BIOSCIENCES BIOTECHNOLOGY RESEARCH ASIA, December 2016. Vol. **13**(4), 2089-2099

The Effect of Speed, Accuracy and Effector on Generalizability of Motor Program

Seyed Mojtaba Hoseini, Mehdi Sohrabi* and Hamidreza Taheri Torbati

Department of Sport Science, Ferdowsi University of Mashhad, Iran.

http://dx.doi.org/10.13005/bbra/2369

(Received: 12 July 2016; accepted: 17 August 2016)

The aim of this study was to examine the effects of speed, accuracy and effector on generality of motor program. Twelve males from Iran's professional futsal league participated in the study. After determining dominance leg of each participant, they were equally divided into two groups of left footedness and right footedness. In order to gather data, markers were placed on the anatomical positions. Then, participants were asked to perform 24 correct instep kicking (in accuracy and speed conditions) on a stationary ball from a marked penalty spot (6 meter) in futsal to target by dominant and non-dominant leg. Kicks were recorded by six high-speed digital cameras and kinematic data were calculated by Simi motion software. MANOVA was used for data analysis. The results indicated that there was no significant difference between the right and left footedness individuals and between dominant and non-dominant leg on the relative timing of interlimb and intralimb ($p < 0.05$). Also, there was no significant difference between the effect of speed and accuracy's strategies on the relative timing of interlimb and intralimb ($p < 0.05$). Overall, the results support the theory of generalized motor program and its prediction based on invariant relative timing and effector independence

Key words: Effector independence, generalized motor program, Instep kicking, interlimb relative timing, intralimb relative timing.

An individual constantly needs to perform thousands of different movements and thousands of distinct forms upon those movements. The brain has to control much of the muscular coordination needed to perform these movements on a subconscious level. While the brain does not have the capability to store information about all of the movements which we perform, it stores patterns to perform fundamental movements which are widely used. These patterns are called Generalized Motor Program (GMP)(1). The GMP is defined by the so-called invariant characteristics (relative timing, sequence of events and relative force) that remained constant from one performance to another, but vary for different classes of movements (i.e. throwing, kicking[2].These programs solve the degrees of freedom problem by providing a single unit instead of many units to control and result in the execution of efficient coordinated movement that does not require feedback or attention. Accordingly, some of motor control theorists believe that movements can be full filled more promptly and without attentional demands since motor programs have been developed for those tasks. According to Schmidt, a motor program is an abstract memory structure that is prepared in advance of a movement, and, when initiated, results in the execution of efficient coordinated movement that is independent of feedback or attentional demands. However, The GMP is a ûexible control structure because variable parameters, without requiring the use of a special

* To whom all correspondence should be addressed.
Mob.: 00989155035459;
E-mail:sohrabi@um.ac.ir

program, could be used to change the movement output[2-3].The exact muscles required to perform the movement, the overall duration of the movement, and the overall force required to produce the movement are parameters that could be changed among trials to alter to outcome of the GMP. One of the predictions of generalized motor program theory is that one can achieve the same target with different muscle groups or limbs. Prevalent examples include the ability of basketball players to shoot and dribble with either hand with similar efficiency. In this context, there are several theoretical approaches. According to Bernstein, the engram was a structure of central nervous system that was responsible for controlling both spatial and temporal characteristics of movements. The whole movement is controlled by the engram, especially the regularity of the muscular contractions and the overall rhythm. These central features of the movement were controlled by the highest-level of a hierarchical control system and remained relatively constant from trial to trial. In lower levels of the system, there are asymmetric features (such as size and muscle group) that the system allows to change the engram and motor equivalency.Schmidt (1975) made the Bernstein's ideas about the structure of the engram in the context of schema theory more transparent[2]. However, motor program's concept has been controversial and opposing views surrounding the concept became the center of the intense debate between advocates of so-called "dynamic" and "cognitive" approaches to motor behavior[4]. Despite all of these challenges, researchers who study motor control theory from the perspective of motor programs are interested in determining what elements of the motor program are fixed and what elements can be controlled by motor program. In this regard, one of the considered issues is invariant relative timing.For several years there were evidences that proved the fact that despite changes in the absolute timing during the execution of motor skills, relative timing of response components remains invariant.Because of these evidences, motor control theorists suggested that the relative timing may be an invariant feature of the central representation (motor program) in well-learned movements. Also, from the perspective of dynamic systems theorists, although representation's notion has been rejected, but they have argued that relative timing invariance is one of the essential variables that specifies the skilled actions[2, 5].

A number of studies have supported relative timing invariance's notion of generalized motor program. Among these, we can point out to investigations carried out byNashner (1977), Shapiro, Viviani and Terzuolo (1980), Hollerbach (1981), Zernicke, Gregor, and Diestal (1981), Clark (1986), Gracco (1986), Roberton (1986), Roberton and Halverson (1988), and Roth (1988)(6).Also, Southard (2014) examined the effect of experience and goal constraints (speed, accuracy) on kicking patterns, in his studies. Results of this study indicated that experience and speed affect absolute timing of joint velocities but do not affect the relative timing of peak joint velocity. Despite this supportive evidence, the role of relative timing as an invariant feature of motor control and a substantial feature of skilled motor performance is still not accepted. Some researchers express that when a strict criterion for invariant relative timing is used, relative timing is frequently violated in empirical data. More importantly, there is evidence showing that relative timing is not a critical factor determining the transfer of learning[7].Based on a comprehensive review and due to insufficient evidence, Gentner (1987) refused invariant relative timing's notion. However, he believed that more elaborate test procedures were required, before it was to be abandoned[8]. In order to test the claims that relative timing is an invariant feature of human gait, Limerick *et al*. (1992) studied the kinematic of stair climbing. Their findings proved that relative timing does not remain strictly invariant across changes in speed, regardless of how the gait cycle was divided. They suggested that relative timing invariance is not a fundamental characteristic of kinematic movement.Debicki and colleagues (2010) also studied shoulder–elbow mechanism for increasing velocity in a multi-joint arm movement and concluded thatwhile fast 2-D throws are generated, the CNS utilized the arm's biomechanical properties by harmonizing elbow and shoulder motion in order to increase the ball's speed. Also, they showed that while relative timing is various in fast movements, it is the same in slow and medium speed. This matter violates invariant relative timing to a class of movements. Kwon *et al*. (2011) indicated that relative timing is more likely to reflect the participant's strategy, rather than being an invariant property specifying movement transfer. In other words, although relative timing can be maintained, it is not required to be maintained. The temporal properties of learned movements emerge due to the task constraints, the participant's intrinsic dynamics and the participant's intentions, whereas the spatial constraint given by the task, such assize - accuracy ratio, is a determining factor of motor control. Therefore, the principle of invariance relative timing is not supported in this study. Bilateral transfer implication, is another indicator for the existence of a GMP for a particular task, which is used to examine the effector parameter[27].In the case of bilateral transfer, because the same engram or GMP is used to control each limb, both the Bernstein's (1967) and Schmidt's (1975) ideas predict the positive transfer. The invariant features would be preserved for use in different limbs, while the parameters could be varied individually for each limb(2). In this regard, the hypothesis of "Effector Independence" has been proposed. Based on this hypothesis, through practice, an abstract mental representation is formed in the memory which is independent of effector and allows the person to carry out the learned skill perfectly with the untrained limb(9).In fact, motor skills learning are supervised by two processes. An abstract and a subjective process that plans the sequence of movements (invariant characteristics), and another one which is in charge of movement execution. In this context, usage of dominant and non-dominant limb in motor performance was partly investigated in confirming the motor program theory and the studies such as Bernstein (1947), Merton (1972) and Raibert (1977) supported the effector independence hypothesis. Also, the effect of extended practice on EMG kinematics and accuracy in dominant and non-dominant dart throwing, was studied by Coleen Waterhouse (2014). His findings showed that dartthrowing is controlled by the same motor program and that changing of effector or muscle group selection for the task is simply a parameter change. In addition, Shapiro (1977), Poston et al. (2009)and Zuoza et al. (2009), by using various task, have confirmed generalized motor program theory and it's prediction that motor learning is effector independence[2,10-12]. However, the effector independence hypothesis is still in doubt due to significant kinematic differences between various limbs for performing movements, as well as inconsistent with the notion of dynamic optimization (with the increasing volume of exercise, due to rising information on specific effector, the response becomes increasingly effector dependence)[13].This subject is noticeable in the results of the studies performed by Sainburg and Kalakanis (2000), Amemiya et al. (2001), Bagesteiro and Sainburg (2002), Park and Shea (2003), Sainburg and Schaefer (2004), and Hore *et al*. (2010) which are in contradiction with the theory of effector independence. Also, Teixeira and Caminha (2003) examined inter-manual transfer and demonstrated that transfer of force control was partial.A portion of proficiency in this task seems to need practice with the specific effector system and therefore is dependent on effector. Park and Shea (2003) also investigated the effect of Practice on Effector Independence and demonstrated that when the same effectors are used, practice would lead to a more effective movement, but is of partial value when various effectors are needed. In addition, they propose that the way in which types of movements are represented in memory changes across practice. In the beginning stages of practice, the response seems to be represented in a relatively abstract method, which results in effector-independent performance capabilities. As the practice continues and as participants exploit effector-specific characteristics in an attempt to refine the movement pattern, the response becomes more literally represented, resulting in enhanced performance when the same muscle groups are used but less effective performance when circumstances require the response to be executed with a new muscle group.

Thus, in most of the studies regarding generalized motor programs, motor program parameters have changed and invariant characteristics (especially the relative timing of movement components) have been investigated, and thereby, the concept of motor program has been examined. However, most of the studies in examining the invariant feature have only evaluated the interlimb relative timing (The relative timing of involved limbs in a skill) or the intralimb relative timing (The relative timing between joints of involved limb in a skill) and almost none of them have studied simultaneously the invariance of interlimb and intralimb relative timing in complex discrete skill. Also, in most of these studies, participants were right footedness and few studies have simultaneously examined left and right footedness at the same time. In addition, the speed, accuracy and effector are the challenging and interesting variables for behavioral science researchers, especially among scientists of motor science who are always interested to manipulate them in order to observe the influence of these variables on different aspects of movement and motor patterns in the field of motor control. According to the above-mentioned contexts and the inconsistent results of previous studies in relation to generalized motor program theory, and the hypothesis of effector independence, in this study, researchers intend to investigate the effects of speed, accuracy and changing effector on the interlimb and intralimb relative timing of instep kicking skill for left and right footedness professional futsal players; and experiment the concept of generalized motor program by investigating the time allocated to different parts of movement in a temporal proportion.

Materials and Methodology

The method of this study is semi-experimental. All of the Iran professional futsal league players were the statistical population of the study which among these, twelve male players (aged between 22– 29) who were playing in Khorasan Razavi professional league clubs in 2015, participated in the study. After determining the dominant leg of participants, with kicking a stationary ball with high force and also hopping, they were divided equally into two groups, left footedness and right footedness. The criteria for selecting players for the sample were as follows: having a good health condition and having at least a history of two years of continuous participation in the professional league. All participants were asked to wear shoes that were used recently in practice. Following a warm up, providing explanations to participants about how they must perform kicks and performing several instep kicking with both dominant and non-dominant legs to gain familiarity with laboratory environment condition, markers were placed on stretch clothes in the anatomical locations of body. In order to collect data, five markers were placed on the anatomical positions including the highest point of iliac crest, major trochanter, lateral epicondyle of the femur, lateral malleolus and the lateral aspect of the distal head of the fifth metatarsus. Participants were asked, using a desired approach run up to 4 meters, to perform correct instep kicking under speed and accuracy condition from 6 meters penalty spot to target. In this way, participants were asked to perform at least 24 instep kicking, including 12 kicks in terms of speed (6 kicks with dominant leg and 6 kicks with non-dominant leg) and 12 kicks in terms of accuracy (6 kicks with dominant leg and 6 kicks with non-dominant leg) a stationary ball (size 4) from a marked penalty spot (6 meter) in futsal. These kicks were announced randomly by examiner. It must be noted that in speed conditions, the players were asked to kick towards the goal as quickly as possible from a six meter distance (first penalty point in futsal) by instep of foot and in accuracy condition, participants were asked to kick towards target ($1\times1m^2$) that was determined in the middle of the goal by instep of foot. In accuracy conditions, if the kick did not hit the target, it was repeated. Kicks were recorded by six high speed 200 Hz digital cameras. A second order, low pass Butterworth filter with a cut-off frequency of 7 Hz was applied to the displacement data before analysis. All of the kinematic data related to confirmed kicks were analyzed by Simi motion software to calculate the spatial and temporal position of markers. To measure the interlimb relative timing, the movement time and the relative timing of three main parts of instep kicking, in speed and accuracy conditions, were computed in each performance. These parts include: 1) kicking leg toe-off to heelcontact of foot plant with the ground 2) heel contact of support foot with the ground to ball contact leg of kicking 3) contact kicking foot with ball to maximum extension of knee in kicking foot in follow through.Also, the relative timing of peak angular velocities were used to measure the intralimb relative timing in each kicks. For this purpose, the relative timing of peak angular velocities for each hip, knee and ankle joints were calculate in speed and accuracy conditions.

In this study, descriptive statistics were used to examine the mean and standard deviation. In order to examine the effect of speed, accuracy and effector on interlimb and intralimb relative timing in groups were used 2 × 2 × 2 (group× used leg × strategy) multivariate analyses of variance(MANOVAs). For assessing, the homogeneity of variance and covariance were used Levine and box tests. The Kolmogorov–Smirnov test was applied to explore normality of data's distribution. Data were analyzed bySPSS 20.0 (SPSS, Inc.) software.

RESULTS

In table 1, the mean and standard deviation for age, height, weight and history of the professional league's participants is provided in the two groups of right and left footedness. The interlimb and intralimb relative timing'smean and standard deviation of instep kicking with dominant and non-dominant leg were demonstrated respectively in Table 2 and 3 for two groups.

Before analyzing the data, The variance and covariance's homogeneity of groups was confirmed by Levine and box tests ($p< 0.05$) and the normality of data was verified by Kolmogorov-Smirnov test ($p< 0.05$).

The results of multivariate analysis of variance in order to evaluate the interlimb relative timing (relative timing of 1, 2 and 3 parts) showed that the main effect of group was not significant, Wilks' λ=0.95,F(3,38) = 0.59, p = 0.62. This means that there was no significant difference between the right and left footedness individuals on the interlimb relative timing ($p< 0.05$). Also, that the main effect of used leg was not significant, Wilks' λ = 0.94, F (3, 38) = 0.80, p = 0.49. These results suggest that there was no significant difference between the dominant and non-dominant leg in the interlimb relative timing ($p< 0.05$). The main effect of strategy was not significant, Wilks' ë = 0.94, F (3, 38) = 0.79, p = 0.50. The results showed that in both groups, the right footedness and the left footedness, there was no significant difference between the dominant and non-dominant leg in the interlimb relative timing ($p< 0.05$). In addition, the interaction effect between group and used leg was not significant, Wilks' λ = 0.95, F (3, 38) = 0.65, p = 0.58, meaning that in both the right and left footedness, there was no significant different between dominant and non-dominant leg on the interlimb relative timing ($p< 0.05$). The interaction effect between group and strategy was also not significant, Wilks' λ = 0.97, F (3, 38) = 0.38, p = 0.76 which shows that in both the right and the left footedness groups, there was no significant different between the effect of speed and accuracy on the interlimb relative timing ($p< 0.05$). The interaction effect between used leg and strategy was not significant, Wilks' λ = 0.98, F (3, 38) = 0.15, p = 0.92, meaning that in both the dominant leg and the non-dominant leg of participants, there was no significant difference between the effect of speed and accuracy on the interlimb relative timing ($p< 0.05$). The interaction effect between group, used leg and strategy was also not significant, Wilks' ë = 0.96, F (3, 38) = 0.50, p = 0.67.

The results of multivariate analysis of variance in order to evaluate the intralimb relative timing (the relative timing of peak angular velocities in hip, knee and ankle joints) showed that the main effect of group was not significant, Wilks' λ = 0.94, F (6, 35) = 0.34, p = 0.90 which indicates that there was no significant difference between the right and left footedness individuals on the intralimb relative timing ($p< 0.05$). Also, that the main effect of used leg was not significant, Wilks' $\lambda = 0.81$, F (6, 35) = 1.31, p = 0.27. These results suggested that there was no significant difference between the dominant and non-dominant leg in the intralimb relative timing ($p< 0.05$). The main effect of strategy was not significant, Wilks' $\lambda = 0.88$, F (6, 35) = 0.79, p = 0.58. The results showed that in both groups, the right footedness and the left footedness, there was no significant difference between the dominant and non-dominant leg in the intralimb relative timing ($p< 0.05$). In addition, the interaction effect between group and used leg was not significant, Wilks' $\lambda = 0.72$, F (6, 35) = 2.27, p = 0.059 that means in both the right and left footedness, there was no significant different between dominant and non-dominant leg on the intralimb relative timing ($p< 0.05$). The interaction effect between group and strategy was not significant, Wilks' $\lambda = 0.94$, F (6, 35) = 0.37, p = 0.89, meaning that in both the right and the left footedness groups, there was no significant difference between the effect of speed and accuracy on the intralimb relative timing ($p< 0.05$). The interaction effect between used leg and strategy was not significant, Wilks' $\lambda = 0.97$, F (6, 35) = 0.12, p = 0.99. This fact means that in both the dominant leg and the non-dominant leg of participants, there was no significant difference between the effect of speed and accuracy on the intralimb relative timing ($p< 0.05$). The interaction effect between group, used leg and strategy was also no significant, Wilks' $\lambda = 0.94$, F (6, 35) = 0.35, p = 0.90.

DISCUSSION

Results of the present study about instep kicking of both groups of professional futsal players (right footedness and left footedness) showed that strategies of speed, accuracy and changing the effector, had no effect on interlimb and intralimb relative timing. Also, no significant differences were seen on the effects of the speed, accuracy and effector on interlimb and intralimb relative timing. These results confirmed the effector independence hypothesis and the relative timing as an invariant characteristics support. Despite the differences of the total time needed to complete a movement such as instep kicking in terms of speed and accuracy and applying the left and right dominant limbs, different parts of movements hold their temporal proportion.

In other words, the results of this study showed that the times allotted to the various phases of the movement remain in a constant ratio of the total movement time.Even if the movement time varies in accordance to different task dynamics, the relative timing remains unchanged. The results of this study supported Bernstein (1967) and Schmidt's (1975) ideas about using the same engram or generalized motor program to control every effector during performing a class of movements with dominant and non-dominant limb. Accordingly, one can perform a motor response with different muscle groups or limbs so that motor program invariant characteristics such as relative timing remains constant[2]. The findings of this study agrees with previous results fromViviani and Terzuolo (1980), Hollerbach (1981), Shapiro and colleagues (1981), Clark (1986), Gracco(1986), Roberton (1986), Roberton and Halvorson (1988), Ruth (1988), and Roy *et al*.[6].Also, these results accord with the findings of Southard (2014) about striking pattern. He showed that absolute timing of joint velocities is affected by experience and speed, but they have no effect on the relative timing of peak joint velocity.Heuer *et al*. (1995) showed a very strong temporal invariance when participants were asked to produce simultaneous but different rapid movements with the two arms; they demonstrated that the temporal structure of each limb, as well as the temporal structure across limbs, was scaled linearly in time that is, invariant relative timing was present for the whole bimanual task[14]. Also, Left and right hand's behaviour under different circumstances was investigated by Zuoza and colleagues (2009) and poston and et al (2009).They showed that used GMP for both limb was the same, because the relative timing patterns were very similar in both limbs. The findings of this study are in line with results of Merton (1972), Raibert (1977) and Bernstein (1947). The researchers studied the handwriting and signatures of individuals with different limbs. They indicated that these skills are represented abstractly and widely effector independence. This result is documented to well learned motor skills[13, 15].

Plus, the results of Van Mier and Petersen (2006) studies on inter-manual transfer indicated that a central abstract representation is suggested consisting of a common description of the movement in such a way that the movement can be executed with different effectors or different muscles groups of the same effector. They came to the conclusion that learning takes place at an abstract level which is independent to the effector. Also, Shapiro (1977) examined left and right hand's supination and pronation rotations and indicated that a motor program which is acquired for one of the effectors, can also be used for another one. Therefore, the results support the view that the nature of motor learning as a function of practice, is not a specific muscle but also abstract and effector independence[7, 13].

The fact that the timing of motor functions is relatively independent of the particular effector system, was also supported by Teixeira (2000). Based on these results, timing can be applied in different sensorimotor maps without necessity of particular practice with special effector.Coleen Waterhouse (2014) examined The Effect of Extended Practice on EMG Kinematics and Accuracy in dominant and non-dominant dart throwing. His findings supported that dart throwing is controlled by the same motor program and that the changing of effector or muscle group selection for the task is easily such as changing a parameter and kinematic difference between the limbs might have been a result of the subject's greater conscious attention and potentially an over compensation for lower levels of technical skill in the throw.Schmidt and Lee (1999) realized that characteristics of muscles or joints which are utilized during performing a task, is another parameter which can be determined by the motor program[9]. But on the other hand, there are significant amount of evidence which would prove that motor control mechanisms of the dominant and the non-dominant arm systems have various quality in different aspects[16]. The findings of this study are not in line with previous results fromSainburg and Schaefer (2004) and Sainburg and Kalakanis (2000). Sainburg and Kalakanis (2000) investigated control of limb dynamics during dominant and non-dominant arm reaching and showed that every limb use different strategies to achieve the target. Despite there were no interlimb differences in spatial accuracy, the limbs were controlled by different GMPs.In another study, (17)) showed that transfer of force control was partial and it seems that part of the efficiency in this task needs to be practiced with a particular effector system and is dependent on effector. Also, results of this study disagreed with previous results of Hore et al. (2005). They examined overarm throws in different speeds. Apparently, skilled throwers have different joint coordination pattern in order to change ball speed for the dominant limb. However, when learning to throw with the non-dominant limb, their spatial pattern was very identical in the beginning which indicates using the same GMP across changes in speed. The results showed that the performance of novice throwers is independent to the effector, while in the skilled individual this factor is mostly effector dependence. The findings of Parks and Shea (2003) also showed that the way in which different movements are represented in memory changes across practice. It seems that at the beginning of practice, the response is represented in a relatively abstract method that leads to the capability of performing effector independence. As we move towards the end of the practice, one attempts to refinethe movement pattern, he uses the specific characteristics of effector, which at this time, the response becomes more literally represented. Performance is increased when using the same muscle group, but when in the circumstances of using a different muscle group, movement is performed inefficiently. In addition, Proteau and his colleagues (1992) showed that after extensive practice, improvement in performance is due to enhanced optimization of effector in a way which the effector information is coded with sequence information. At this time, the effector independence decreases. This idea is in line with the findings that a response becomes increasingly effector specific with the enhanced amount of practice[13]. During the examination of dominant hand advantages in controlling dynamic limbs byHikosaka and colleagues (1999) and Bagesteiro and Sainburg (2002), they found that motor representations is more specified tothe effector and dependent on it.Also, they showed that distinct neural control mechanisms are used for dominant and non-dominant arm movements and there are significant qualitative differences in dynamic control arms.

The results show that the effector independence hypothesis is not in line with dynamic optimization view. Based on this view, after extensive practice, anatomical and neurological properties of specific effector systems are exploited to increase response production[13]. Also, findings of this study disagreed with Leuthold and Jentzsch's results (2011). The hypothesis of invariant relative timing was rejected by ERP findings in their studies.Debicki et al. (2010) also represented through the study of control mechanism of shoulder and elbow in 2-D overarm throwing, that the central nervous system (CNS) uses biomechanical features of arm to enhance ball speed when producing fast 2-D throws. CNS did this by coordinating shoulder and elbow movements. They also showed the relative timing of slow and intermediate movements were the same, while fast movements were different. This issue violates invariant relative timing for a class of movements. In another study, Thomas et al. investigated the matter that which aspects of an overhand throwing is controlled by a generalized motor program. Their findings showed that the more complex and coordinated parts of a throwing action is not controlled by the GMP and there's a possibility that kinematics and joint position are not planned within GMP. They indicated that at the beginning of learning to throw, participants use a central pattern to control joint kinematics; then, after acquiring the skill, this central control is canceled by a more complex pattern of movement, in order to exploit degrees of freedom and improve movement outcomes. They suggested when first learning to throw, participants use a central pattern to control joint kinematics; then, as skill is acquired, this central control is overridden by a more complex pattern of movement exploiting degrees of freedom to optimize throwing outcomes. Also, the results of present study disagreed with the findings of Limerick and *et al.*, (1992) and Cowan et al (2011).Their results showed that the relative timing doesn't remain unchanged, and it is possible that the invariant relative timing would not bea necessary property of movement kinematics. Most probably the relative timing reflects person's strategy instead of being an invariant characteristic of a well-learned motor skill.Heuer and Schmidt (1988) failed to support for invariant relative timing as well. They proposed the hypothesis of a continuous difference between temporal patterns in their interpretation of empirical results. According to this hypothesis, invariant relative timing is a strategic phenomenon that is limited to certain patterns called "natural". They indicated that invariant relative timingis more of a strategic phenomenon, rather than being a mandatory one; A phenomenon that according to it, some of the patterns of timing are preferred over other[7-8, 18]. Heuer (1991) also concluded that both the dynamics of the peripheral system and the requirements of external events impose constraints on the central command of the GMP that influence the preference for some movement patterns over others[18]. Gentner also confirmed the fact that invariant might be kept at a level (e.g. recorded EMG) but does not exist at other levels (e.g. kinematic level)[6]. Thus, invariant relative timing has been observed in several studies, including present study, but as mentioned, there are studies that failed in supporting this concept. Different reasons are proposed for these types of contradictions. First, different conclusions can come from studies of different motor patterns or different variations of a particular pattern. Such paradoxes primarily show that the theory of a generalized motor program with invariant relative timing may have a limited domain of validity. Second, diverse conclusions can also due to studies of almost identical tasks, even from analyses of identical data sets and these contradictions seem to pose more serious problems. In addition, one of the main causes for varying results, even in the studies that have used the same task or even more, the similar set of data, is the different methods of testing invariant relative timing. At one end, relative-timing invariance can be indicated in a highly significant style with the proper visual presentation of the data; but on the other end, relative timing invariance hypothesis can be easily rejected by sufficiently precise statistical procedures. Gentner demonstrated that invariant relative timing does not exist in a strict sense at all. Whether or not, relative timing will be found invariant does therefore only depend on the power of the statistical procedures. However, the relation between theory and observation is not quite as simple. While observations are made on peripheral kinematics, theoretical concepts refer to a central level of control[19]. The one hand, study of typists (Viviani and Terzuolo, 1980) provided significant experimental evidence in favor of an internal timing structure of well-learned actions. On the other hand, the abundant studies have provided us with numerous evidences which show the matter that relative timing is an essential property of interactions within the body and between the body and the environment[20]. Also, Invariance of relative timing can be caused by the inability of subjects to modify the temporal structure of a learned motor pattern or from their unwillingness. In the first case the tendency towards relative timing invariance would be a mandatory phenomenon, but in the second case it would be strategic[21].Gentner also states that the results of the invariant relative timing has been determined based on the average values of participating groups. He argued that classifying invariant features of motor program needs evidences collected from individual data. It also showed that the results were not supported by invariant relative timing when the relationships were analyzed for those perspectives[22-23]. Other researchers have also suggested that invariant has been evaluated by the behavioral level while invariant features of motor program are in the central nervous system. The second issue which arise in divergence to the relative timing invariance, is that if the relative timing of a skill is invariant, therefore, it is associated with a generalized motor program[22].

Heuer (1988) also stated that the lack of relative timing invariance in movement kinematics does not reject its existence at another higher level of the motor system. He alleged that inertial properties of the system is one of the main reasons for the absence of the relative timing invariance in kinematic. Another reasons for this variability in the kinematic level include delays between the arrival of nerve impulses and muscle tension development and also contend that the aspects of invariance could be maintained at the electromyographic (EMG) level rather than at the kinematic level[24]. Therefore, it can be said that peripheral events timing can be moderately altered by the central program and peripheral factors. As a result, the timing of peripheral events can be determined to variable degrees by a central program and by peripheral factors. Even a perfect invariance at a central Level of control can be distorted as the central commands enter the motoneuron pools and are transformed into linear forces in the muscles, into joint torques, joint movements, and finally movement of an end effector.

Altogether, the researchers expressedthat there is no reason to assume that changes on the way from transforming the central command to kinematic properties will not have effects on the invariant relative timing. Thus, generalized motor program's concept actually does not forecast that the invariance of relative timing should be observed in the strict sense; But in many occasions only expected to have a tendency towards invariant[21]. Also, it can be said that we are not expecting a same performance by an untrained limb as well as a trained one, probably due to the factors such as perception, biomechanics, specific practice, index difficulty. Based on this, considering the point that some of the movement features could not be transferred to contralateral limb in an effective matter, we can conclude that these features are coded more specific and effector dependent.

CONCLUSIONS

Overall, in this study, it was observed that adopting speed and accuracy strategies and changes in effector, did not have significant effects on the interlimb and intralimb relative timing of instep kicking task. Also, Interaction between group (right footedness and left footedness), strategy (speed and accuracy) and used leg (dominant and non-dominant) had no effect on used timing patterns. In fact, the outcomes of this study indicated that speed, accuracy and effector are variables associated with performance and may be required to adapt behavior with different expectations of performance environment. These results supported the invariant relative timing's prediction of generalized motor program.Alldata supported this conclusion that speed, accuracy and the change in effector, are as easy as changing the parameters of motor program, and minor differences in timing the various parts of movement can be due to limited amount of research data or errors in measurement. On the other hand, the results showed that in players with matured patterns of instep kicking, such variables (speed, accuracy and effector) don't lead to a change in the relative timing of the kicks. However, it is likely that these variables in individuals with an immature pattern result in changing the kicking pattern and therefore change in the relative timing. Therefore, in future researches, it is recommended that the effect of speed, accuracy and changing effector is studied on invariant relative timing's instep kicking pattern in novice players and be compared with the elite players. Moreover, the effect of these variables on invariant relative timing in central level (EMG records) and behavioral level (kinematics analysis) in various motor skills should be studied and compared with each other. Also, it is suggested to study the effect of factors like difficulty index and anthropometric measurements on the used motor program of different effectors.

REFERENCES

1. Crossley J. Personal Training: Theory and Practice: Routledge; 2012.
2. Sherwood DE. Aiming accuracy in preferred and non-preferred limbs: implications for programing models of motor control. Frontiers in psychology. 2014;5.
3. Montgomery P, Connolly BH. Clinical applications for motor control: Slack Incorporated; 2003.
4. Summers JJ, Anson JG. Current status of the motor program: Revisited. Human Movement Science. 2009;28(5):566-77.
5. Scott Kelso J, Putnam CA, Goodman D. On the space-time structure of human interlimb co-ordination. The Quarterly Journal of Experimental Psychology. 1983;35(2):347-75.
6. Burgess-Limerick R, Neal RJ, Abernethy B. Against relative timing invariance in movement kinematics. The Quarterly Journal of Experimental Psychology. 1992;44(4):705-22.
7. Kwon O-S, Zelaznik HN, Chiu G, Pizlo Z. Human motor transfer is determined by the scaling of size and accuracy of movement. Journal of motor behavior. 2010;43(1):15-26.
8. Heuer H. Adjustment and readjustment of the relative timing of a motor pattern. Psychological research. 1988;50(2):83-93.
9. Heyrani a, Farokhi A, bahram A. The independence of effector in complex bimanual coordination drawing tasks.
10. Poston B, Van Gemmert AW, Barduson B, Stelmach GE. Movement structure in young and elderly adults during goal-directed movements of the left and right arm. Brain and cognition. 2009;69(1):30-8.
11. van Mier HI, Petersen SE. Intermanual transfer effects in sequential tactuomotor learning: evidence for effector independent coding. Neuropsychologia. 2006;44(6):939-49.
12. Waterhouse C. The Effect of Extended Practice on EMG, Kinematics and Accuracy in Dominant

and Non-dominant Dart Throwing. 2014.

13. Park J-H, Shea CH. Effector independence. Journal of motor behavior. 2002;34(3):253-70.
14. Schmidt RA. Motor schema theory after 27 years: reflections and implications for a new theory. Research quarterly for exercise and sport. 2003;74(4):366-75.
15. Drever J. Rapid acquisition of long spatial sequences in long-term memory: lmu; 2012.
16. Kirsch W, Hoffmann J. Asymmetrical intermanual transfer of learning in a sensorimotor task. Experimental brain research. 2010;202(4):927-34.
17. Teixeira LA, Caminha LQ. Intermanual transfer of force control is modulated by asymmetry of muscular strength. Experimental Brain Research. 2003;149(3):312-9.
18. Amazeen PG. Is dynamics the content of a generalized motor program for rhythmic interlimb coordination? Journal of Motor Behavior. 2002;34(3):233-51.
19. Kelso JS. The self-organization of brain and behavior. Cambridge, MA: MIT Press; 1995.
20. Zatsiorsky MLLnAVM. Motor Program. Biomechanics and Motor Control. 2016.
21. Fagard J, Wolff PH. The development of timing control and temporal organization in coordinated action: invariant relative timing, rhythms and coordination: Elsevier; 1991.
22. Gentner DR. Timing of skilled motor performance: Tests of the proportional duration model. Psychological Review. 1987;94(2):255.
23. Magill RA, Anderson D. Motor learning and control: Concepts and applications: McGraw-Hill New York; 2007.
24. Spinks W, Reilly T, Murphy A. Science and Football IV: Psychology Press; 2002.