballistics, locomotion and stance) can reach maturity at about six years of age (Gallahue, Ozmun and Goodway, 2012), but also, that SMS and motor skills are the most important factors in tennis performance (in tSMS Paradigm), we reach a very interesting conclusion: by the age of 7 or 8, players with perfect form† could have developed (Papageorgiou, 2020b).

Event Onset Shifts (EOS) and *Adaptive Correction Responses* (ACR).

So, we follow an external pacer, but unexpectedly (or expectedly in. e.g. music *ritenutos*) the IOI is disrupted, either momentarily or continuously (Schulze et al., 2005; Repp et al., 2012; López, Laje, 2019). Such disruptions in SMS are called EOS and they are dealt with by ACR. ACR to EOS can cause errors (asynchronies to the next action) and this is the main reason we study them. ACR can be both intentional (e.g. music) and unintentional (automatic). In the special case we know EOS will happen our response is called Anticipatory Phase Correction (APC). APCs are important because they show us that intentional control may be exerted.

As is customary in the Distal Method, we always practice on and around the transition point – whatever that may be. Practicing around transition points is based on both the *deliberate and well-structured practice* approach of K.A. Ericsson and the classic *zones of proximal development* of Vygotsky (Papageorgiou, 2014). EOS provide us with such opportunities, especially in the case of APCs where we may attempt to stretch the limit of the APC we are able to make. Probably, from a point on, APCs revert to unexpected EOS corrections (or may be treated as such in an approximation theory). Anchors and subdivision strategies may be developed to help us deal with such (very usual) types of asynchronies.

Everything described until now is nice, but it presupposes that we have tuned to a pacer. So, *when* do we really start getting in tune? It seems we need at least three signals to "catch" the IOI and synchronise with it ("period setting" in Repp, 2005; see also Semjen et al., 1998). That makes the return of the serve a borderline case since we have to synchronise to two signals, i.e. one IOI (from the opponent's racket to the bounce in our service box). This seems to be as a problem seeking a solution.

Our previous experience may be helpful in quickly adjusting or anticipating the interceptable object (the ball). However, this is only a passive process which takes some time to build up and doesn't feel like a good competitive strategy. A much more useful solution could be *mental imagery*. Indeed, SMS is responsive to such approaches and this is also backed up by neuroscientific studies showing how similar the brain responses to covert and to overt SMS are (Osman et al., 2006). In a way, for the brain, it is the same thing whether we imagine something or actually experience it (Gentili et al., 2010). Since the main causes of errors are central, mental

* Based on the "attacking attractor" model, we attempt to consciously deepen suitable attractor basins and prevent recidivism to older coordination patterns.

† In the Distal Method we have at least three such components: *technique* (the biomechanical model drawn on a piece of paper), *form* (application of the model to a human body) and *style* (personalized form after years of practice). The other components are: *sense* (universal), *feeling* (personal), *emotion* (sum of feelings), *tactics* (set of sequences of skills, if "skill" is e.g. a specific technical form/tennis stroke), *strategy* (set of tactics), *life purpose* (set of strategies).

imagery seems as a fine strategy to apply to serve-returns. This way, the problem of tuning may be transformed to a problem of ACR or even APC, in case the actual pace of the serve is different from what we have imagined.

SMS control.

The final theme that I will discuss is one with many philosophical connotations, even though I will stick to the behavioural (and neural) ones: do we control SMS or does it control us? Experiments have taken place based on the pseudo-SMS methodology: participants were called to discern whether they were, or were not, in control of an isochronous metronome that unbeknownst to them, switched to feedback mode and vice versa (Repp, Knoblich, 2007). In both cases it took the participants several IOIs before they detected a shift in control. Not only that: participants were biased towards judging in favour of being in control. Just the causal belief about the locus of control by itself is enough to change the relative contribution among the sensorimotor networks (Buchholz et al., 2019). An important finding for us is also that when the feeling of control was ambiguous, performance was disrupted (Couchman et al., 2012).

This magical feeling of control should be enhanced and we must create exercises that both establish it (based on e.g. the tactus of the learner) and extend (or transfer) it to more difficult coordination patterns (always by working on the transitional points). Stressing control may also have implications for Csikszentmihalyi's flow state where the feeling of control is maximised (Csikszentmihalyi, 1990; Weinberg, Daniel, 2015). Playing, while being "in the zone" is one of the most universal characteristics of world-class performers, and it can be taught. Breathing exercises may also support this process.

As the final and most general message to take away, I will sum up the previous discussion in the phrase: *synchronization enhances basic perceptual and motor skills*.

Practical applications in tennis

Directionality vs orientation.

In our approach, having court orientation is the static skill of being able to accurately point to specific parts of the court without directly looking at them. Directionality is the skill of directing the ball to the desired target. Orientation is the prerequisite: we may be able to accurately direct the ball to where we *thought* the target was, even if we were mistaken about the location of the target. However, orientation does not guarantee directionality: we may accurately know where the target is but fail to direct the ball there. Directionality is heavily dependent on SMS; orientation is not.[*] All dynamic movements in tennis are affected by directionality, hence by SMS. This is the basic understanding we need to establish before saying anything more about tSMS.

IOI in tSMS.

The first theme in tSMS has to do with our decision to define the IOI. As is the case with everything I say from now on, this is also open to discussion and reform. But I will go on and attempt to establish the basics based on my own understanding.

What IOIs can we establish in tennis? An IOI from the opponent's contact point until the ball bounce to our court, seems to be the most appropriate candidate since it is easily identifiable, within the IOI limits and relevant to our decisions. Similar IOI would be from contact point to contact point (a necessity when it comes to volleys) or even from opening our rackets until the contact point (if we assume perfect control and the feeling that we set the IOI ourselves). This way one could view the period from the opponent's contact point until the bounce in our court as either the IOI or the ITI. Let us conventionally define IOI as the period between these two "clicks" (contact point – bounce). In this approach, the period from contact point to contact point is considered two IOIs.

Subdivisions.

In any way a task (skill) is organised (part or whole practice), two basic rhythms are proposed, 1:3 (123) for novices and 1:5 (12345) for all other levels. 1 in both cases may be the ball's contact with the opponent's racket and the ball bounce coincides with 2 for novices and 4 for all others. 3 and 5 correspond to (our) contact point. 1 may also be named as "check" salva veritate (instruct the player to check). Especially in the case of 1:5, the subdivision of the IOI is not symmetrical but seems to work very well with the flow of the game. In that case, 4 may coincide with the bounce of the ball or not (later if we face lobs and earlier if we play more aggressive shots).

[*] On the other hand, orientation may be affected by internal *Zeitgebers*; periodicity is always present in life!

Metrical accents.

Exercises should also target the unification of the contact point with that of the end position, in order for us to be able to incorporate metrical accents into our shots. One such exercise is proposed in the tennis Distal Method Coach Development program which uses the concepts of the universal reference point (the furthest point *after* contact point that the kinematics of the stroke remain the same) and of the hitting position (the furthest point *prior to* contact point that the kinematics of the movement remain the same). An advantage of this exercise is the unification of *part practice* with *whole practice* (or the shift from part to whole practice – a never ending process according to the Performance Spiral). The unification happens as follows: either using only 1:2 or 1:5 subdivisions, the whole movement is performed in three stages:

I. from contact point to contact point (almost no motion at all);
II. from hitting position to universal reference point;
III. from opening position to end-position.

The periods (time) from contact point to contact point; from contact point to universal reference point (II), from contact point to end position (III) should be equal in length.

Antiphase and in-phase.

Generally speaking, hitting the ball on the rise should be considered antiphase while hitting later should be viewed as in-phase (and hitting a semi-volley or volley or smash could all be categorised as in-phase). A good idea would be to start from in-phase strokes and then proceed to antiphase (before trying to mix them in any sort of serial or random practice programs).

Training more complex rhythms.

Apart from in-phase and antiphase there are more complex rhythms (such as ¾). More complex rhythms tend to revert to more stable* rhythms as we speed up to reach the Phase Reversion Point. Again, practicing at, and around that, (transitional) point is deemed necessary (in this Paradigm). Let us first see some ideas about IOI subdivisions that may be helpful in various conditions, from standard baseline rallies to volleys, returns, high-speed strokes etc. The general idea is:

A. 12345
B. 2345
C. 345
D. 45
E. 5

As simple as this classification may be, it includes all possible and trainable cases. A possible interpretation of this 12345-based subdivision method is that 4 in the cases of A, B and C corresponds to the ball bounce whereas cases D and E have no ball bounce (D could be first volleys and E could be second volleys which are closer to the net). Case C could be serve returns and case B could be used in fast baseline rallies. Case A in slower rallies. In all cases the first number designates the ball's contact point in the opponent's racket. Again, practicing these rhythms would require the proper use of practice programs (where "proper" in the Distal Method Paradigm is exemplified by the two kinds of periodisation protocols known as Performance Spirals, one for motor skills and one for physical conditioning).

Antifragility…

… which is expressed in sports as the *contextual interference effect* should also be a part of the practice – for antifragility (see Taleb, 2012). The introduction of perturbations and of distractor stimuli is an effective way to achieve that. In the case of SMS (and tSMS), the closer the distractor sequence is to the IOI, the more difficult the drill becomes.

Practicing on the two IOI limits.

In respect of the biomechanical limit, there would be a critical ITI which would designate the transition of a *serial kinetic chain* to a *unit kinetic chain*. That critical ITI should be treated as a transitional point. When the biomechanical limit poses less threat (in longer IOIs), using varying metronome sequences might be beneficial (hence the development of the tSMS app).

* westerners are addicted to a certain type of music that is based to simpler rhythms, such as 2/4 or 4/4). I say addicted because all modern western music is based on the tempered system; Helmholtz doubted that people will ever tolerate such dissonant musical intervals, alas, here we are listening to only such music…

For the upper limit, where SMS becomes reaction time, subdivisions strategies and cognitive anchors might do the trick. Both may be achieved by the 12345-subdivision strategy presented earlier. When the two limits have been practiced, they should be mixed as the random-practice rationale would dictate.

Anticipatory phase corrections.

The use of metronomes (or applications such as the tSMS app) could be used to achieve smooth speed changes (both accelerations and decelerations of the tempo). Tempo changes could be small or big up to the point of losing synchronicity. Again, transitional points should be identified and practice should revolve around them. Finally, practicing in many rhythmic variations should also be attempted (in-phase, antiphase etc.).

Serve returns.

Serve returns are identified as one of the most important strokes (since, like serves themselves, you cannot avoid them). 345-subdivision strategy is proposed. 3 would coincide with the check. In the first learning stages, the finish of the check (landing on both feet) should coincide with ball's contact point at the opponent's racket (in-phase). Later on, an antiphase strategy is preferable (contact point to coincide with our feet's greatest distance from the ground. 2 (ball bounce) coincides with our racket's maximum opening (which should be as big as time permits it to be). 3 is the returner's contact point.

Eye training.

The movement of the eyes has become a popular subject in various websites and discussions. Indeed, the eyes are our most valuable source of information, even if the sound is so important for effective SMS (hearing impaired people do play tennis, heavily visually impaired people usually do not). The "quiet eye" phenomenon is observed in expert performers (Gonzalez et al., 2017). The eye's saccadic movements may be trained with various methods so they become smoother and therefore, eyes spend more time "locked" on the ball or relevant stimuli; at any rate, more conscious training of gaze strategies is in line with the Distal Method principle that "everything is trainable". Again, transitional points may be identified and worked out.

Paired synchronicity training.

As is the case with martial arts, pairs should specifically work on their own synchronicity using e.g. mirroring games. Exactly the way two practitioners in Aikido mirror each other's movements in weapons' training in order to improve coordination, tennis players should do the same. Such exercises need no balls, just two players facing each other and mimicking each other in great detail, as if they were connected in some more concrete way (which indeed is the case as their brainwaves might reveal). Two transitional points may be identified here: one has to do with speed (at what speed does the synchronicity break) and the other one has to do with distance (ideally pairs could remain in perfect synchronisation even when being as far as behind the two baselines of the full court; however the connection is lost as they distance themselves from each other).

Other synchronicity games.

Following the general ideas presented above, one could devise a great number of drills and games to enhance synchronicity, such as playing through a flexible net (so when the ball is not hit in time, it is not hit at all), or vertical feeding drills with varying ball-height, while the eyes close before the ball bounces. The latter drill is similar to self-feed, but nevertheless it should be done by another person because self-feed is not SMS but rather a closed motor task.

Bioinformatics and tSMS

Bioinformatics deals with the analysis of biological data with the help of informatics technologies. Its applications extend from mapping the human genome to biomechanical analysis (Zhao, Chen, 2018).

It should be noted that bioinformatical applications in sports are rare and in tennis there is no prior experience. Hence, this is mainly an approach to possible applications of bioinformatics to tennis.

Advancements in smartphones (and smartwatches/wristbands) make it possible to develop applications with novel characteristics. Such characteristics may include the identification of various activity parameters in sports (Shoaib et al., 2014; Charlton et al., 2015).

The development of AI agents (in the form of expert systems) may provide new possibilities for training. Using the various sensors of the mobile phones (or even the camera), such systems could both monitor and guide the development of synchronicity. Transitional points (described in the previous sections) could be identified so that training may be adapted to each individual's needs.

Such systems may identify parameters regarding synchronicity (e.g. with a metronome) and measure mean error, providing both feedback in the end of the session and the possibility to adapt the stimulus (e.g. the IOI) to keep it within the optimum learning zone.

Another potential use may be in eye-tracking. For example, in exercises that require from the athletes to keep their eyes fixed on a rhythmically moving target, an application could monitor the eye's trajectory, its saccadic movements and its error in synchronicity.

In much more complicated, 3D representations, applications would provide all sorts of feedback about the coordination of the various body segments (in relation to each other or to the ball). The general idea is that bioinformatics could and should supplement the learning experience in tennis.

3. Conclusion

Based on the ideas presented here, both scholars and practitioners should reconsider their priorities when both researching and teaching tennis (or any other similar sport). For the tSMS, all other factors (physical conditioning, technical form etc.) are important, but they should complement sound SMS development protocols and computerised tools, not the other way around.

The obvious limitations of this study, as they have already been identified, are two: interpretation of data may vary among researchers and a lot of experiments and studies (indeed, a Research Programme) are needed to transform all these ideas into specific procedures and guidelines.

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