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The Influence of the "Stutter-Step" on the Penalty Taker-Goalkeeper Dynamics in Association Football

Dissertação elaborada com vista à obtenção do Grau de Mestre em Psicologia do Desporto

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Resumo

A grande penalidade tem sido investigada por desenhos experimentais não-representativos (i.e., video análises e simulações computadorizadas), com o comportamento decisional do guarda-redes associado à abilidade de predizer a direção da bola. Fundamentada por uma abordagem representativa e da dinâmica ecológica objetivou-se estudar os efeitos da paradinha no sistema rematador–guarda-redes. Cinco rematadores e dois guarda-redes brasileiros da primeira divisão sub-20 executaram vinte e duas penalidades *in-situ*, sob regras oficiais. Através de duas condições para os rematadores (i.e., livre e paradinha) o movimento dos jogadores foi capturado e digitalizado. A coordenação espaço-temporal revelou um atractor de acoplamento de 30º de fase na condição free e um padrão mais instável na condição paradinha (i.e., 30º, 60 º e 90º de fase). Os guarda-redes estavam afinados ao padrão crescimento-rapido-seguido-de-decréscimo presente na velocidade de aproximação dos rematadores, mas esta parece ser uma variável não-especificadora da decisão para os guarda-redes. Identificou-se que ambos os jogadores controlam ações prospectivamente através de uma troca de informações, e devem agir para densenrolar eventos que especifiquem sucesso decisional. Conclui-se que o ultimo segundo para o contato pé-bola é crítico às perturbações e para captação de informações relevantes, bem como que os guarda-redes são vulneráveis à habilidade enganosa da paradinha.

Palavras-chave: dinâmica ecológica, tomada de decisão, sistemas dinâmicos, grande penalidade, guarda-redes, rematador, habilidades enganosas, paradinha, corrida de aproximação, futebol.

Abstract

Penalty kicks has been investigated by unrepresentative designs (i.e., video analysis and computer simulations) with goalkeepers decisional behavior associated to abilities of predict ball direction. Grounded by a representative and ecological dynamic approach this research aimed to investigate the effects of the stutter-step misleading skill on the penalty taker-goalkeeper system. Five penalty takers and two goalkeepers U20 of Brazilian first division performed twenty-two penalties in-situ and under official rules. Through two conditions for penalty takers (i.e., free and stutter-step) players' motion was captured and digitized. The space-time coordination revealed a coupling attractor of 30º of phase in free condition and a more unstable pattern in the stutter-step condition (i.e., 30º, 60 º and 90º of phase). Goalkeepers were attuned to a fast-increase-followed-by-decrease pattern on the approaching speed of penalty takers, however run-up may be a non-specified variable to goalie decision. It was identified that players prospectively controlled their actions by exchanging information and that both players must to act in order to unfold events that specifies successful decision making. It is concluded that the last second before foot-to-ball contact is critical to perturbations and pickup of relevant information, and also that goalkeepers are vulnerable to the effects of the stutter-step.

Keywords: ecological dynamic, decision making, dynamic systems, penalty kick, goalkeeper, penalty-taker, misleading skills, stutter-step, approaching run, football association.

Introduction

Penalty kick situations has been investigated under the paradigm of anticipatory behavior and search of gaze patterns mostly by video analysis and computer simulations conditions. Nowadays scarce research has analyzed penalty kick situations grounded in more ecological and dynamic approaches.

The present research aimed to investigate the penalty kick situations on an ecological dynamics framework, in order to understand the effects of the stutter-step on the penalty taker–goalkeeper dyadic sub-system. The stutter-step is a skill performed by penalty takers during their approach run to the ball in order to mislead the goalkeeper, and in the present research it was applied to investigate the decisional dynamic of penalty taker-goalkeeper sub-system.

In order to achieve these aims, the current research started with a literature review to elucidate and understand the different theoretical frameworks which together give rise to the ecological dynamics approach to decision-making in sport. It was also reviewed the research about penalty kick situations in the scientific literature. This allowed to clearly stated the objectives and the hypothesis of this study. After describing the methods, we presented the results with an original description of the behavior of the goalkeeper and penalty taker along time. This data allowed for an overall view about details that were further analyzed later, taken form a representative experimental design of the penalty kick situation. The next section of results focused on average approach in order to extract patterns revealed by the analysis of each time series. Finally, results about the total behavior of the penalty kick situation as a dynamic system were analyzed. We finalize this document by discussion the data and offering the main conclusions.

Literature Review

The conceptual division between mental and physical, subjective and objective, and so on, may constrain people's actions when facing life vicissitudes. As proposed by Kelso and Engstrøm (2006) perhaps nature is not about contraries but it is about complementary.

In sport psychology this fragmented vision split perception from action and reinforced systems analyses to be concerned with the enhancement of predictability and the reduction of uncertainty (Araújo & Davids 2011). Those deterministic explanations placed the brain as the command center (Dunwoody, 2006/2007; Schmidt & Lee 1999), the organizer responsible for storing information, manage and lead the transformation from perception to action (i.e., organization and regulation of action). Contrary to this view, James Gibson (1979/1986) testified: "moving from place to place is supposed to be "physical" whereas perceiving is supposed to be "mental", but this dichotomy is misleading" (p.225).

Hence, along with the works of Roger Baker, Egon Brunswik and Urie Bronfenbrenner Gibson´s work (1979/1986) grounded a new approach for human behavior, the ecological psychology (see Araújo & Davids, 2009; Hammond & Bateman, 2009; Kaminski 2009; and Krebs, 2009).

The Ecological Approach to Perception and Action

The backbone of the ecological approach dwells in the functional interaction between the organism and its environment. To Gibson (1979/1986) "information about the self accompanies information about the environment, and the two are inseparable (…) one perceives the environment and coperceives oneself" (p.126).

Thereby, for the ecological approach, information guides behavior and it is not inside the brain, it is available in the context. In order to perceive one must move, but in order to move one must perceive, locomotion depends on perception as much as perception depends on locomotion (Gibson 1979/1986, Araújo, Davids & Hristovski, 2006).

The ecological approach tone down the role of indirect perception and internal structures (e.g., symbols, representations, mental plans) and magnifies the functional relationship of the organism-environment system. Since humans and animals are not equipped with internal tools that allow them to perceive space in meters or time in seconds (i.e., the physical world is not interesting at this point) and there is no need for semantic representations (Araújo & Davids, 2011), the solution relies on the interaction organism-environment and the capability of these organisms to directly perceive *change* and *persistence,* that is *environmental events* (Gibson, 1979/1986). Overall, everything in the world persists or changes in some respect, and the perceiving of persistence and change (i.e., instead of color, form, space and time) underpins direct perception (Michaels & Carelo 1981; Turvey 1992).

Besides, in indirect perception stimulus are time-slice and perception of a environmental event must be considered as a deduction from the collection of partitioned and static samples (i.e., snapshots). Thus, to detected a dynamic event the succession of discrete moments need (in somehow) be tied together and reconstructed.

Opposed to it, direct perception argues that information (not stimulus) is over time and coextensive with the event. Thus, perception is an ongoing activity of the registration of meaningful information (instead of discrete parts that must be related), and perceivers need only to detect the event (i.e., change and persistence) as specified by the information.

Moreover, since information is not limited to an instantaneous present, time and space are not understood as absolute notions, rather in direct perception they are fused in a continuum of unfolding events that are perceive and describe the information that specifies change and persistence (Michaels & Carello, 1981; Van Gelder & Port, 1995). Thus, the information that specifies change or persistence is available in the context coupled with the unique characteristics of the organism (i.e., leg length, claws, wings and so on) and the organism must explore the context to become sensitive and to pick up *affordances* (Gibson (1958, 1979/1986).

Understood as opportunities for action, affordances describe the environment in terms of behaviors that are possible at a given moment and under a given set of conditions (Fajen, Riley & Turvey, 2009; Araújo et al., 2006). They are not inherent properties of the object, surface, actors or environment, instead the affordance assemble the functional relationship that is established among them. For this reason, the "theory of affordance implies that to see things is to see how to get about among them and what to do or not do with them" (Gibson, 1979/1986, p.223).

Affordances specifies either information about the environment (i.e., exteroception) and information about the actor itself (i.e., proprioception). and embraces a functional relationship that arises through the coupling between the properties of the environment with the properties of the actor. Therefore a same object, surface or situation, may offer different possibilities for action to different actors. In this sense the affordances are unique to each actor´s abilities and capabilities.

Although an affordance is always available in the context the actor may or may not perceive it. However, the opportunity for action offered by the affordance still remains the same, since it does not change as the need of the actor change (Gibson, 1979/1986). As an example, in football the same ball may afford kick to a penalty taker but also may afford grab or slap to a goalkeeper. Independent of the actor´s goal the ball offers its opportunities.

Online Control of Movement, Perceptual Attunement and Calibration

Relying in Gibson´s approach (1958; 1979/1986) perceptual systems should be defined in terms of the functions they perform, with the detection of perceptual information been an active and exploratory process. So, actions can be understood as visually controlled and visually oriented by exploratory movements across of which changes in the optic array creates ambient arrays that specify meaningful properties of their context.

In general, sports contexts are extremely dynamic and fast-paced which requires that athletes must be extremely aware of the ever-changing opportunities for action afforded by each event (Araújo et al., 2006; Fajen et al., 2009). For example, Craig and colleagues (Craig, Berton, Rao, Fernandez & Bootsma, 2006; Craig, Goulon, Berton, Rao, Fernandez & Bootsma, 2009) demonstrated in virtual-based reality how along its non-linear trajectory a foot-ball kicked toward the goal may provide different perceptual information (and consequently possibilities for action) in expert goalkeepers. They also suggest that the human visual system may not be sensitive to extremely fast-paced changes, like some balls trajectory, and that in game conditions goalkeepers could prospectively guided their action.

The role of affordances to prospectively control movements seems to be a promising way to understand sport behavior. The main assumption of prospective control mechanism relies in the ability of biological systems to perceive and use perceptual variables to guide the action.

Therefore, movements can be understood as guided prospectively by information in the changing optic array, so information that specifies action-relevant properties of the environment may be used in the control of action (Turvey, 1992). Moreover, this information is perceived in action units and allows actor to produce on-line regulations based on the perception of their current relationship to the environment (Montagne, 2005; Fajen, 2005).

Perception plays a preparatory role in action as well as an on-line role in tuning action as it unfolds (Fajen et al., 2010), thus given that the current state is maintained the prospective information guide the actors in relation to the unfold next event (i.e., current future) and consequently it also informs actors about how to modify (or not) his/her movements (Montagne, Bastin & Jacobs, 2008).

Research have suggested that when facing trouble in perceive the arrival place of a moving target under normal circumstances prospective rather the predictive (i.e., anticipation forthcoming events based on partial or incomplete sources of visual information) is the strategies adopted by actors (Montagne, 2005).

For example, Morice and colleagues (Morice, François, Jacobs & Montagne, 2010) manipulated ball path display curvature and availability in order to investigate walking speed adjustments to intercept approaching target in virtual environment. Authors found that whereas actors adopted the strategy that relies on prospective information when poor information was available, when rich information was available they adopted the strategy that also includes predictive information. Therefore, research concluded that actors use different control laws under different environmental constraints. They also discussed that the adoption of the strategy including predictive information when facing rich information may occur in order to minimize unnecessary changes (i.e., principle of efficiency) since prospective control allow success in the task but can cause unnecessary adjustments.

Overall, these evidences suggest that on-line control increase the opportunities to reach successful in the task and became substantial to movement adaptation when facing dynamic and fast-paced context such as sport. They also establishes that is not necessary to know in advance the place or the time of contact (Montagne, 2005).

Visually guided actions have been studied under the assumption of a control mechanism relying on the operation of the information-movement loop that demonstrated a continuous functional adaptations of the displacement (i.e., information-based approach). Thus, most of these research also presents some control law of a right pattern of optic flow that must be cancel or keep constant in order to reach success, which means that these approaches attested that the specification of an action mode precedes the control of the action.

This is what happens for example with Chapman´s theory (1968) of the optical acceleration cancelation (AOC) where an actor must act to keep a certain optimal angle in relation to the ball trajectory in order to null the optical acceleration and to catch the ball successfully (the further action!). The same ecological variables are found in a research with dogs catching frisbees (Shaffer, Krauchunas, Eddy & McBeath, 2004) and baseball players catching balls (Shaffer & McBeath, 2002), where a linear optical trajectory (LOL) must be kept constant.

Although AOC informs that a baseball fielder will arrive at the right place at the right time to catch a fly ball if he/her runs at the only constant velocity for it (Chapman, 1968) the theory does not consider the actor limits running capabilities.

According to Fajen (2005, 2007a) this is an essential concept of the theory of affordances that has been overlooked in information-based approach since affordances are actor-relative and implies a fit between actor and environment. Through breaking studies Fajen (2007a) demonstrated that control of action is modified by actor´s maximum action capabilities and proposed an affordance-based approach. The model claims that affordances are not only perceived in order to select the appropriate action before an action but it is also applied to monitor the control during the execution of the action.

For example within the AOC assumption theory (Chapman, 1968), it implies that if the baseball player takes too long before cancel his/her optical acceleration the required speed might become higher than player´s maximal capability of speed. Under this condition the ball could not be caught. However, if the baseball player keeps cancellation of optical acceleration inside a range whose boundaries are his/her lower and higher running speed capabilities, catch the ball becomes possible. Recent studies (Bastin, Fajen & Montagne, 2010; Dicks, Davids & Button, 2010 and Fajen & Matthis, 2011) has demonstrated evidence of this boundary action capabilities.

Another important process in the continuous perception-action loop that underlies improvement in perception and success in task-oriented actions are attunement and calibration (Withagen & Michaels, 2005; Fajen 2008; Jacobs & Michaels, 2007, Araújo & Davids, 2011).

Attunement process entails that actors must achieve a high sensitivity to informational variables that specify the aims of the actions. However, actors may also exploit a variable that relates ambiguously to the perceived property, namely a nonspecifying informational variable.

The detection of specifying information is a necessary but not a sufficient condition for action to be precise. Actors need to be metrically accurate and appropriately scaled to the detected information and the process that determines this scaling is calibration, a tight adjustment to task-relevant informational variables.

According to Fajen (2007a) actor ever-changing action capabilities are the only significant units to perceiving-acting systems in order to reach success in performance: “the only sense in which actors know their action capabilities is in terms of the calibratory state of the perceptual system that allows them to reliably perceive what they can and cannot do." (2007a, p.397).

Perceptual attunement to different informational variables, as conditions change, is a general principle that underlies learning and flexibility to adapt to dynamic environments (Fajen et al., 2009). Research suggested the ability to be perceptually attuned to multiple relevant information sources as conditions change (Van der Kamp, Savelsbergh, Smeets, 1997; Caljouw, Van der Kamp, Savelsbergh, Heiko, & Geert, 2004).

Thus, changes in the decisional behavior may be refer as an ongoing processes of reattunement and recalibration where information of some sort is required to induce these processes. Once actors are able to prospectively control their actions adjustments may occur simultaneously to the unfolding events (i.e., on-line).

An informational variable is not in and of itself specifying or nonspecifying, rather the variable is specific to the perceived property and depend on the constraints in the task. This might lead to the supposition that in a ecological penalty kick situation for example, despite approach run to the ball be a homogeneous action performed by penalty takers to ball contact occurs, if their approach run differ in time, velocity and shape this should not specify the time to ball contact occurs.

The pickup of nonspecifying variables yield errors that differ from errors that result from miscalibrations and so unsuccessful performance may occur either due to an attunement to nonspecifying variables as well as miscalibration process. Withagen and Michaels (2005) clarify that an actor who relies on a nonspecifying variable (i.e., ambiguously to the perceived property) in a dynamic touch paradigm for example, could perceive rods of different lengths as equal or equal rods length as different. In the other hand, a miscalibration (i.e., inappropriate action scaled) could yield a general underestimation or overestimation of perceived rod length by actors.

These are important assumptions to improved learning process, to organism adapt to the context in a functional way and consequently to decision making.

Ecological Dynamics of Decision Making

According to Gibson (1979/1986) regardless the complexity of the property to be cognized, our awareness of it is necessarily rooted in perception. Perception is so an exploratory and not passive activity where observers are actively engaged in a dynamical exchanges with their environment aiming for a functional coupling. To reach an intended outcome actors need to be attunement and calibrated to a specific information and this action can be control prospectively.

These assumptions coupled perception and action in a continuum loop and turned the affordances pickup the vital point to the ecological study of what humans perceive, but also how they decide and act. So, when a actor moves with respect to his/her surroundings opportunities for action persist, emerge and dissolve, and subtle changes of action can give rise to multiple and marked variations in opportunities for subsequent actions. Since goal-oriented actions can be understood by detecting informational constraints specific to goal-paths (Araújo et al., 2006), goal constraints taking the form of a rule that prescribe how an actor should act if some outcome is intended within a particular context.

Using concepts and tools of dynamical systems in order to understand decisional behavior that emerging from the interactions of individuals with environmental and task constraints over time towards specific goals, and considering the scale where the relationship between actors and their environments occur, Araújo and colleagues (Araújo, Davids & Hristovski, 2006) established the ecological dynamic decision making approach in sport. Therefore, the concept of emergent decision making under constraints aims to understand how living systems assemble, sustain and disassemble the macroscopic patterns among the huge number of system components embedded in their environments (Davids, 2009).

A dynamic system is understood as a set of changing aspects or sub-systems whose states (or patterns) specify aspects that happen in that moment. The totality of all possible states in which a system can be allocated is called state space and the behavior of the system can be describe as a sequence of points unfolding over time (Kelso, 1995; Van Gelder & Port, 1995). Factors that affect the system evolution are referred as parameters, thereby a control parameter lead the system through the different collective states without contain or prescribe the code of the emergent pattern, whereas an order parameter generally is identified near nonequilibrium phase transitions (where loss of stability gives rise to a new pattern) and characterizes how patterns form and evolve in time (Kelso, 1995).

Other significant properties of dynamic systems are attractors, fluctuations, bifurcation, multistability, abrupt and qualitative change. Roughly, when a system undergoes a perturbation, a control parameter reaches some specific values, and at a certain critical value only one macroscopic state is possible for the system to remains stable. However, when the control parameter is near a critical value, there are fluctuations, i.e., instability in the system, which may causes the occurrence of bifurcation(s). These fluctuations are expressed by the observation of different states in the behavior of the system, a phenomenon called multistability. In a bifurcation point transitions in the system state may occur. A system is stable when it is placed in one *attractor*, however, when at a bifurcation point, several attractors may attract behavior. With a continuous change in the control parameter a phase transition may occur through an abrupt change in the order parameter. Thus expresses a qualitative change (i.e., a reorganization) of the system (Kelso, 2005; Van Gelder & Port; Araújo et al 2006). The whole process is self-organized, but “there is no self, no agent inside the system doing the organizing” (Kelso, 2005, p.8).

In order to analyze how functional patterns of behavior emerge from the interaction of an actor and his/her structured environment over time (i.e., temporal evolution) Warren (2006) proposed a framework called behavioral dynamic, where a functional behavior (e.g., decision making) can often be described by changes in a few key variables. Thus, in behavioral dynamics the adaptive behavior corresponds to trajectories in the state space of behavioral variables (i.e., the hypothetical totality of all the possible states in which a system can be allocated), goal states are attractors (i.e., regions in state space toward which trajectories converge), avoid states are repellers (i.e., regions from which trajectories diverge) and sudden changes in the sequence of points that unfold over time are bifurcations in behavior (i.e., qualitative transitions).

Hence, the behavior is influenced by initial conditions and the more an actor becomes closer to his/her intend goal, the more his/her exploratory behavior must couple with ever more specific information in order to narrow the possible action paths available in the system in a unique emergent path at the goal accomplishment instant. This process underpins decision making as a functional and emergent process in which a selection is made among converging paths for an intended goal. Choices (i.e., decisions) are made at bifurcation points where more specific information becomes available, constraining the environment–athlete system to switch to the most functional path. Therefore, decision unfolds moment-to-moment and actors use their movements to influence contextual interactions to define a path towards a specific goal. (Araújo et al., 2006).

The type of order that emerges in a decisional path is not only influenced by initial conditions and intentions (i.e., attractors and repellers) but also by constraints which are conceived as parameters whose boundaries or features shape a system´s behavior (Newell, 1986; Davids, Button, Araújo, Renshaw & Hristovski, 2006; Davids, 2009).

Constraints can be classified as belonging to the actor (e.g., morphological characteristics, technical proficiency and psychological states), the environment (e.g., social influences, light conditions and temperature) and the task (e.g., aim and rules of the task, number of plays involved and implements employed such as a ball) (Newell, 1986), but these three categories are mutually interactive (Bernstein, 1967; Kelso, 1995).

Decisional behavior emerges controlled by a single confluence of key constraints acting on the system (Davids, Button & Bennett, 2008; Araújo, Davids, Bennet, Button, & Chapman, 2004) where changes in constraints values (i.e., parameters) affect the state of order in the system driving the variability implicit in the landscape (i.e., the hypothetical all possible states) to fewer options of qualitative stable states.

So, in a complex system few states of organization are adopted and the system resides only in certain parts of the landscape of all hypothetically possible states. It means that complex system present a limited trajectory and only some set of qualitative states (i.e., bifurcations) can be sufficiently maintained to sustain a decision (Van Rooji, Bongers & Haselager, 2002). In penalty kick situations for example, it can be describe by the emergency of the decision of to move or not move (i.e., two possible qualitative states) of the goalkeepers when penalty-takers approach to the ball.

The Penalty Taker–Goalkeeper Dynamic System

In face of other studies ecological dynamics of decision making can provide an alternative explanation for results already obtained since to successful of the task this framework entails perception-action cycles to become attuned to relevant information and allows a more substantial emphasis on the understanding of how each actors acts to assemble unique performance solutions in order to satisfying the range of personal, environmental and task constraints (Araújo, et al., 2006).

Research on penalty kick situation

Penalty kick situations has been investigated under the paradigm of anticipatory behavior and search of gaze patterns mostly by video analysis and computer simulations. Therefore, anticipation has been associated with the ability to make accurate predictions from partial or incomplete sources in order to anticipate the outcome of a observed action.

As a component of the perception-action system, anticipation appears to be an essential mechanism to minimize errors of the decisional behavior on fast-paced sport situations (Williams, Huys, Cañal-Bruland & Hageman, 2009; Ward, Williams, Bennett 2002; Abernethy 1991).

Thus, in a time where the rule of the game does not allowed goalkeepers to move before ball contact occurs Morris and Burwitz (1989) found in a in-situ design that elite goalkeepers moved before ball contact as an anticipatory strategy in penalty kicks. In a quantitative biomechanical analysis of information on the approach run of skilled penalty takers, Williams and Griffiths (2002) found, on right-footed penalty takers, different approach angles when kicking to right side of the goal (35°) and when kicking to left side (27°) and consequently different angle of the hips. Moreover, visual cues was highly player-specific and results suggested that penalty takers were better identified by the prevalence of visual cues made available to goalkeepers. The study appointed that penalty takers may benefit from standardizing their angle of approach to minimize the visual cues available to the goalkeeper.

In order to examine skilled-based differences in anticipation and visual search, Savelsbergh, Williams, Van der Kamp and Ward (2002) investigated how expert and novice goalkeepers moved a joystick in response to penalties presented on a film that end upon foot-ball contact, including eye-tracking measures. Results indicated that experts were more accurate in predicting direction of the penalties waited longer to initiating a response and were anchored in fewer fixations areas of long duration (i.e., kicking leg, non-kicking leg and ball) in the moment of the foot-ball contact. In a another study, Savelsbergh, Van der Kamp, Williams and Ward (2005) also investigated expert goalkeepers on simulated film-based penalty kicks that end upon foot-ball contact with eye-tracking technology. Results suggested that successful visual anticipation in goalkeepers seem to rely on the coupling of pickup predictive information located in the penalty taker non-kicking leg with later initiated actions. In a field simulation with intermediate-level soccer players, Van der Kamp (2006) concluded that anticipated goalkeeper´s movement during approach run (i.e., keeper-dependent strategy to decision making) is a risk and may degrade performance, due to the short time available to modify the kicking action. In turn, Bar-Eli, Azar, Ritov, Keidar-Levin and Schein (2007) analyzed penalty kicks in top leagues and interviewed top professional goalkeepers in order to demonstrate action bias in goalkeepers decisions. These authors argued that goalkeepers are biased in jumping to the left-or-right side (i.e., this is the norm), despite information available to make a decision. A possible explanation is that they feel better doing it than standing still when a goal is scored.

Dicks et al. (2010) studied individual differences in perceptual-motor behavior of goalkeepers in a visual anticipation task. In order to investigated if skilled goalkeepers scale the timing of their movement initiation, experienced goalkeepers faced penalty kicks taken with deceptive and non-deceptive kicking actions in a full-size goal (7.32x2.44m) represented by a white screen in an indoor Astroturf training facility. Data revealed individual differences in action capabilities (i.e., the faster the goalkeeper the later the goal-keeping actions was initiated).

In a in-situ experimental task constraints, Dicks, Button and Davids (2010) research the impact of deception (i.e., to intend kick to one side of the goal, but actually to shoot at the opposite site) and non-deception (i.e., to shoot directly at the desired goal location without any intent to deceive) penalty-kick strategies on goalkeeping performance. One experienced penalty taker and eight experienced goalkeepers performed penalty kick situations in a full-size goal (7.32x2.44m) represented by a white screen in an indoor Astroturf training facility. The availability of visual information for goalkeepers was confined exclusively to a penalty taker´s run-up and kicking action, that were added to ball-flight information across consecutive presentation points based on unfolding kinematic information during the kicking action (i.e., a temporal presentation paradigm). Results revealed that goalkeepers initiated movement response earlier and that performance accuracy was directly influenced by penalty-kick strategy. In addition, goalkeeper were better in save non-deception trials than deception trials and they also demonstrated more response corrections in deception trial than non-deception trials. The studied concluded that goalkeepers are likely to benefit from not anticipating a penalty taker´s performance outcome on information from the run-up, in preference to later information that emerges immediately before penalty taker´s kicking action.

Researching the ability to anticipate the actions of others by a biological motion perception paradigm, Diaz (2010) investigated the goalkeeper problem (i.e., the lack of time to decide after foot-ball contact). Over three experiments the author analyzed two classes of information: the spatially localized to a specific place on the body and the information that is distributed across the body. In the first experiment quantitative methods to the motion data of penalty kicks performed by experts college level soccer players aimed to produce reliability measurements of both local and distributed sources of information as predictors of the outcome of a penalty kick. Results revealed that reliable sources of information included the orientation of the hips, the knee of the kicking foot and the lateral point of foot-to-ball contact. Several sources of distributed information were also found as reliable indicators of kick outcome, with both local and distributed information been most informative in the third and final phase of kicker's approach (Diaz, 2010).

In a second experiment motion data from the first experiment was used to create animations of a penalty kicker approaching and kicking a ball (i.e., visual stimuli that ended upon foot-ball contact). Under the goalkeeper view undergraduates with uniformly inexperienced of penalty kick judged perceived kick direction by right or left shifts on a keyboard. Successful performance was characterized by later responses relative to unsuccessful and results indicated predictable relationship between perceived kick direction and sources of information that included yaw angle of the hips, the lateral point of foot-to-ball contact, and two sources of distributed information (Diaz, 2010).

A third experiment aimed further narrow preceding results (i.e., information sources of yaw angle of the hips, the lateral point of foot-to-ball contact and two sources of distributed information). Inexperienced undergraduates were given practice on anticipating kick direction and in the first four blocks they judged kick direction stimuli used in the earlier experiments. On the two last blocks catch trials were randomly interspersed and artificial stimuli in specific sources of information were made unreliable. Whereas in the “hip-only” stimuli just hip markers were reliable indicators of kick direction, in the “ball-unreliable” stimulus, foot-to-ball information was made unreliable and distributed sources of information as well as hip-information remained reliable. Results on the catch trials (i.e., performance after practice) revealed that participants were still able to perceive kicking direction in the “ball-unreliable” stimuli condition, but they were unable to perceive kicking direction on catch trials in “hip-only” stimuli condition. Data suggested strong evidence against the use of hip information and information related to the location of foot-to-ball contact. Moreover, they supported the conclusion that judgments of information use were made on the basis of distributed information (Diaz, 2010).

Overview of penalty kicks literature review

The present literature review reveals that penalty kick situations appears to be focus in identify possible sources of information on penalty taker´s approach and kicking action in order to goalkeepers predict ball direction. Although within of their experimental protocol deceptive and non-deceptive strategy has been used, only one recent research (Dick et al, 2010) investigated the effects of deceptive and non-deceptive movements of penalty taker in the goalkeepers action. However, the majority of these deceptive strategies has been the instruction to penalty taker look or intend that will shoot to one side and so to shoot to another side.

A lack of representative design and ecological scale in researching of penalty kick situations was also showed (see also Lopes et al., 2008). Given that perception-action cycles involve a functional coupling actor-environment, unrepresentative experimental designs that split perception from action may lead to different assumptions of those that could be found by more representative designs (Van der Kamp, Van Doorn & Savelsbergh, 2008).

According to Brunswik (1956) statistical logic of induction should hold for environments and actors since behaviors must cope with the multiple, noisy, messy situations, which occur in the environment. Therefore, to be representative of the setting to which an actor is adapted, the informational variables collected in a sample must be derived from the actor´s environment.

Given that important features that underpin perception-action involves attunement, calibration, prospective control and task constraints, experimental designs should allow actors to explore the context not only to perceive in order to act, but also to act in order to perceive (Araújo et al., 2006).

Only by arrangement of contextual conditions towards the experimental or practice results that an investigator intend to generalize can be reliable (Araújo, Davids & Passos, 2007; Brunswik, 1956).

Penalty kick situation as an ecological dynamic system

Under a dynamic ecological decision making framework penalty kick situations are conceived as a dyadic sub-system of 1vs.1 (Lopes et al., 2008; Araújo et al., 2006; Davids, Araújo & Shuttleworth 2005; McGarry, Anderson, Wallace, Hughes & Franks, 2002).

In penalty kick situation goalkeeper and the penalty taker share information about the field and the ball, they also share an unintentional coordination undergoing to the same rules of the game and in compete in order to defend or to score a goal. Thus, just before referee´s whistle authorizing the action, a not deliberate coupling penalty taker–goalkeeper occurs, and the dyad is established through the exchange of a continuum flow of information that becomes available with the exploratory behavior of both penalty taker and goalkeeper. These actions are guiding by intentions and personal, environment and task constraints.

Thereafter, penalty taker-goalkeeper actions become coordinated one to another in an intra-coupling manner (i.e., couplings among players between teams) (McGarry et al., 2002) and the two players act in an interdependent way in the sense that the temporal, spatial and intensive characteristics of the movement on each player are constrained with regard to the movements of the other player (Kelso, 1995; McGarry et al., 2002; Araújo et al., 2006; Bourbousson, Sève & McGarry, 2010).

In penalty kicks goalkeeper´s actions intend to sustain the existent condition by creating opportunities for the ball does not cross over the goal line. In turn, penalty taker´s actions intend to break the existent condition creating opportunities for the ball cross over the goal line. The system is attracted by two possible states “score” and “not score” the goal, and the actions of both players create perturbations that cause imbalances in the system and may lead to one stable state to another (McGarry et. al., 2002; Araújo et al., 2006).

For penalty takers for example, a critical perturbation can be the performance of a misleading skill that creates a disruption in the goalkeeper´s defense capabilities leading to the emergence of a goal score opportunity.

Misleading Skills

Effects of misleading skills has been associated in research of judgment and anticipation couple with the expertise level. These skills have been seen as an strategy to gain advantage over opponents since an actor provides information that misleads an observer and leads him/her to an incorrect judgment of the deceiver´s intention.

As already seen in the present research in a in-situ experimental task constraints, Dicks, Button and Davids (2010) research the impact of deception (i.e., to intend kick to one side of the goal, but actually to shoot at the opposite site) and non-deception (i.e., to shoot directly at the desired goal location without any intent to deceive) penalty-kick strategies on goalkeeping performance. However, the great majority of studies have been made in a video-simulation paradigm.

Thus, using a video paradigm occlusion anticipation of deceptive movements by experts and novices rugby players was investigated from the perspective of a defensive player. Results revealed that novices were more susceptible to deceptive movements than experts (Jackson, Warren & Abernethy, 2006). Expert and novices ability of detect deceptive intentions was also studied in basketball where participants were asked to predict the occurrence of a true or a fake pass by watching short videos, point-light animations and static images of basketball players. Results revealed that experts outperformed novices in normal and point-light video (i.e., dynamic movements) but not with static images (Sebanz & Shiffar, 2009).

The signal detection theory and temporal occlusion paradigm was used to analyze the impact of response bias, perceptual and motor expertise on differentiating deceptive and non-deceptive actions. Thus, skilled and novices handball players had to detected in a video with side view whether a penalty taker shot or faked a shot at the goal by pressing a button. Results indicated no differentiation in perceptual sensitivity for both level players but revealed that expert handball goalkeepers were significantly biased to judge movements as deceptive (Cañal-Bruland & Schmidt, 2009).

Finally, Brault and colleagues (Brault, Bideau, Craig & Kulpa, 2010) aimed to study biomechanical factors in order to examine how an attacker tries to deceive the defender in a 1 vs. 1 real duel in rugby. Results revealed that medio-lateral displacement of the center of mass and lower trunk yaw were minimized during both effective and non effective deceptive movements. Data also suggested that player exaggerated body-related information intentionally to deceive the defender to run in one direction while minimizing other postural control parameter to disguise a sudden change in posture necessary to modify final running direction.

Objectives and Hypothesis

Previously literature review demonstrated that penalty kick researches focus were specifically in the goalkeeper problem of perceive and anticipate the correct direction of the ball and apparently only one recent research has worried about the effects of penalty taker´s deceptive movements in goalkeeping performance. The ability of predict ball direction in order to anticipate it cannot be understood as split of the goalkeeper timing of response. Moreover, studies have shown a prospective control rather than predictive control when poor informational conditions to guide movements are available (Montagne, 2005), and the fast-paced sports context of a goalkeeper in penalty kick situation, appears to fits this condition.

In congruence with this information, the actual research challenges how important is to anticipate and predict ball direction if the goalkeepers do not perform their decisional movement in a optimal timing and aimed to show that goalkeepers are not attuned to a relevant information in their decisional behavior.

For this purpose we aimed to investigate the effect of the stutter-step misleading skill in penalty kick situations grounded in an representative and ecological dynamic approach.

Given that the stutter-step skill consists in the manipulation of the of the timing to foot-to-ball performed by the own player during penalty taker´s approach run it can be consider as an independent variable with the decisional behavior of goalkeepers being so the dependent variable.

Thus, initially we aimed to analyze the penalty taker–goalkeeper dynamic system by a qualitative dynamic. Following, the analysis intended to understand the space-time coordination of penalty-taker goalkeepers and the effects of a penalty taker´s misleading skill (i.e., stutter-step) on both, penalty takers and goalkeepers decisional behavior.

In addition the present research aimed to test the following hypotheses:

i) The penalty taker´s misleading skill (i.e., stutter-step) anticipate the emergence of goalkeeper´s decision making.

ii) The stutter-step skill changes the approaching run of penalty takers and increases the time for the occurrence of foot-ball contact happens.

iii) The penalty taker´s misleading skill (i.e., stutter-step) changes the space-time coordination pattern on the penalty taker-goalkeeper system.

Method

Participants

Five Brazilian penalty takers and two goalkeepers under-20 (M=17.7; SD=0.5 years), from the first division of São Paulo, made up ten different dyads of 1vs.1 (i.e., penalty taker–goalkeeper) in a total of 50 penalty kick trials.

The players practiced football for M=8.4; SD=2.4 years, with a load of fifteen hours per week plus four games per month. Moreover, before data collection all participants signed a consent term to collaborate in the present research. Researchers assured confidentiality about their identities.

Procedure

In order to ensure a ecological scale and representative design (Araújo et al., 2007; Brunswik, 1956) the present data were collected in-situ and under official penalty kick rules established by FIFA´s board.

Instructions

Both, expert penalty takers and goalkeepers started with a session of routine warming-up leaded by their physical trainers and subsequently participants were separated according with their role, namely penalty takers (i.e., PT) and goalkeepers (i.e., GK). The instructions were differentiated according with the participants’ role, so goalkeepers were informed that each should perform 25 penalty kicks, with the aim of saving them. In turn, penalty takers were informed that each should perform 5 penalty kicks for each goalkeeper (i.e., 10 in total), with the aim of score a goal in every trial. In addition, penalty takers were instructed that at least twice within the 10 trials, they must executed the misleading skill knowing as the “stutter-step”. Thus, as in a football match, they could choose when to perform the misleading skill without informing the goalkeeper.

Apparatus and sample

All players were coded in a sequence of the penalty kick trials, always following the official rules of the game. Player´s motion was captured using a digital video camera model Sony Handy cam DCR-DVD101 placed in a lateral view of the penalty area, as shown in Figure 1.

Through the observation of the recorded video images the 50 dyads were grouped according to the presence or absence of the misleading skill in the penalty takers´ approaching run. Thus, two categories of penalty kicks were defined: “free” (i.e., without the misleading skill) and “stutter-step” (with the misleading skill).

Figure 1. Capture motion´s player viewpoint.

At the end of data collection 12 trials were classified as “stutter-step” and, accordingly, 12 trials classified as “free” were randomly selected for further analysis (see Table 1).

Table 1. The sequence of the penalty kick trials and their classification.

Round01	PT1GK1/F	PT2GK1/F	PT3GK1/SS	PT4GK1/F	PT5GK1/SS
Round02	PT1GK2/F	PT2GK2/F	PT3GK2/F	PT4GK2/F	PT5GK2/F
Round03	PT5GK1/F	PT4GK1/F	PT3GK1/F	PT2GK1/SS	PT1GK1/F
Round04	PT5GK2/F	PT4GK2/SS	PT3GK2/F	PT2GK2/F	PT1GK2/F
Round05	PT2GK1/F	PT1GK1/SS	PT5GK1/F	PT4GK1/F	PT3GK1/SS
Round06	PT2GK2/F	PT1GK2/F	PT5GK2/F	PT4GK2/F	PT3GK2/SS
Round07	PT4GK1/F	PT5GK1/SS	PT1GK1/F	PT3GK1/F	PT2GK1/SS
Round08	PT4GK2/F	PT5GK2/F	PT1GK2/F	PT3GK2/F	PT2GK2/F
Round09	PT3GK1/F	PT1GK1/F	PT2GK1/F	PT5GK1/F	PT4GK1/F
Round10	PT3GK2/SS	PT1GK2/F	PT2GK2/SS	PT5GK2/F	PT4GK2/SS

PT = Penalty Taker; GK = Goalkeeper; F = Free; SS = Stutter-Step

Variables

Taking into account previous literature review two variable were established to describe the dynamic of the penalty taker-goalkeeper system. Thus, a first variable was defined as the approach speed of the penalty takers which were established in relation to one fixed point in the penalty mark, namely the point number 1 in figure 2. The independent variable was the performance of a misleading skill in the penalty taker approaching run performance, namely the stutter-step. The stutter-step skill consists in the abrupt reduction of the approach speed by increase the permanence in the supporting leg, almost stopping the run, just before foot-to-ball contact occurs.

A second variable was defined as the approach speed of the goalkeepers which were established in relation to a fixed point resulting to the congruence of the left side post (the one closer of the video camera position) and the goal line, namely the point number 4 in figure 2. The decisional behavior of the goalkeeper was measured through this variable which represented the dependent variable.

Data treatment and analysis

The sample of 24 video-clips of the penalty kick situations (i.e., 12 free trials and 12 stutter-step trials) were cut following the same principle: each clip started from the frame of the initiation of the first step of the penalty taker's approaching run to the ball, and stopped on the first frame after the initiation of ball movement.

Figure 2. The four calibration field points.

The 24 video-clips were analyzed according to the method of capturing complex human behavior in representative sports contexts described in Duarte et al. (2011). Thus, all penalty kick situations were digitized with the software TACTO 8.0 at 25 Hz (Fernandes, Folgado, Duarte & Malta, 2010).

Given that four points were necessary to calibrate and extract players´ *x* and *y* virtual coordinates, point 1 was defined as the penalty mark, point 2 was defined as the closer intersection of the lines of the small area and points 3 and 4 were respectively defined as the intersection of the right and left post to the goal line (Figure 2). Points 1, 3 and 4 were selected considering the importance of these marks on penalty kick situations (i.e., the initial position of the ball and the goal line). The point 2 was selected as the closest point of the camera viewpoint. . Following, the virtual coordinates were transformed into metric coordinates by a Direct Linear Transformation method (2D) conducted using the software MATLAB (version R2009b) and approach speeds in absolute values were extract in data time series.

In the absence of a precise mathematical model Van Gelder and Port (1995) advice that a qualitative dynamical descriptions of the phenomenon recorded in precise data time series may be used in order to detail how behavior unfolds in real time. The most commonly used method for representing continuous data are time series graphs.

Thus, qualitative dynamics of the penalty taker–goalkeeper system were obtained by plotted both variables approach speed of penalty taker and approach speed of goalkeeper versus time for free trials and stutter-step trials situations (Duarte et al., 2011).

Inter-trial point-by-point average band analysis of free and stutter-step conditions

In order to obtain a graphical representation of the variability of the dependent variables, a multiple-trial aggregate average curve, along with two additional curves representing the aggregate average (M) plus and minus the standard deviation ($M_i \pm SDi$) value for each data point were calculated (Stergiou, 2004). According to Stergiou, the point-by-point method is sensible for data that have been temporally aligned to a single critical event.

Thus, to perform this analysis data time series were aligned by the critical event of penalty taker´s foot-to-ball contact. This was established as the time zero. In addition, frames were removed from the beginning of the data time series and aligned by the point where at least half of possible records were available (i.e., 6 of 12).

Despite of being representative of the entire series, this method do not elicit detailed information about the variability occurring at specific locations along the series. Rather the band represents the average variability across all data points (Stergiou, 2004).

Finally, expansions in the bandwidth indicate that the values diverge on that correspondent data points, while contractions in bandwidth indicate that the values converge on the correspondent data points.

Penalty taker and goalkeeper point-by-point average band analysis

By plotting only the approach speed of the penalty takers in both free and stutter-step conditions, and by plotting only the approach speed of the goalkeepers in both free and stutter-step conditions a new point-by-point average band analysis was obtained, The aim of this analysis was to investigate where in the total time penalty kick becomes more influent in the behavior of goalkeepers and penalty takers in both conditions (i.e., free and stutter-step).

Thus, after calculated the mean time of the total of 24 data time series (M=2.18s; SD=0.51s) each data time series were cut in the frame matching to the value of the division (i.e., 1.12s) of the mean obtained previously (i.e., 2.18s).

Two different groups of average band point-by-point were created, one with the zero time starting at the beginning of the approach run and ended 1.12s after the beginning of the approach run (i.e., 1.12 s from the onset movement), and another with the zero time starting at the foot-to-ball contact and ended 1.12s before foot-to-ball contact (i.e., 1.12s to the ball contact).

Relative phase analysis

Without regard the opponent more interactive sports (e.g., soccer and tennis) are susceptive to the effects of strong or weak profiles awarded to a player when doing a performance measure analysis. Thus a better contemplation should arise to the interactions of players where these interactions are considered indivisible (Bourbousson et al., 2010).

In order to examine the effects of the misleading skill (i.e., stutter-step) in the space-time coordination patterns of the penalty taker–goalkeeper´s dyadic system, the approach speed of penalty taker variable and the approach speed of goalkeeper variable were subjected to relative phase analysis using the Hilbert transform (Palut & Zanone, 2005).

Statistics analyses

All statistics treatment were applied by using the software SPSS (version 19) and although homogeneity of all data was confirmed, the assumption of normality was violated by data of the average time of stutter-step condition on the analysis of the average approaching time of penalty takers. However, parametric and non-parametric test application lead to equal significant ρ-values. Thus, given that parametric tests are powerful to qualitative data were opted to present the parametric test result.

Results

Penalty Taker-Goalkeeper Decisional Dynamic

By visual inspection of the qualitative data present in the graphs of figure 3, it is possible to identify the absence of a small plateaus in the approach speed of penalty taker variable on the free trial conditions and the presence of a small plateau (indicated by the arrow in graph “d”) in the approach speed of penalty takers variable in the stutter-step trial conditions. The emergence of these plateaus on the unfolding behavior of the approach speed of penalty takers variable states the occurrence of misleading skill (i.e., stutter-step).

The dynamic description also allowed the detection of the moment that goalkeeper decision making occurs through the presence of peaks that emerged in the unfolding behavior of the approach speed of goalkeeper variable. While in free trial condition the peak emerged just before the contact with the ball, in the stutter-step trial condition these peaks emerged associated with the plateau occurrence on the approach speed of penalty take variable, as indicated by the arrow in the graphic “b”.

A paired sample t-test was conducted to compare the approaching time to foot-to-ball contact of penalty takers in free and stutter-step conditions. There was a significant difference in the approaching time of penalty takers in free (M=1.86s, SD=0.37s; n=12) and stutter-step (M=2.51s, SD=0.42s, n=12) conditions; t (11)=-4.685, $p < 0.01$, d=0.83.

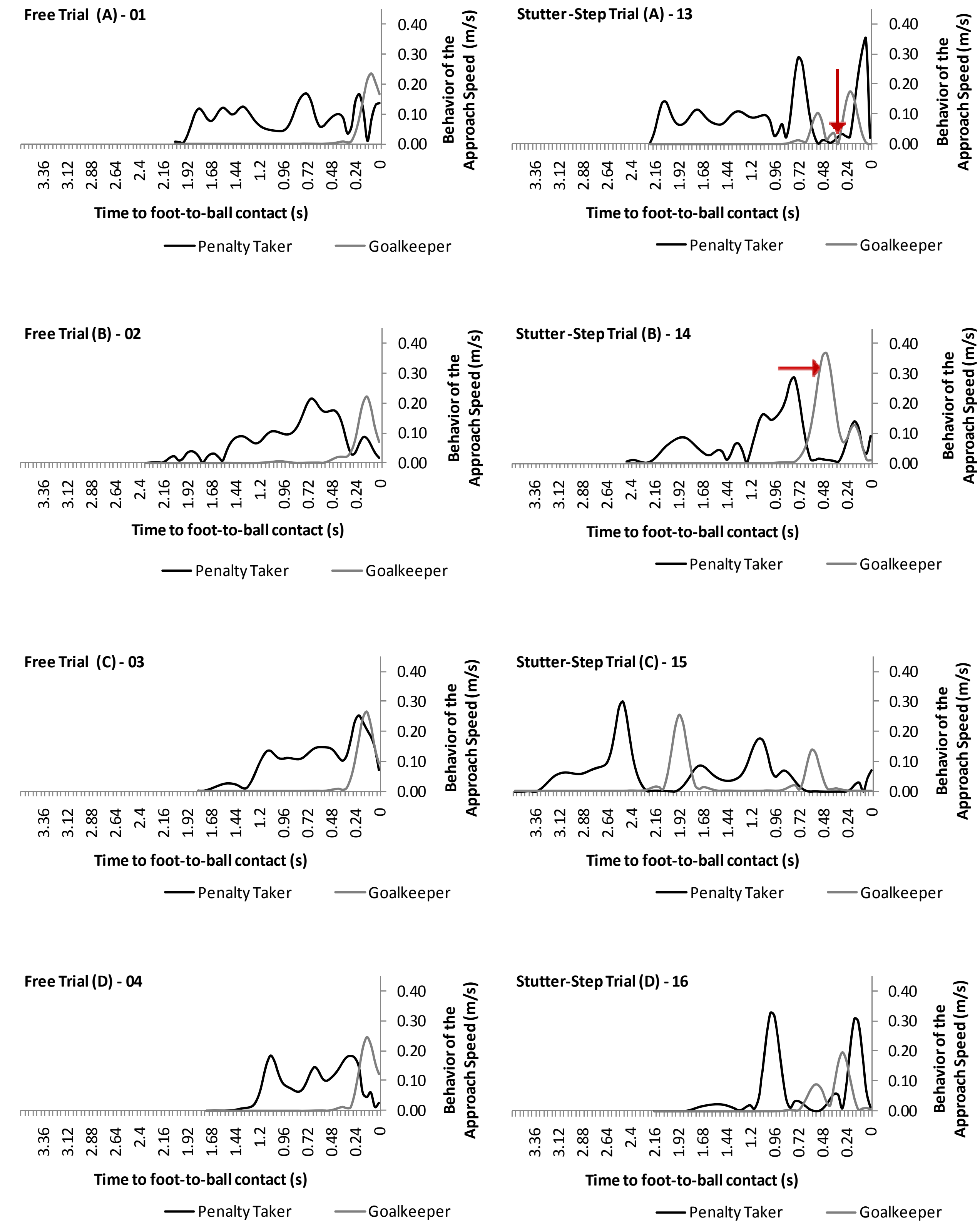
Since the goalkeeper´s response movement was associated with the rising of a first peak in the behavior of the approach speed of goalkeepers variable, we verified the stutter-step effect in the anticipation of the goalkeeper´s response to penalty taker approach to foot-to-ball contact.

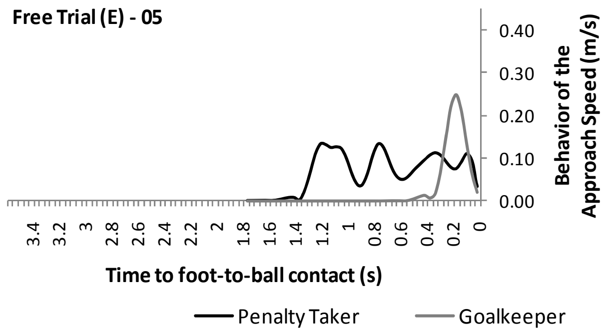
Thus, we defined the onset time of the goalkeeper response as being the second value that was present in the first sequential increase of values on the data time series.

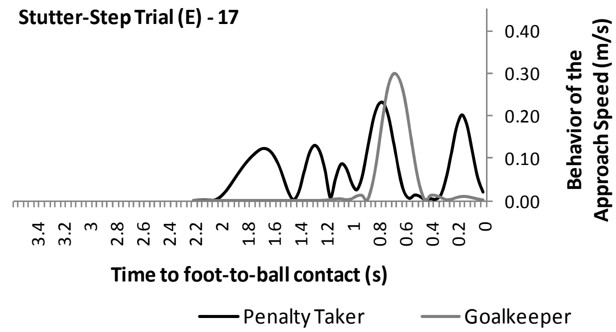
A paired sample t-test was conducted to compare the average percentage of total time that the first-peak begins to emerge on goalkeeper´s behavior in free and stutter-step conditions. There was a significant difference in the average percentage of total time that the first-peak begins to emerge on goalkeeper´s behavior in free (M=72.80%, SD=9.74%, n=12) and stutter-step (M=56.11%, SD=13.03%, n=12) conditions; t (11)=4.109, $p < 0.01$, d=1.55.

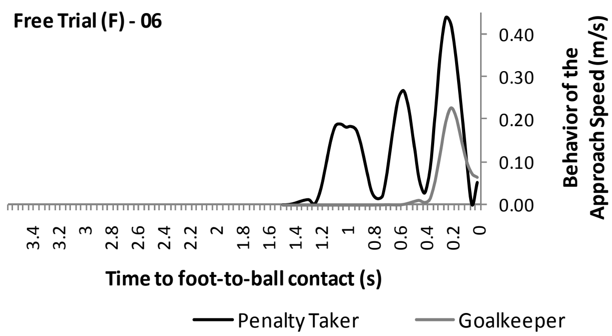
In addition the graph analysis demonstrating that the highest values of approach speed of the penalty taker variable happened just before foot-to-ball contact in free conditions and just before the misleading skill in the stutter-step condition.

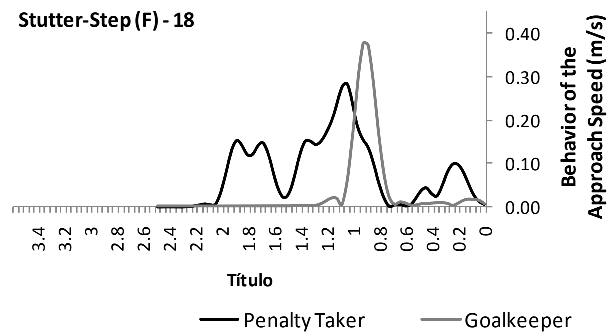
These initial analysis suggested the not only there were a intra-coupling between penalty taker and goalkeepers over the penalty kick situations, but also that both penalty takers and goalkeepers prospectively controlled their movements by pickup movement information of each other.

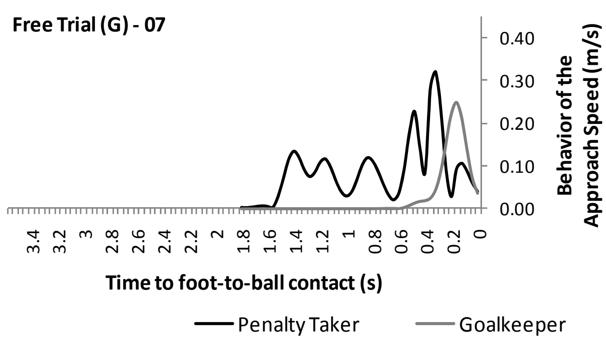

Free Trial (A) - 01
Stutter-Step Trial (A) - 13
Free Trial (B) - 02
Stutter-Step Trial (B) - 14
Free Trial (C) - 03
Stutter-Step Trial (C) - 15
Free Trial (D) - 04
Stutter-Step Trial (D) - 16
Behavior of the Approach Speed (m/s)
0.00
0.10
0.20
0.30
0.40
Time to foot-to-ball contact (s)
3.36
3.12
2.88
2.64
2.4
2.16
1.92
1.68
1.44
1.2
0.96
0.72
0.48
0.24
0
Penalty Taker
Goalkeeper

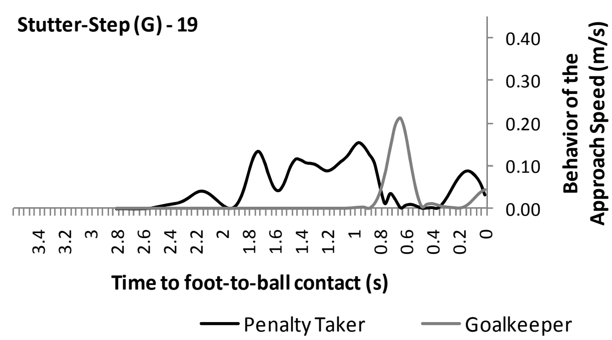

Free Trial (E) - 05
0.40
0.30
0.20
0.10
0.00
Behavior of the Approach Speed (m/s)
3.4 3.2 3 2.8 2.6 2.4 2.2 2 1.8 1.6 1.4 1.2 1 0.8 0.6 0.4 0.2 0
Time to foot-to-ball contact (s)
Penalty Taker
Goalkeeper

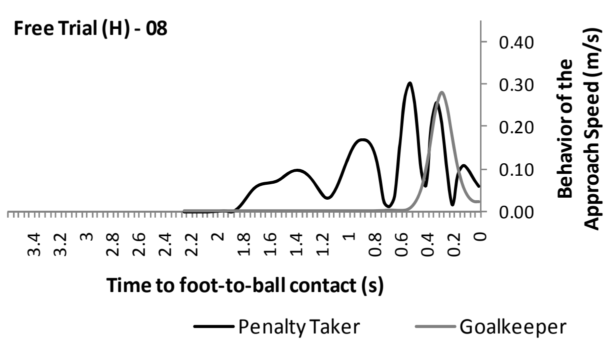

Stutter-Step Trial (E) - 17
0.40
0.30
0.20
0.10
0.00
Behavior of the Approach Speed (m/s)
3.4 3.2 3 2.8 2.6 2.4 2.2 2 1.8 1.6 1.4 1.2 1 0.8 0.6 0.4 0.2 0
Time to foot-to-ball contact (s)
Penalty Taker
Goalkeeper

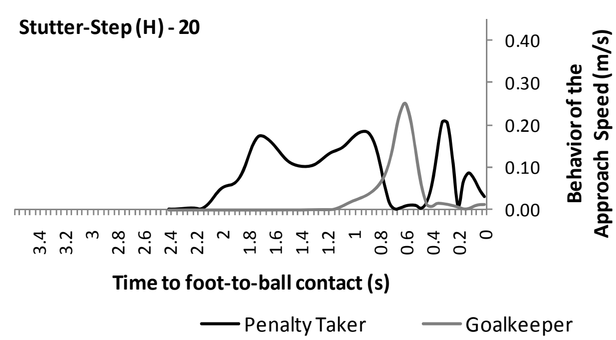

Free Trial (F) - 06
0.40
0.30
0.20
0.10
0.00
Behavior of the Approach Speed (m/s)
3.4 3.2 3 2.8 2.6 2.4 2.2 2 1.8 1.6 1.4 1.2 1 0.8 0.6 0.4 0.2 0
Time to foot-to-ball contact (s)
Penalty Taker
Goalkeeper

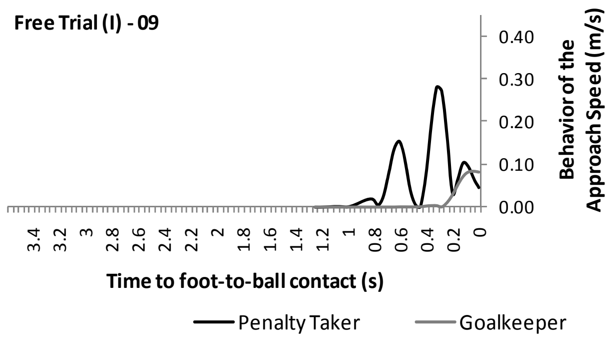

Stutter-Step (F) - 18
0.40
0.30
0.20
0.10
0.00
Behavior of the Approach Speed (m/s)
3.4 3.2 3 2.8 2.6 2.4 2.2 2 1.8 1.6 1.4 1.2 1 0.8 0.6 0.4 0.2 0
Título
Penalty Taker
Goalkeeper

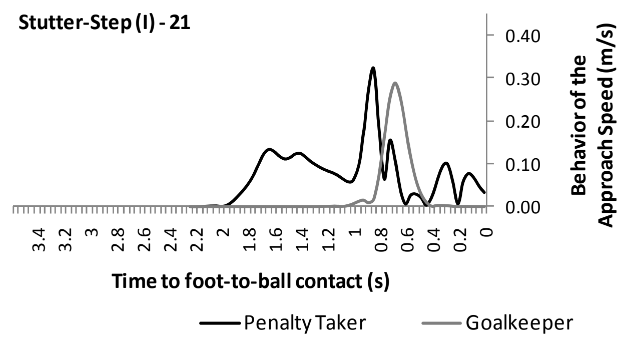

Free Trial (G) - 07
0.40
0.30
0.20
0.10
0.00
Behavior of the Approach Speed (m/s)
3.4 3.2 3 2.8 2.6 2.4 2.2 2 1.8 1.6 1.4 1.2 1 0.8 0.6 0.4 0.2 0
Time to foot-to-ball contact (s)
Penalty Taker
Goalkeeper

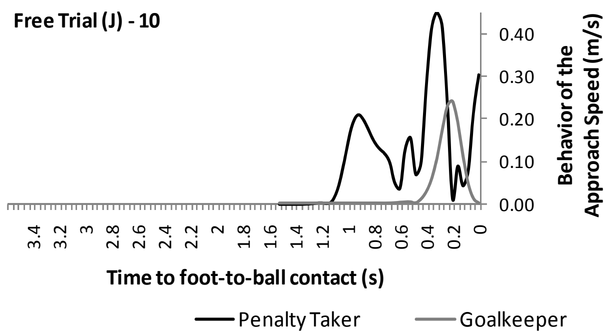

Stutter-Step (G) - 19
0.40
0.30
0.20
0.10
0.00
Behavior of the Approach Speed (m/s)
3.4 3.2 3 2.8 2.6 2.4 2.2 2 1.8 1.6 1.4 1.2 1 0.8 0.6 0.4 0.2 0
Time to foot-to-ball contact (s)
Penalty Taker
Goalkeeper

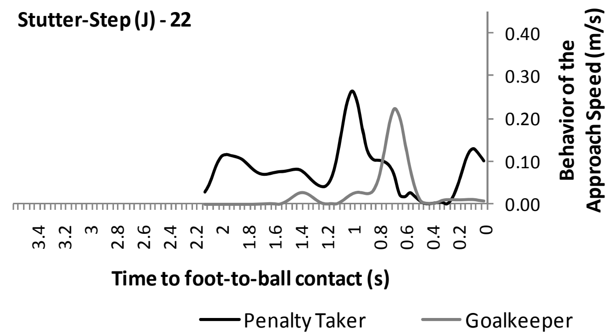

Free Trial (H) - 08
0.40
0.30
0.20
0.10
0.00
Behavior of the Approach Speed (m/s)
3.4 3.2 3 2.8 2.6 2.4 2.2 2 1.8 1.6 1.4 1.2 1 0.8 0.6 0.4 0.2 0
Time to foot-to-ball contact (s)
Penalty Taker
Goalkeeper

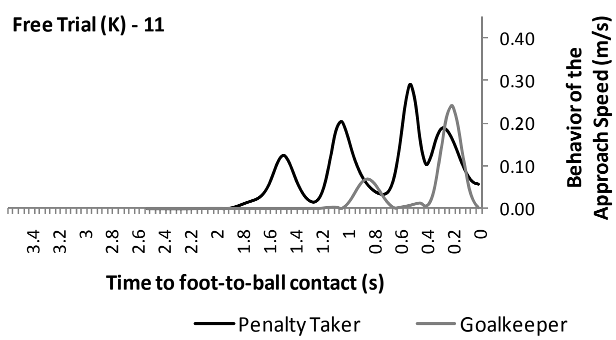

Stutter-Step (H) - 20
0.40
0.30
0.20
0.10
0.00
Behavior of the Approach Speed (m/s)
3.4 3.2 3 2.8 2.6 2.4 2.2 2 1.8 1.6 1.4 1.2 1 0.8 0.6 0.4 0.2 0
Time to foot-to-ball contact (s)
Penalty Taker
Goalkeeper

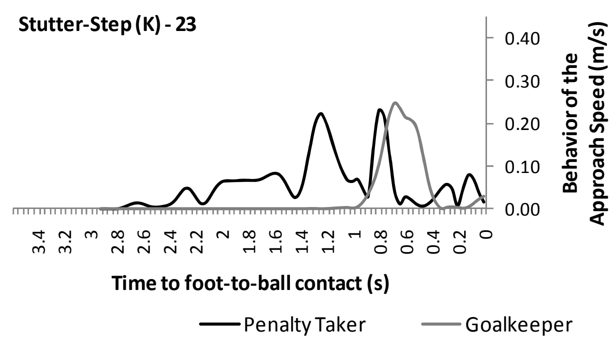

Free Trial (I) - 09
Behavior of the Approach Speed (m/s)
Time to foot-to-ball contact (s)
Penalty Taker
Goalkeeper

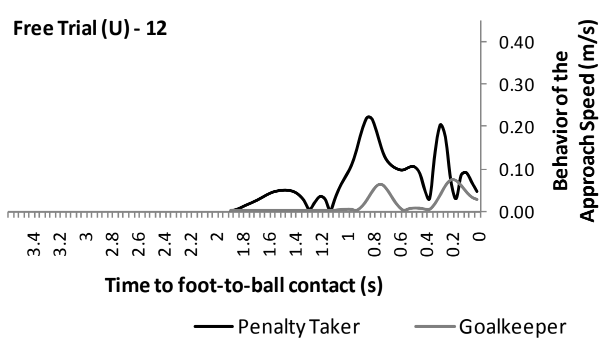

Stutter-Step (I) - 21
Behavior of the Approach Speed (m/s)
Time to foot-to-ball contact (s)
Penalty Taker
Goalkeeper


Free Trial (J) - 10
Behavior of the Approach Speed (m/s)
Time to foot-to-ball contact (s)
Penalty Taker
Goalkeeper


Stutter-Step (J) - 22
Behavior of the Approach Speed (m/s)
Time to foot-to-ball contact (s)
Penalty Taker
Goalkeeper


Free Trial (K) - 11
Behavior of the Approach Speed (m/s)
Time to foot-to-ball contact (s)
Penalty Taker
Goalkeeper


Stutter-Step (K) - 23
Behavior of the Approach Speed (m/s)
Time to foot-to-ball contact (s)
Penalty Taker
Goalkeeper


Free Trial (U) - 12
Behavior of the Approach Speed (m/s)
Time to foot-to-ball contact (s)
Penalty Taker
Goalkeeper

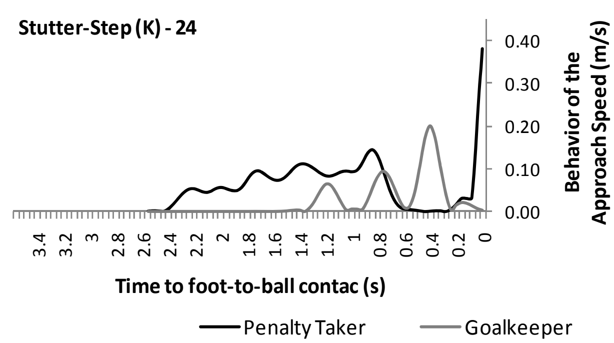

Stutter-Step (K) - 24
Behavior of the Approach Speed (m/s)
Time to foot-to-ball contac (s)
Penalty Taker
Goalkeeper

Figure 3. Unfolding dynamic of the aapproach speed of penalty taker variable (dark line) and approach speed of the goalkeeper variable (light line) on free and stutter-step condition. Arrows in figure “b” and “d” respectively indicate the emergence of the stutter-step plateau on the approach speed of the penalty taker variable and the emergence of the peak of response on the approach speed of the goalkeeper.

Behavioral Patterns in the Penalty Taker-Goalkeeper System

In figure 4a narrows help to indentify that in free condition the larger variability for penalty takers lied in the increment of velocity just before foot-to-ball contact. In addition, large variability on the goalkeepers behavior lied in their peaks of response.

In free condition (figure 4a) a clear pattern can be observed with the penalty takers starting their approaches with reduced speeds and so increasing their speeds moments before the foot-to-ball contact (see PT-free from 0.44s until 0.20s on figure 4a). In turn, in free condition the goalkeepers lie still along (even if sometimes they may step up -) and only after the penalty takers increasing their speeds just before foot-to-ball contact the goalkeepers fast change their behavior increasing their speeds (see GK-free from 0.36s until 0.32s on figure 4a).

In figure 4b the arrows highlight important moments of more or less variability in the behavior of both penalty takers and goalkeepers.

In stutter-step condition (figure 4b) the behavior of the approach run of penalty takers begins with a great speed variability (see PT-s.step from 2.52s to 2.36s) to next becomes more homogeneous in a low speed (see PT-s.step from 2.36s to 2.12s). A gradual increase unfolds in the approach run and a speed peak is reaching just before the stutter-step (see Pt-s.step from 1.08s to 0.68s). Although a pattern can be identified, the peak point is surrounded by greater variability when compared to free conditions. After reaching a peak the unfold behavior of approach run narrow to a similar pattern and converging to a defined pattern of lower speed and small variability (see PT-s.step from 0.60s to 0.36s). This is the stutter-step misleading skill pattern. Following the stutter-step event (see PT-s.step from 0.28s to 0.00s) the speed approach begins to rise again with great variability until foot-to-ball contact.

In turn, in stutter-step condition the goalkeepers behavior appears much more unstable rather than in free condition. The step-up (see GK-s.step from) shows more variability in the speed approach of goalkeepers and the peak velocity observed is not flatter and not so defined as in the free condition. Variability in goalkeepers behavior begins when penalty takers increasing their speeds just before the stutter-step (see GK-s.step from 1.08s to 0.84s), and extends longer until the foot-to-ball contact. Despite, a pattern can be identified in the goalkeepers behavior, namely the increase of their approach speed around the stutter-step (see GK-s.step from 0.84s to 0.28s). in Figure 4.

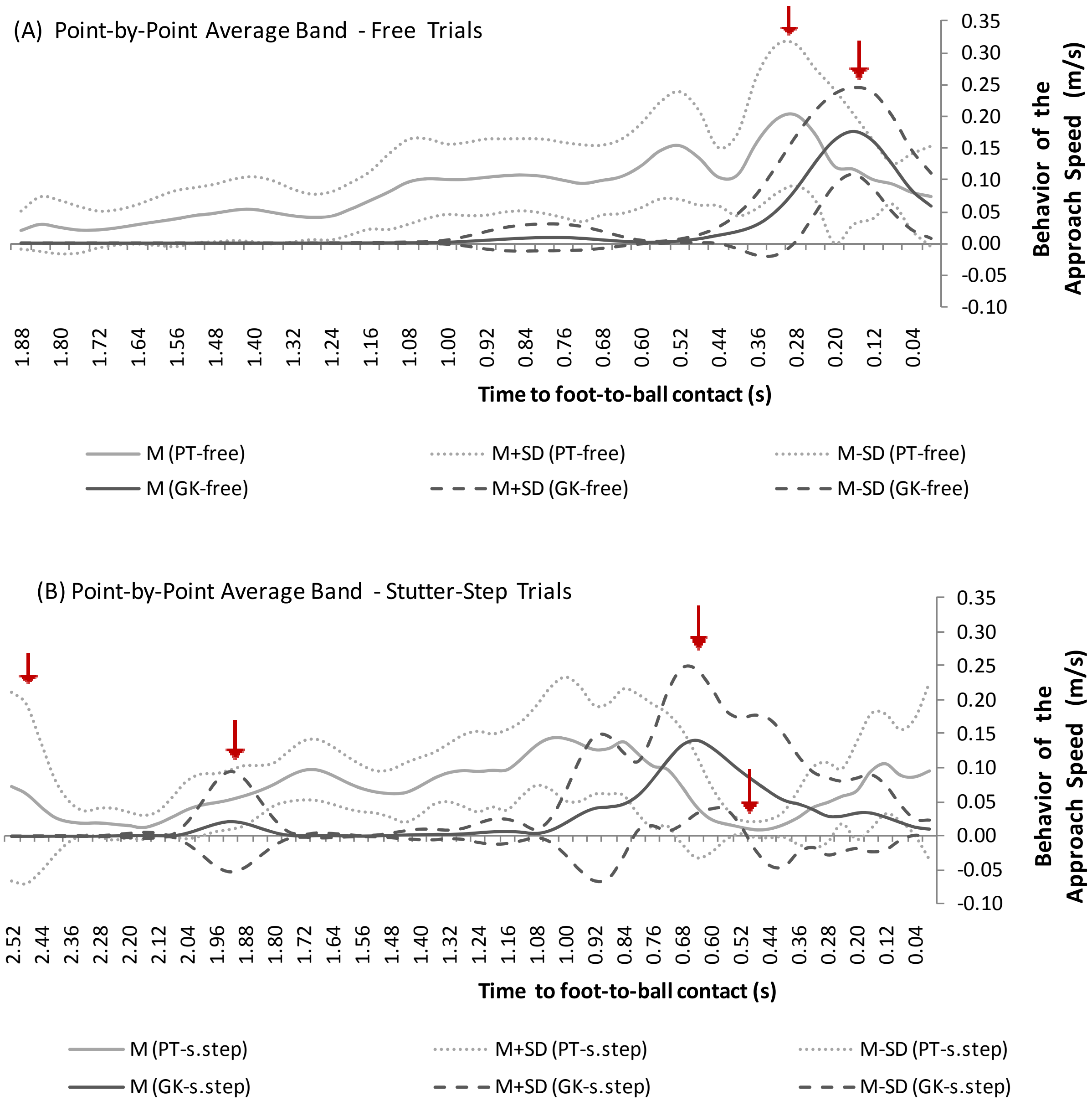
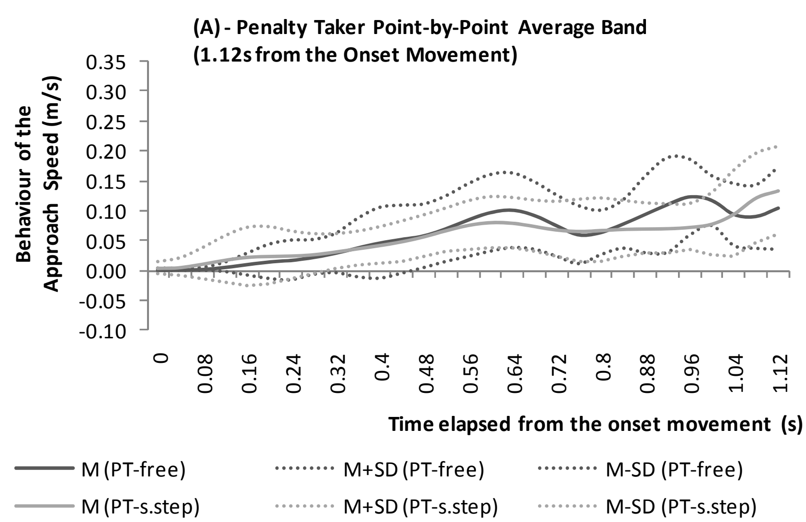


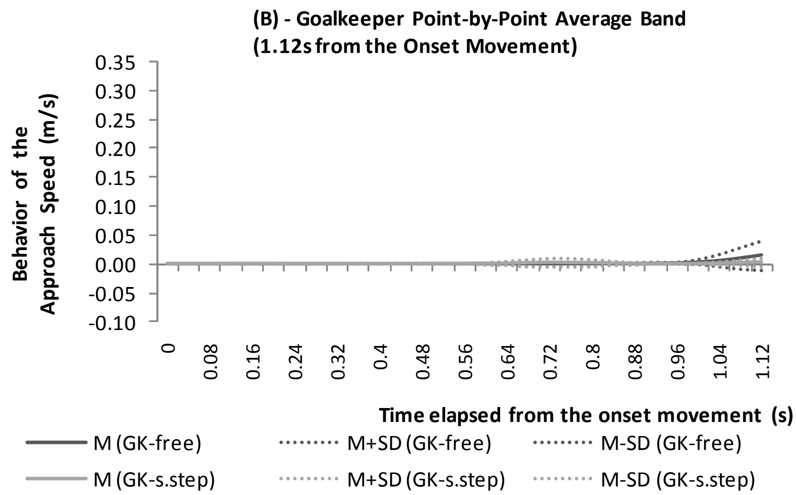
Figure 4. Inter-trial point-by-point average band of penalty taker–goalkeeper on both free and stutter-step conditions. Arrows highlight important moments of more or less variability in the behavior of both penalty takers and goalkeepers.

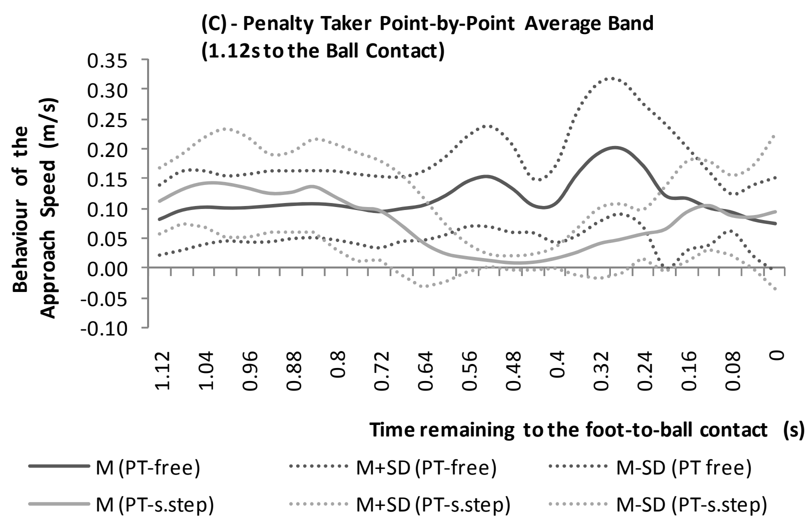
Critical Moments in the Penalty Kick Situations

The analysis of results showed in figure 5 allows to identify that 1.12 seconds before foot-to-ball contact penalty takers reached the highest peak of speed in the approach run and also performed the stutter-step misleading skill (see figure 5c). In turn, the analysis of the behavior of the approach speed of penalty takers 1.12s from the onset movement, appears to identify a phase of gradual increase of the approach speed of penalty takers.

In addition, the results also allow to identify that goalkeepers reached the highest peak of speed approach 1.12 seconds before foot-to-ball contact (see figure 5d). In turn, the analysis of the behavior of the approach speed of goalkeepers 1.12s from the onset movement do not allow identify visual differences (see figure 5b).




(B) - Goalkeeper Point-by-Point Average Band
(1.12s from the Onset Movement)
Behavior of the Approach Speed (m/s)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
0
0.08
0.16
0.24
0.32
0.4
0.48
0.56
0.64
0.72
0.8
0.88
0.96
1.04
1.12
Time elapsed from the onset movement (s)
M (GK-free)
M+SD (GK-free)
M-SD (GK-free)
M (GK-s.step)
M+SD (GK-s.step)
M-SD (GK-s.step)


(C) - Penalty Taker Point-by-Point Average Band
(1.12s to the Ball Contact)
Behaviour of the Approach Speed (m/s)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
1.12
1.04
0.96
0.88
0.8
0.72
0.64
0.56
0.48
0.4
0.32
0.24
0.16
0.08
0
Time remaining to the foot-to-ball contact (s)
M (PT-free)
M+SD (PT-free)
M-SD (PT free)
M (PT-s.step)
M+SD (PT-s.step)
M-SD (PT-s.step)

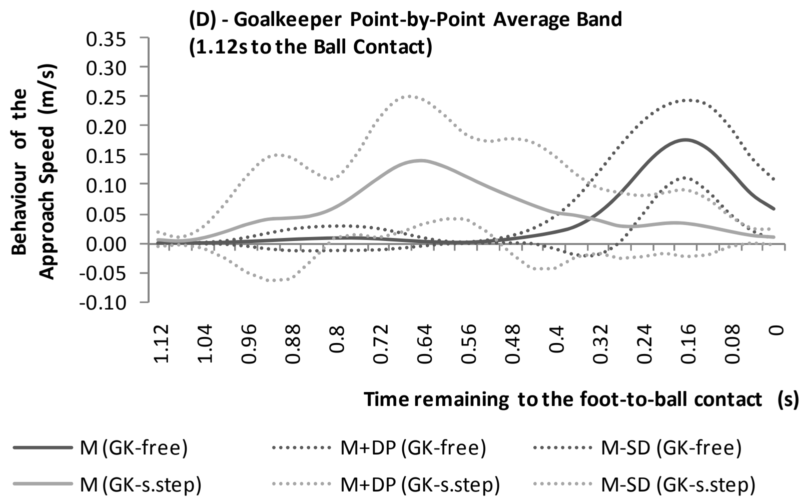
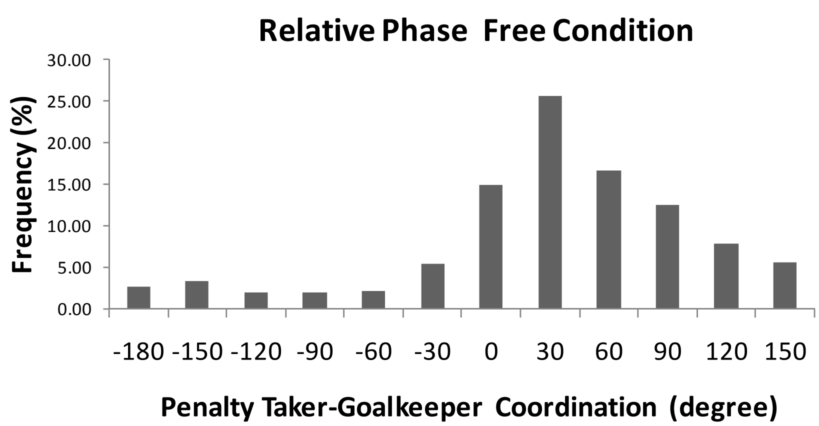


Figure 5. Point-by-point average band of the penalty taker and of the goalkeeper 1.12s from the onset movement (a; b) and 1.12s foot-to-ball contact (c;d).

Space-Time Coordination of Penalty Taker-Goalkeeper System

The space-time coordination of between the approach speed of the penalty taker variable and the approach speed of the goalkeeper variable reveals a predominant attractor to 30° of phase (25,55%) in free condition and two predominant attractor to 30° of phase (17,43%) and to 60° of phase (18.09%) in the stutter-step condition. It means that in both conditions the approach speed of the penalty taker leaded the approach speed of the goalkeeper. Moreover, it also means that in free condition first the approach speed of the penalty taker increase and after the approach speed of the goalkeeper increase, and that the alignment between these two peaks of approach speed present a predominant angle of 30 degrees (i.e., lag of 30°) in free conditions. In the other hand, in the stutter-step condition the predominance of this varies among 30 degrees (i.e., lag of 30°), 60 degrees (i.e., lag of 60°) or even 90 degrees (i.e., lag of 90°). It means that in the stutter-step condition the coordination pattern is more distributed along the attractors than in the free condition.

An independent sample t-test was conducted to compare the frequencies in the bin 30° in free and stutter-step conditions. There was a significant difference in the frequencies in the bin 30° in free (M=25.81%, SD=10.21%; n=12) and stutter-step (M=17.40%, SD=8.34%, n=12) conditions; *t* (22)=2.212, p = 0.038, d=0.90.



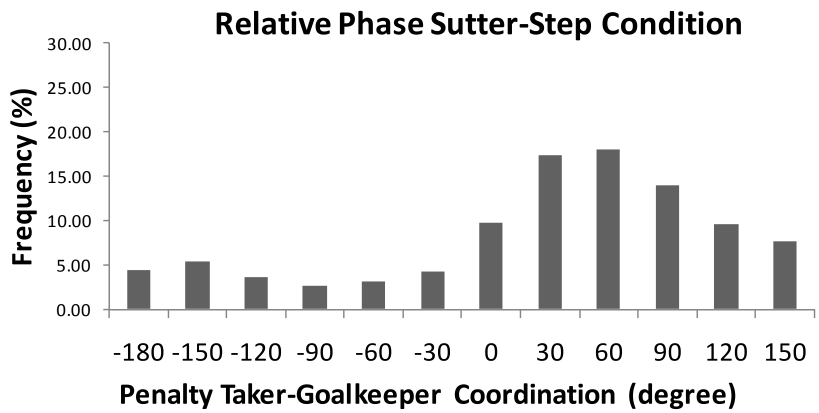


Figure 6. Relative phases of penalty taker–goalkeeper system in free trial and stutter-step trial situations.

Discussion

Penalty Taker-Goalkeeper Decisional Dynamic

Data in the qualitative dynamic analysis (Van Gelder & Port, 1995) of penalty taker-goalkeeper system demonstrated the intra-coupling between penalty taker´s behavior and goalkeeper´s behavior (McGarry et al., 20002) and the change of information available. It suggest that the decisional behavior of penalty takers and goalkeeper is controlled prospectively with the exchange of information that becomes accessible by the actions of both players. These findings are in agreement with Gibson (1979/1986), Kelso (1995), Araújo et al. (2006), Montagne (2005) and Fajen, et al. (2009) and can be confirmed by the visual changes in both variables when facing the presence and absence of the stutter-step misleading skill.

The occurrence of an emergent peak in the behavior of the approach speed of the goalkeeper variable in the data of all penalty kick conditions (see figure 3) confirmed previously research (see Dicks et al., 2010; Van der Kamp 2006; Savelsbergh et al., 2005, 2002; Morris & Burwitz, 1989) that goalkeepers started their movement before or just before penalty taker´s foot-to-ball contact.

Information presented in the approaching speed of penalty takers seems to provide a powerful constraint to the emergence of goalkeeper´s decision making. The approach run of penalty takers has been investigated and constrained on different penalty researches (e.g., Williams & Griffiths, 2002; Savelsbergh et al., 2002, 2005; Van der Kamp, 2006; Dicks, Davids & Button, 2010; Dicks, Button & Davids, 2010; Diaz, 2010).

The presence of the emergent plateau in the behavior of the approach speed of the penalty taker variable followed by the emergent peak in the behavior of approach speed of the goalkeeper variable suggested that goalkeepers are highly sensitive (i.e., attuned) to penalty takers approaching run. Van der Kamp (2006) and Dicks, Button and Davids (2010) advised that by doing it goalkeepers becomes very susceptible to penalty takers deceptive information, something that was also confirmed in the present study with the use of the stutter-step. Moreover it´s not clear if the approach run per se is a specified variable (see Withagen & Michaels, 2005; Fajen 2008; Jacobs & Michaels, 2007, Araújo & Davids, 2011) for goalkeepers since it do not provide confident information for the decisional behavior of the goalkeepers. Rather, results point more towards the direction of the approach run of penalty taker as being a nonspecified variable of the timing of foot-to-ball contact and so on to goalkeepers decisional behavior.

Statistical analyses confirmed both hypothesis, that the stutter-step misleading skill affect the behavior of penalty taker approach run namely by increasing the time to foot-to-ball, and that the stutter-step misleading skill anticipate the decision behavior of goalkeepers by reducing the average time to initiate their movement response in stutter-step conditions. Contrary to previous research anchored on video-simulation and temporal occlusion paradigms (e.g., Jackson et al., 2006; Sebanz & Shiffar, 2009 and Cañal-Bruland & Schmidt), the present results is one of the pioneers to present findings about the effect of misleading skills in a representative, dynamic and ecological scale (i.e., real game conditions), given that Dicks et al (2010) presented information of penalty taker approach run through a temporal presentation paradigm.

Overall, the stutter-step misleading skill shows that the penalty takers act in order to incite changes in the optic array making visible the opportunity to score the goal (i.e., the affordance that invite to action) (Gibson, 1979/1986; Michael & Carello, 1981). Therefore, by doing the stutter-step penalty takers offer information that seems to be relevant to goalkeepers action. This information could be understood as a negative affordance (Gibson, 1979/1986) since it leads the goalkeeper to a different action from the one that could result in successful of the task. Once coupled with this negative affordance goalkeepers may anticipate their decisional behavior providing changes in the optic array. In turn, these changes may for example, increase the empty area in one of the sides of the goal, which may be perceived by penalty takers as a affordances to score the goal with greatest chances of success in penalty kick situations. Since the affordance magnifies a functional relationship between organism and environment, the personal constraints (Newell, 1986) and the limit actions capabilities (Fajen, 2007; Dicks, Davids, Button, 2010) may influence the functional coupling. Thus, subtle changes in the empty area of the goal provides by anticipatory goalkeeper movement through the stutter-step may afford opportunity to score to a penalty taker with a good calibration for example, whereas to another penalty taker with miscalibration these changes may have to become more extreme to afford the opportunity to score. It could suggest different times to kick the ball to the goal and the perception of different changes in the goalkeeper behavior in order to afford the opportunity to score the goal.

Behavioral Patterns in the Penalty Taker-Goalkeeper System

Results available on the present analysis suggest a more unstable and variable pattern of coordination when stutter-step was performed. Together with the visual analysis of figure 3, figure 4 highlights information present in the first analysis and strongly suggested that more than attuned to the penalty takers´ approaching speed per se, goalkeepers appears to be attuned to an *fast increase-followed-decrease* pattern that emerge in the approach speed of the penalty taker variable. The pattern appears just before foot-to-ball contact in free conditions, just before the misleading skill and (albeit more smoothly) it also appears in the fast moment comprised between the stutter-step and the foot-to-ball contact in the stutter-step conditions. In figure 3f the interesting event of two stutter-steps performed in the same trial highlight this behavior with the goalkeeper reacting even in the first one when the distance between the penalty taker and the ball does not allow any kind of contact.

These data may suggested that the fast-increased-followed-decrease is an invariant in penalty kick situations and specify ball´s contact to goalkeepers. Also, it may suggested a necessary pattern for penalty takers to perform a kicking with enough stamina for the ball reaches the goal in a faster way and to reduce goalkeeper opportunities of saves.

If this is true, stutter-step misleading skill may be explain by the ability of penalty takers to perform a false pattern of fast-increased-followed-decrease instants before real ball contact and to wait enough time (the plateau on the approach speed of the penalty taker variable) for the pickup of the information that goalkeepers provide when coupled with the misleading skill. By succeed in their deception, penalty takers do not need the same stamina for kicking (as demonstrated by the smoothly pattern comprised between the stutter-step and the foot-to-ball contact) since goalkeeper may already be lying on the ground for example.

Overall previously research focused on the ability to predict (i.e., anticipate) ball direction in penalty kick situations (Savelsbergh et al., 2002, 2005; Diaz, 2010) suggested that distributed information on kicking leg, non-kicking leg and hips of penalty takers are potential sources for goalkeepers successful predict ball direction, and only in one experiment Diaz (2010) found strong evidences against hip information related to the location of foot-to-ball.

Therefore, given that the rules of the game do not favor goalkeeper´s visual angle, do not allow them to move forward (just right or left above the goal line) and the penalty mark is too close, the goal is too large and nowadays balls become faster and unpredictable, in penalty kick situations the rules of the game constrain an essential assumption of Gibson´s (1979/986) theory. So, goalkeepers have a reduced have a reduced opportunity to move in order to perceive and to perceive in order to move.

According to Araújo, Davids and Serpa (2005) when individuals are not attuned to a relevant information sources they tend to engage in exploratory behaviors of the local environment to seek information that allows them to make better judgments and decisions. However, if actions are not meeting the goal, more actions will occur, exploring the context in order to find the relevant information to rely upon (i.e., to be attuned).

This is exactly what the sources information found on previously research that predict ball direction appears to suggest, that under intensive constraints of the rules, goalkeepers acting with their eyes scrutinizing penalty taker´s approach run.

Critical Moments in the Penalty Kick Situations

Previously research has associated wait longer to initiate actions and later information pickup with better chances of goalkeeper success (Dicks, Button & Davids, 2010; Savelsbergh et al., 2002, 2005). In fact, results on the critical moment analysis demonstrated that the last second of penalty kick situations appear to be the most richness and informational timing to pickup relevant information.

This aligns with the information provided in Araújo et al., (2006) that underpins decision making as a functional and emergent process. So, the closest penalty taker and goalkeeper become of they intend goal, much more their exploratory behavior must couple with ever more specific information in order to narrow the possible action paths available in the system in a unique emergent path at the goal accomplishment instant.

However, it may also explain why the last second is the more sensitive to critical perturbation, as suggest by the presence of all stutter-step in the last second for foot-to-ball contact and the speed peaks of penalty takers and goalkeepers (see figure 5c and figure 5d).

Space-Time Coordination of Penalty Taker-Goalkeeper System

Dicks et al. (2010) advise that by relying in the penalty taker´s approach run goalkeepers become very susceptible to penalty takers deceptive information, something that was also confirmed in the present study in the qualitative data (see figure 3 and figure 4).

Results of the space-time coordination of penalty taker-goalkeeper analysis also suggested that penalty takers are capable of destabilizing, through their movements, the previous and more stable condition existing in free trials situations. Data suggest that penalty takers increased the variability (i.e., uncertainty) in goalkeepers decisional behavior by performing the misleading skill.

Relative phase analysis also indicated that penalty takers lead the dyad in-phase and with a lag in both free and stutter-step conditions. It indicates that predominantly first the approach speed of the penalty taker increase and after the approach speed of the goalkeepers increase (the happens to the decrease of approach speed).

The more distributed pattern of space-time coordination on stutter-step and the shifted of predominantly pattern coordination present by statistical analysis on bin 30° in free and stutter-step conditions, reveal that what penalty takers perform with the stutter-step is create an extension of the lag (from 30° to 60° and 90°) probably on a critical moment (i.e., close to foot-to-ball contact) in order to trigger the emergence of an reliable and relevant information in goalkeeper´s decisional behavior. Moreover, the stutter-step also breaks the predominantly coordination pattern present giving rise to a more unstable (i.e., uncoordinated) patter, as the distributed frequencies of stutter-step condition attest.

Practice Applications and Future Researches

Although information about kicking ball direction is useful to goalkeepers decision making, the present research argued that it is necessary do not split it from the correct moment of the defensive actions (i.e., jump or anticipated). Thus, the majority problem with researches that looking only for predictive sources in order to anticipate ball directions on unrepresentative designs, is that it may bias the understand of the decisional behavior of goalkeepers and generalize it to practice. Penalty kicks are not about predict the ball direction. The evidence of it is that on many penalty kick situations observed during an association football game what is seen is a goalkeeper who jump to the right side in the wrong timing. Therefore, it is fundamental to provide research that helps goalkeeper to be attunement and calibrated to a relevant information that specify not only ball direction (apart of other actions).

The law 14 of penalty kick in FIFA´s rule state: “Feinting in the run-up to take a penalty kick to confuse opponents is permitted, however feinting to kick the ball once the player has completed his run-up is now considered an infringement and an act of unsporting behavior for which the player must be cautioned”. When performed within the rules misleading skills are allowed in the game. Thus, the stutter-step has demonstrated that penalty takers are able to vary their speed approach in non constantly ways and even they are capable to stop in their non-kicking leg for briefly few moments in order to retard foot-to-ball contact. In fact, the run-up seems to be the best options for penalty takers acquire advantage in the penalty kick situations.

Until now in penalty kick situations the only invariant remains in the fact that in order moving the ball in goal direction penalty takers must to kick it with their leg. At the same way, in order to kick with their leg penalty takers need to approach to the ball. This approach can be performed in a single way if we consider the relational properties of an affordance as well as penalty takers limits capabilities and possibilities (see Dicks, Davids & Button, 2010).

For that reason a challenge for future research is to investigated the effects of different approach runs in goalkeepers decisional behavior under representative designs. In turn, for learning and training environments the challenge is provide penalty kick situations with different run-up and different penalty takers in order to help goalkeepers pickup a relevant information for their defensive actions and developing calibration among different penalty takers.

A important information revealed with the present investigation is the fast increase-followed-decrease pattern in the approaching speed of penalty takers, something that remained invariant over the conditions and deserve further researches.

For practice however, the fast increase-followed-decrease pattern could be an useful information to prepare goalkeepers to the emergence of the next (and maybe relevant) information that is going to unfold very briefly just after this pattern, but not for the goalkeepers relying their decision,

Finally, even knowing that goalkeepers are extremely constrained in penalty kick situations there are still some possibilities to acting that must be trained in practice sessions beyond eye movements. For example, goalkeepers can be training in learning to waited longer; developing their prospective control. In addition, rather than performed only eye movement in order to perceive, goalkeeper can also explore the penalty kick context by moving their arms;

moving laterally on the line and mainly developing and training misleading anticipatory movements.

Conclusions

The present research aimed to investigate penalty kicks situations under a representative and ecological dynamic paradigm. In addition, these investigation challenged previously research focus on the anticipation of the outcome of ball direction based on predictive cues. Toward a emergent and dynamic decisional behavior, prospectively control by the perception-action loop of unfold events (i.e., change and persistence), the present research conclude the following points:

- Goalkeepers and penalty takers approaching speeds are space-time coordinated in penalty kick situations.
- The stutter-step skill is a critical perturbation and constrains the dynamics of the dyadic system by change the coordination pattern and increasing uncertainty in the system. It probably trigger to penalty taker a relevant information about the decision making of the goalkeeper on an advantage moment and the affordance to score the goal.
- The fast increase-followed-by-decrease pattern of the approach speed of penalty takers specifies decision (i.e., ball contact) for the goalkeepers.
- Goalkeepers are attuned to a fast increase-followed-by-decrease pattern presented on the penalty taker approaching speed, but this may be a non-specified variable for the goalkeeper's decisional behavior and to specifies foot-to-ball contact.
- Goalkeepers should not relying their decisional behavior only in the penalty takers approach run.
- The last second before foot-to-ball contact is critical to perturbations and consequently to the arise of relevant information in the penalty taker-goalkeeper system.

- Goalkeepers anticipate in penalty kick situations but they are likely to benefit to latter initiate their response movements.
- In penalty kick situations both players penalty taker and goalkeeper prospectively control their movement and act in order to unfold an event that afford and specify successful information for their intend actions.

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