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THE EFFECTS OF INTERACTIVE METRONOME TRAINING ON FEMALE SOCCER PLAYERS TIMING ABILITY

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The aim of this study was to investigate how timing training by Interactive Metronome ® (IM) affects motor timing and rhythmicity in soccer players. Twenty-four female soccer players (age 19 ± 2.8) participated, and were randomly assigned to either a control or an IM training group. All participants took part in a functional magnetic resonance imaging (fMRI) session before the start of the training period, to find out what brain areas are activated during different tempos. The fMRI outcomes indicate that some of the active areas are the inferior parietal cortex (BA 40), frontal/SMA and precentral cortex and postcentral (BA 6) and inferior frontal cortex (BA 45). Pre- and post-measurements of motor timing deviation and variability was made. The result shows that after four week of IM training a significant improvement of motor timing was found for the IM group in comparison to the control group. The findings indicate that timing training can improve timing ability in healthy sport perpetrators.

To be able to perform any motor action there are several different components that play important roles. One of them is timing. There are a number of studies that show that timing is important in producing coordinated motor actions (e.g. Meegan, Aslin & Jacobs, 2000; Buhusi & Meck, 2005). When it comes to highly complex and demanding athletic movement performance, good timing is supposed to be even more important. However there are still few investigations of how timing training can affect sport performance. Therefore the main aim of the present study was to try to find out if timing training in soccer players can improve their motor timing ability.

Precise timing is a key feature for all movement. And to be able to coordinate all the parts of complex movement, timing in the range of hundreds of milliseconds is essential (Medina, Carey & Lisberger, 2005). Complex movements require synchronization between physical and cognitive activation. To be able to optimize a sport activity dynamic processing and integration between attention, motor planning, sensory-motor coordination, organization and sequencing are necessary (Sommer & Rönqvist, 2009). Movement involve change in muscle length over time, therefore motor control and timing are closely related (Mauk & Buomonano, 2004). Thus, complex, multilevel motor control activations require a successive and accurate initiation and timing on the level of milliseconds.

Rhythmicity is another ability that is important regarding motor actions and is closely connected to timing. Zachopoulou, Mantis, Serbezis, Teodosiou and Papadimitriou (2000) performed a study to investigate rhythmicity in children who trained in different sports. Their results indicate that rhythmicity is important in motor skill performance and that children's rhythmicity gets improved from participating in motor skill training. Kornysheva, von Cramon, Jacobsen and Schubotz (2010) found, in an fMRI study that musical rhythms that are judged as beautiful enhanced the blood-oxygen-level-dependent (BOLD) response bilaterally in the precentral operculum/ventral premotor cortex and the cerebellum. They

also found that preference-associated effects in motor areas also appeared when the musical consideration is reduced to only tempo. These findings indicate that the motor system is not only concerned during attention to rhythm in general, but that it is more concerned for a preferred rhythm over a non preferred rhythm. In a rhythm task Platel et al. (1997) found through a positron emission tomography (PET) study, that only the left hemisphere was activated. Platel et al. also found that there was statistical significant activation in Broca's area, which is Broadmann area 44 and 6.

Regarding the brain areas that are active during timing there seem to be several neural structures that are involved. The basal ganglia and the cerebellum are two areas that are well supported to be involved in timing in the literature. It has also been indicated that different neural structures are activated depending on what kind of timing that is concerned, which is if it is circadian, interval or millisecond timing (Hinton & Meck, 1997). According to Ivry (1996) the cerebellum is involved in shorter time intervals and the basal ganglia when it comes to longer intervals. The basal ganglia seem to mostly be involved in timing on the range of seconds (Mauk & Buonomano, 2004). Timing in the millisecond range is crucial for motor control. The cerebellum has been found to be involved in this kind of timing by Buhusi and Meck (2005), who found that it is responsible for automatic motor control. Cassidy et al. (2002) found that the basal ganglia may be involved in motor planning. Both when it comes to ongoing movements and feedback processing. Also Nenadic et al. (2003) carried out an fMRI study that indicates that the basal ganglia are an important component in temporal processing. Rao, Mayer and Harrington (2001) also performed a study which indicates that the basal ganglia are involved in formulated representation of time. Parietal cortex (BA 40), Frontal/SMA and precentral cortex and postcentral (BA 6) and Inferior Frontal cortex (BA 45) are three other brain areas that are involved in timing. This is supported by several studies. In a study on stroke patients Harrington, Haaland and Knight (1998) found that the right parietal cortex seems to be involved in temporal processing. In an fMRI study Rao et al. (2001) also found that the parietal cortex might be involved in attention, which they argue theoretically regulates timekeeping. In the same study Rao et al. also found that premotor (BA 6) and right dorsolateral prefrontal cortex was activated during time perception.

Lewis and Miall (2003) have further argued that there seems to be dissociation in neural activity depending on the interval to be measured, what movement to be used to define time and also on the continuity of the task. This provides support for two different systems for time measurement. One the automatic system, which is closely linked to motor and premotor circuits, thus, not involve the prefrontal or parietal cortices. The other, the cognitively controlled that is, mostly involves the prefrontal and parietal cortices (Lewis & Miall, 2003). The prefrontal cortex is thought to be flexible in function. Therefore Lewis and Miall, further suggested that it is possible that direct attention to a timing task can lead to recruitment of flexible modules to construct a versatile temporary clock system.

There is also research that supports other functions to some of the brain areas that are involved in timing. Di Pellegrino, Fadiga, Fogassi, Gallese and Rizzolatti (1992) found that in area F5 in monkeys, the premotor cortex is not only active when retrieving an appropriate motor act to sensory stimuli. It can also be activated as a response to the meaning of a gesture that is made by another individual. This is performed by a special type of neurons. Later Fadiga, Fogassi, Pavesi and Rizzolatti (1995) found that there seems to be a similar system in humans, a system that matches action observation and execution. In their study Fadiga et al. used transcranial magnetic stimulation and found that there was activation in the motor system when observing an experimenter grasping an object. Rizzolatti, Fadiga, Gallese and Fogassi (1996) also suggest that there is a system in humans that is similar to that found in monkeys. The system responsible for this is called the mirror neuron system. Mirror neurons are not only activated when the individual itself performs a motor action, but also when watching somebody else perform the same action. In humans the rostral part of the inferior parietal lobule, the lower precentral gyrus and the posterior part of the inferior frontal gyrus form the center of the mirror neuron system (Rizzolatti & Craighero, 2004). Mirror neurons have also been found in other brain areas in humans, these are the areas that seem to overlap with the areas involved in timing. Grafton, Arbib, Fadiga and Rizzolatti (1996) performed a study using PET to localize the brain areas that are involved in representation of hand grasping movements. They found that grasp observation activated the left superior temporal sulcus (STS), the left inferior frontal cortex (BA 45), left rostral inferior parietal cortex (BA 40), rostral part of the left supplementary motor area (SMA) and the right dorsal premotor cortex. Rizzolatti et al. (1996) also carried out a PET study to find out what areas are activated during observation of hand grasping movements. In this study they found that the areas involved are the left STS and the caudal part of the left inferior frontal gyrus.

Meegan et al. (2000) discovered that training on a perceptual auditory task showed a significant transfer to a motor task. They suggest that the motor learning was a product of enhanced representation of a temporal interval, and that this was caused by the auditory training. This occurred in a plastic network that is shared between sensory and motor systems. This indicates that it is possible to affect the underlying timing control even without sport specific training. There are different ways to assess and train a person's timing and rhythmicity without it being sport specific. There are studies that show benefits of metronome based motor training in different areas. One form of metronome training is the Interactive Metronome (IM). The theory that lies behind the IM is that motor planning processes are based on an internal sense of rhythm (Koomar et al., 2001). Further Koomar et al. argue that rhythm provides a foundation for timing. Gorman (2003) describes that IM training can improve several different abilities e.g. attention and mental processing. With this training form, among others, Shaffer et al. (2001) found that boys with ADHD who received IM training improved attention, motor control and language processes among other things. This was compared to boys that received a video game treatment and boys that did not get any treatment at all. Sabado and Fuller (2008) also found that IM training might benefit language skills in a female with a language learning disorder. Taube, McGrew and Keith (2007) performed a

study with elementary school children with difficulties to read, and found that IM timing training significantly improved their timing and rhythmicity. Additionally, the experimental group significantly improved their ability to fluently recognize familiar words, the Test of Word Reading Efficiency (TOWRE).

Hence, timing training has been used in different settings and for different purposes with documented success. As a consequence of this it has also become popular to use timing training to try to improve different sport performances. However there have only been a few scientific studies that have investigated the effects of timing training on sport performance. Libkuman, Otani and Steger (2002) executed a study that indicates that timing training improves golf accuracy. Timing training for 10 hours spaced over four weeks significantly improved the participants golf shot accuracy. Another study that investigated the effects of synchronized metronome training (SMT) in form of IM training was made by Sommer and Rönnqvist (2009) that also show significant effects of SMT in motor timing and in synchronization for golf players. In the same study they also found that the golfers significantly improved scores on some golf shot accuracy variables. This improvement also occurred after only four weeks of training. These findings indicate that training does not have to be golf-specific to have positive effect on golf performance. Therefore it seems likely that timing training may improve other sport specific features as well, without it being sport specific, for example soccer players motor timing and rhythmicity. So far, few, if any scientific studies have been focusing on motor timing training in soccer players. The majority of earlier evidence based investigations on timing training has been focusing on individuals with different kinds of disabilities or neurological impairments. There has hardly been any timing training research performed on healthy average people, neither is there any research on soccer players and timing and rhythmicity. Also almost all research that has been performed on soccer players have been done on male players.

Thus, the main purpose of the present study was to determine the effects of SMT in form of IM training on motor timing and rhythmicity in female soccer players. An additional aim was to find out what brain areas that are activated while the participants are exposed with sequences of motor timing tasks, with different tempos in form of a short movie sequence of a person producing IM-based hand claps, here exposed without sound.

Method

The inclusion criteria for the present study were healthy elite (players from teams in Sweden's highest, and second highest soccer division) female soccer players between the ages of 16 and 27. The study was approved by the local ethical committee at Umeå University, and conducted in accordance with the Declaration of Helsinki.

Participants

The total number of participants in the study was 24 soccer playing women. The age of the participants ranged between 16.2 and 25.8 years (mean 19.4 years). The participants weight ranged between 46 kg and 72 kg (mean 61.6 kg). The participants height ranged between 160 cm and 180 cm (mean 169.2 cm). The participants were randomly assigned to either the IM-training group or the control group. The groups did not differ significantly on any of these background properties.

Additionally, all participants' hand preference was assessed by the Edinburgh Handedness Inventory (Oldfield, 1971). In addition the participants' foot, eye and soccer lateralization were also assessed with modifications of this inventory adjusted to the different areas. A laterality index was further calculated by the equation $(R-L)/(R+L)$ for each assessment. This procedure results in an index ranging from -1 to 1 where negative values represent a leftward bias and positive a rightward bias. Values ranging between -0.3 to 0.3 were regarded as a mixed handedness. The IM group hand lateralization index (LI) ranged between -1.0 and 1.0 (mean 0.78) and the control group hand LI ranged between 0.85 and 1.0 (mean 0.9). The IM group foot LI ranged between 0.25 and .075 (mean 0.48) and the control group foot LI ranged between 0.17 and 0.83 (mean 0.4). The IM group eye LI ranged from -1.0 to 1.0 (mean 0.53) and the control group eye LI ranged from -0.17 to 1.0 (mean 0.64). The IM group soccer LI ranged between -0.5 and 0.87 (mean 0.5) and the control group's soccer LI ranged between 0.53 and 0.7 (mean 0.52). The IM group overall LI ranged from -0.42 to 0.88 (mean 0.6) and the control group overall LI ranged from 0.56 to 0.87 (mean 0.62).

There was no significant difference on lateralization index outcomes between the control and the IM group, on hand LI ($t(22) = -0.7, p = 0.49$), foot LI ($t(22) = 0.99, p = 0.33$), or on eye ($t(22) = -0.5, p = 0.62$). Neither was there any significant difference between the two groups on soccer LI ($t(22) = -0.17, p = 0.86$) nor on overall LI ($t(22) = -0.41, p = 0.68$).

Apparatus

To assess the participants timing and rhythmic skills the Interactive Metronome (IM) ® system were used. The system was used at pre- and post-test for both groups and was also used to perform the training intervention on the IM training group. The IM is a computer program that is based on the traditional music metronome. The setup for the IM equipment is a set of headphones which provides the metronome beat, and a set of contact-sensing triggers. The triggers include hand triggers and footpads. The participants should perform several different rhythmic hand and foot movements in combination with the reference beat which is heard through the headphones (Figure 1). The movements to be performed are both uni- and bilateral. From the IM equipment three different measures are obtained, the mean millisecond discrepancy from the reference beat, the variability average and the highest number of hits the participant stays within ± 15 ms of the reference beat (Sommer & Rönqvist, 2009).



Figure 1. Illustration of the IM set-up (photograph printed with permission).

The functional Magnetic Resonance Imaging (fMRI) test was performed in a GE 3,0 T (T2* weighted) scanner with a 32 channel head coil. And a gradient echo-planar imaging (EPI) sequence sensitive to blood oxygen level dependent (BOLD) contrast. The parameters for the functional scanning were: repetition time: 2000 ms, 37 slices (3.4 mm), echo time: 30 ms, flip angle: 80 degrees and field of view: 25x25 cm, 96x96 matrix. During the fMRI scanning the participants were lying with their heads in the head coil and viewed movie sequences through a tilted mirror. The participants wore headphones and earplugs to minimize the scanner noise. Cushions placed inside the head coil were used to minimize head movement. The stimuli were presented using E-Prime 2.0 (Psychology Software Tools Inc., PA, USA).

Procedures

In the beginning of the test period the participants were informed about the experiment protocol and they gave their informed consent to participate in the study. All the participants in the study were compensated with 500 SEK for taking part in the study. All the participants performed the IM pre- and post-test, both control group and IM training group, to assess the timing and rhythmic skills of the participants. This test is a standardized assessment which has been developed by the manufacturer that consists of 14 different tasks. In addition to these tasks there were also two soccer specific tasks included in the pre- and post-test sessions in the present study. In the beginning of the test session the hand trigger was attached to the participants hand and the headphones were placed on their head. Before each task the participants were shown a video displaying the appropriate movements to be performed. The pre- and post-test took approximately 15 minutes each to complete. The tempo of the metronome was set to 54 beats per minute (bpm) for all the tasks during these tests.

The fMRI part of the experiment was conducted before the training period started and was made by use of a block-design and consisted of a four minute long movie sequence exposed to the participants. The movie was divided into short segments of three different movie cuts. The participants were instructed to imagine that they themselves were performing the movements that they were watching in the movie. The movie sequence included a person performing the IM hand clapping task during three different tempos (bits per minute: bpm). It was the torso, arms and hands that was shown in the movie sequences. There was only a visual stimulus that was presented to the participants, thus, there was no audio stimulus. Each tempo (beat) was shown six times in a randomized order with a two second pause between each cut were a “+” was shown. Each movie cut was seven seconds long. The three different beats exposed were 42 bpm, 54 bpm and 66 bpm. The total number of movie cuts shown was 18. There was also a still picture of a pair of feet that was presented six times as well. The experimental procedure from the fMRI stimuli presentation is shown in figure 2.

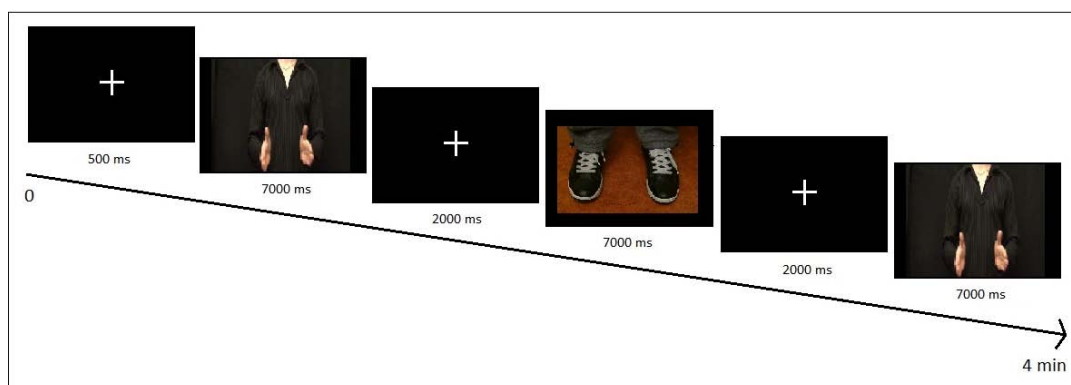


Figure 2. Overview of the fMRI stimuli presentation.

Intervention

The training consisted of using the IM equipment for the training group. They acquired 12 training sessions of IM training. The training was performed three times a week á one hour over a four week period. The training was executed individually and a trainer was present for all sessions.

The IM system transposes the information into discriminative guide sounds that are presented to the participant through the headphones. The guide sounds indicate if the participant was on target, early or late. An early hit generates a low pitch tone in the left ear. A late hit generates a higher pitch tone in the right ear. A hit that is within ± 15 ms of the reference beat generates a higher pitch tone that is presented to both ears at the same time. The purpose of the guide sound is to enable the participants to correct their timing errors as soon as they occur. Guide sounds were not present during the pre- and post-test.

There were in total 32 different exercises where the hand triggers and footpads were used in different ways and combinations. There were two bilateral hand tasks, 18 bilateral foot tasks, two contra lateral tasks, two tasks with the right hand, one with the left hand, five tasks with the right foot and four with the left foot. The different exercises varied between sessions, the participants were

supposed to perform different combinations of task depending on the session. Also the amount of time spent on each exercise varied across sessions (1, 2, 3, 4, 5, 6, 9, 16, 28 and 37 minutes). The tempo for the different tasks varied as well (40, 46, 54, 66, 78, 80, 90 and 100 bpm), but the basic tempo was 54 bpm. This was the most common tempo during the training sessions (330 minutes, 63 % of the total training time). Some of the IM exercises were developed to be soccer specific. After completing the training the participants had performed approximately 25,000 repetitions of handclaps, toe touches, heel touches, volley kicks and other movements with the IM equipment. Both the IM training group and the control group continued to do their regular soccer training during this four week period.

Data and statistical analysis

From the IM data the task average, task variability average and highest in-a-row (IAR) for each participant were analyzed. The task average is the deviation from the reference beat, the person's timing. The task variability is how close each hit is to previous one, the person's rhythmicity. And the highest IAR is how many in a row the participant stays within ± 15 ms of the reference beat. To investigate possible effects between pre- and post-test statistical differences were analyzed by performing a repeated measures ANOVA with group as the between subject factors and test as within-subject factors. The alpha level for all statistical analysis was set to 0.05.

The fMRI pictures were processed with SPM 8 (Statistical Parametric Mapping) which was implemented in Matlab 7.7.0 (Mathworks Inc, MA, USA) as well as in DataZ (developed within Umeå centre for Functional Brain Imaging). Comparison from the fMRI outcome data were made by means of between the still picture and 42 bpm, the still picture and 54 bpm and the still picture and 66 bpm. Further a 2 (group) x 3 (tempo) ANOVA, with repeated measurement on tempo, for each brain activation area (inferior parietal cortex, frontal/SMA and precentral cortex and postcentral, and inferior frontal cortex) of interest were performed.

For the statistical analyses of the fMRI data the alpha level was set to 0.05.

Results

IM data

For task average a 2 (group: IM and control) x 2 (test: pre- and posttest) ANOVA was performed. The ANOVA revealed a significant main effect for group; $F(1, 22) = 4.97$, $p < 0.05$, a significant effect of test; $F(1, 22) = 21.17$, $p < 0.001$, as well as a significant interaction between group and test; $F(1, 22) = 20.74$, $p < 0.001$. The post-hoc comparison showed that only the IM group differed significantly (Scheffé's; $p < 0.05$) between pre-and post-test scores (Figure 3).

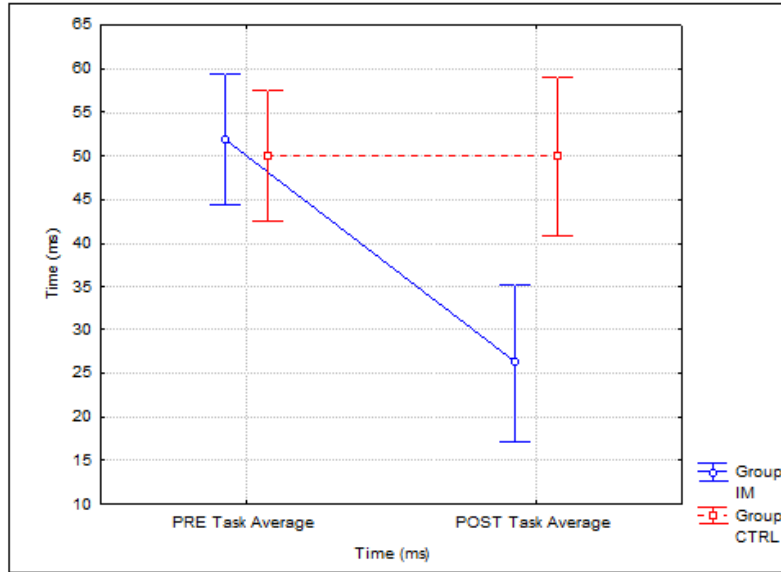


Figure 3. Timing deviation (task average) from the reference beat as a function of group and test.

For the task variability a 2x2 ANOVA was performed. The ANOVA revealed a significant main effect for group; $F(1, 22) = 8.73, p < 0.01$, and a significant effect of test; $F(1, 22) = 15.49, p < 0.001$. There was also a significant interaction between group and test; $F(1, 22) = 12.96, p < 0.01$. The post-hoc test showed that only the IM group differed significantly (Scheffé's; $p < 0.01$) between the pre- and post-test (Figure 4).

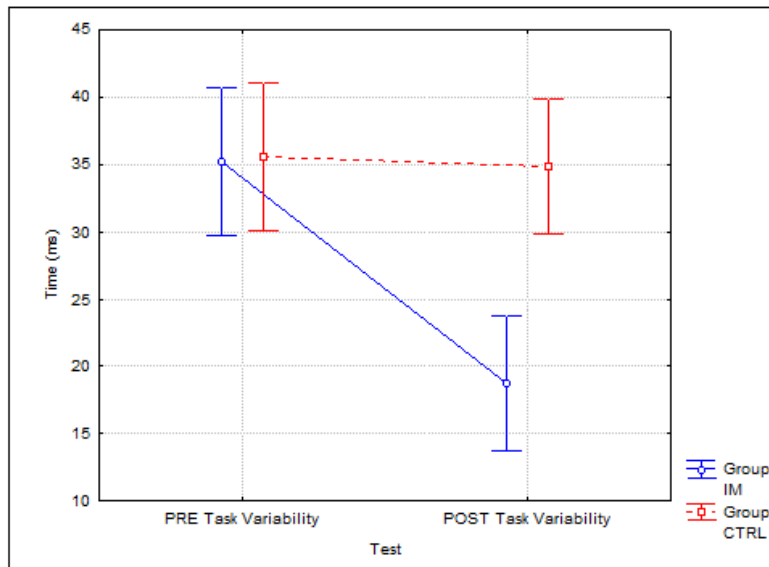


Figure 4. Task variability average as a function of group and test.

Also for highest IAR an ANOVA was performed that revealed a significant main effect for group; $F(1, 22) = 8.05, p < 0.05$, a significant effect of test; $F(1, 22) = 20.81, p < 0.001$, as well as a significant interaction between group and test; $F(1,$

22) = 14.33, $p < 0.01$. In line with the outcome from timing deviation and the task variability, the post-hoc comparison showed that only the IM group differed significantly (Scheffe's; $p < 0.01$) between pre- and post-test scores (Figure 5).

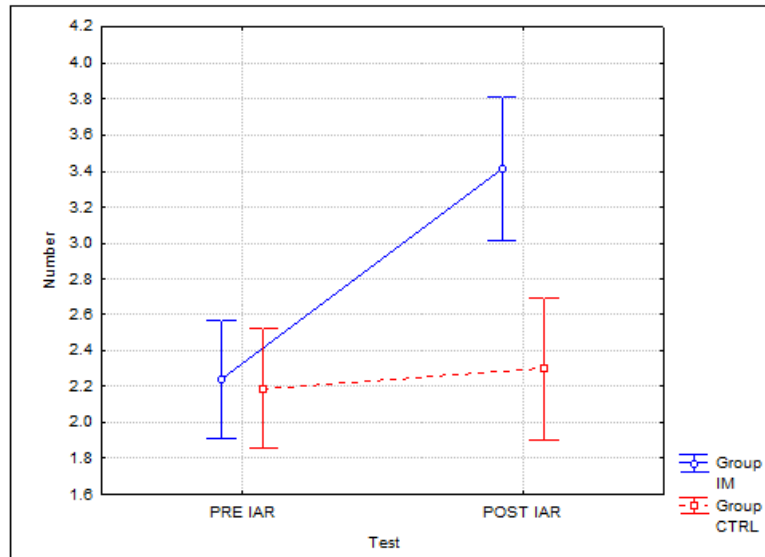


Figure 5. Highest in a row within ± 15 ms of the reference beat as a function of group and test.

fMRI data

The brain areas focused on in this study are the inferior parietal cortex (BA 40), frontal/SMA and precentral cortex and postcentral (BA 6) and inferior frontal cortex (BA 45). From these areas seven peaks were distinguished and chosen for further analysis. They were in BA 40, the inferior parietal cortex, 56 -44 54 = S1, BA 6, the SMA left, -6 -6 70 = S2, BA 6 precentral, 52 0 42 = S3, BA 6 SMA, right, 6 6 70 = S4, BA 6 post central -42 -8 50 = S5, BA 6 precentral, -38 -12 66 = S6 and in BA 45 inferior frontal, -38 46 18 = S7.

The investigation of the fMRI pre-test showed no significant difference between groups; $F(1, 22) = 0.027$, $p > 0.05$, nor any significant difference for group (IM, control) \times tempo (42 bpm, 54 bpm, 66 bpm); $F(2, 44) = 0.53$, $p > 0.05$, for these brain areas (Figure 6). In addition there was no significant difference ($p > 0.05$) between the three different tempos for the different brain areas.

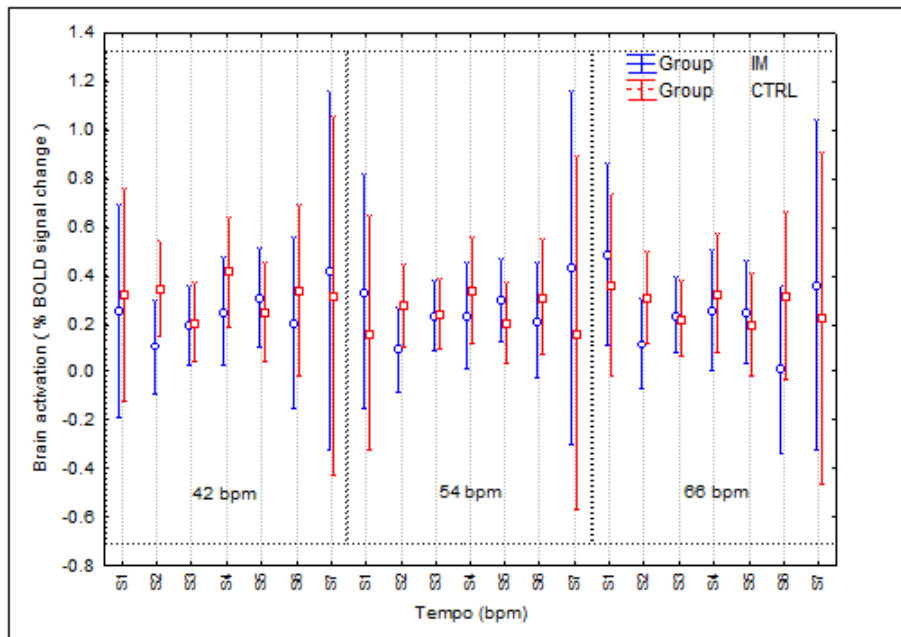


Figure 6. Brain activation for 42 bpm, 54 bpm and 66 bpm compared to mean of session for each peak, S1= BA 40, inferior parietal cortex, S2 = BA 6, SMA left, S3 = BA 6 precentral, S4= BA 6 SMA, right, S5 = BA 6 post central, S6 = BA 6 precentral and S7 = BA 45 inferior frontal.

The brain activation found in the fMRI session for the seven peaks from the chosen brain areas is shown in figure 7. The contrasts are between the still picture and 42 bpm, the still picture and 54 bpm and the still picture and 66 bpm.

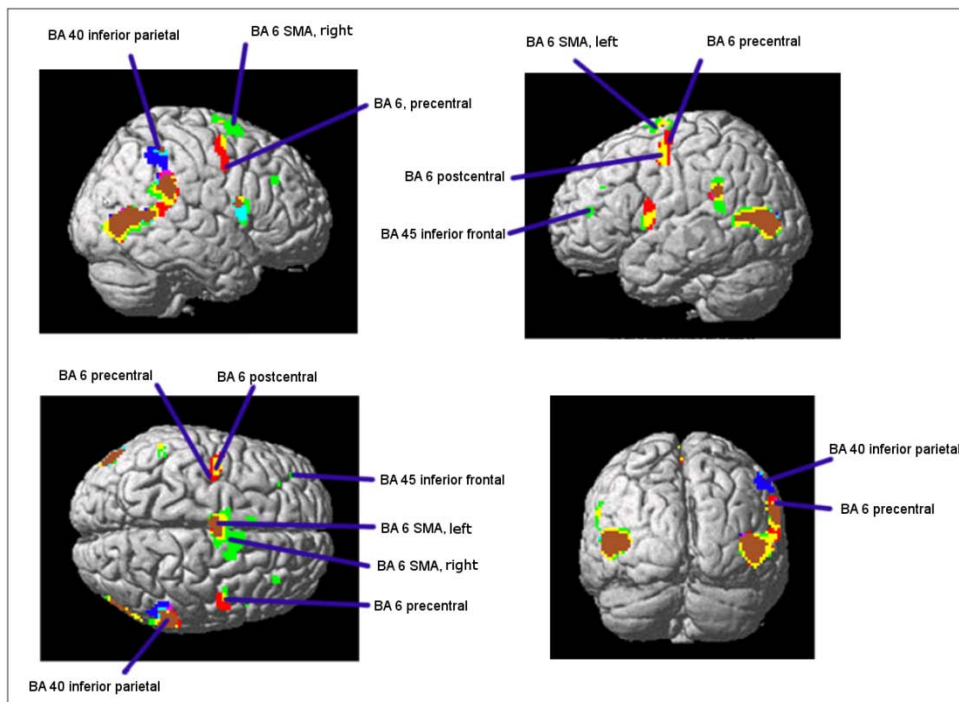


Figure 7. Illustrations of different brain activations during the fMRI sessions. The colored areas illustrate activations in relation to respective exposed tempo; green: 42 bpm, red: 54 bpm and blue: 66 bpm, all other colors overlap.

Discussion

Different kinds of timing and rhythmicity training have been used in a variety of settings. It has been used as treatment for different problems and neurological impairments and has recently become more common in other types of settings; one example is in sport performance. Where there are a few studies that have focused on golf players (Libkuman et al., 2002; Sommer & Rönqvist, 2009). These studies provide evidence for motor timing improvement as well as improvement on golf accuracy after only a few weeks of SMT training in sport perpetrators. However, so far, there have not been any timing studies performed on soccer players. Thus, the main purpose of the present study was to determine if SMT in form of IM training has any effect on elite female soccer players' motor timing and rhythmicity. Additionally, to investigate what brain areas are activated while watching motor timing tasks with different tempos, in form of movie sequences with IM-based hand clapping.

The results from this study provide further evidence that timing training with IM improves motor timing. It also provides support that IM training improves rhythmicity. The soccer players in the IM training group significantly improved both their timing and rhythmicity compared to the participants in the control group. Since previous studies mainly focused on people with disabilities or neurological impairments (e.g. Shaffer et al., 2001; Sabado & Fuller, 2008; Taube et al., 2007) it was of interest to find out how healthy people would respond to IM training. The participants' in the present study are a group of elite soccer players that presuming do persist a good timing ability do to extensive amount of soccer training and performance, still they do improve their timing and rhythmicity abilities. This is in line with previous findings. There are earlier indications that also healthy people can benefit from this kind of training (Libkuman et al., 2002; Sommer & Rönqvist, 2009). Also the IM method has features of rhythmic auditory stimulation (RAS). According to Thaut and Abiru (2010) RAS can increase timing to be the most important control structure when generating complex movement and it can improve muscular control. RAS has also been shown to use auditory-motor pathways to entrain central motor processors and also to stabilize motor control (Thaut & Abiru, 2010). Therefore it is possible that the IM group has acquired a more stable motor control as an effect of the IM training. It also seems possible that their muscular control has become better and that this can explain why the IM training group has improved their timing and rhythmicity abilities significantly compared to the control group. From the results found in the present study it seems likely that well-trained athletes can benefit from this training as well. Even healthy people can improve their motor timing and rhythmicity with timing training. This lends support to more usage areas of the IM. In agreement with Sommer and Rönqvist (2009) this training can be used during sickness or injuries

for athletes, since it is not very physically demanding. It could probably also be used as a complement training for people that do physical exercises on a lower level and wish to improve their motor timing, and perhaps the IM training can contribute to improving their sport specific abilities as well. In addition to improving their timing average and their variability average the IM group significantly improved their highest in a row (IAR) count in comparison to the control group as well. That means that they got better at staying within ± 15 ms of the reference beat. This is also a measure of timing ability, since the better timing a person has, the better the person gets at staying on the reference beat. By considering these results one possible explanation to why the IM group improved their timing is that they get better at concentrating on the task at hand. In line with Sommer and Rönqvist (2009) this can be due to the fact that the participants' get better at concentrating on the task as an effect of the IM training. Gorman's (2003) findings also indicate that IM training can improve attention.

The brain areas focused on in the fMRI part of the present study are areas that in previous research have been found to be involved in timing, and also to be parts of the mirror neuron system. Also other brain areas are activated but were not in focus for the present study. The results from the fMRI data shows that among others the previously mentioned brain areas; inferior parietal cortex (BA 40), frontal/SMA and precentral cortex and postcentral (BA 6) and inferior frontal cortex (BA 45) are active during the watching of the IM-based timing movie cuts. These results indicate that these brain areas are involved in timing and provide further evidence that these areas actually are activated as an effect of timing. Because some of the active brain areas were parts of the frontal cortex, parietal cortex and SMA it is possible that there were mirror neuron activation in these regions, since these parts previously have been found to be part of the mirror neuron system (Grafton et al., 1996). Further Lewis and Miall (2003) suggest that there are different systems for time measurement. The cognitively controlled, recruits prefrontal and parietal cortices. Accordingly, this is areas that were also found to be activated in the present study. Lewis and Miall argue that when directly attending to a timing task these areas, which they argue are flexible, are recruited. In this study the participants were instructed to imagine that they themselves were performing the actions they were watching. Thus, the results from this study when the participants were attending to the timing task, lend further support to Lewis and Miall's theory.

There was no significant difference in brain activation between the IM group and the control group in this pre-test. This indicates that the groups were equal in the beginning of this study. With a post-test as well it would be possible to investigate several interesting issues. For example if there had appeared a change in brain activation as an effect of the timing training in the IM training group. And also to find out if a possible change could be a change in mirror neuron activation as an effect of the timing training. During the timing training period the participants' themselves performed the same motor actions as the person in the movie cuts do. With a lot of repetitions of that same movement it is possible that mirror neuron activation develops. With a post-test it would also be possible to examine if there

had appeared a difference between the different tempos that were presented. In the pre-test there was no significant difference in activation between the different tempos. That may be an indication that the participants did not make a distinction between the different tempos while watching them. After timing training it might be possible to separate them from each other and that may cause a difference in brain activation. During the training period the basic tempo, the tempo that was presented most often, was 54 bpm. Because of this it may be possible that the IM group's brain activation would have changed for this tempo, and would be possible to discriminate from the other two tempos (42 bpm and 66 bpm). Further Kornysheva et al. (2010) found that preferred rhythm activates the motor areas more than non-preferred rhythm. After a four week period of IM training, with most of the training performed at a 54 bpm tempo, it is possible that the participants prefers this rhythm over the others. And this might cause activation in the motor areas for this tempo, but not for the other tempos. All these are matters that are interesting for future research were a post-test session of fMRI is possible to include. Also it would have been of interest to investigate if there would be a difference in brain activation depending on the participants' lateralization indexes. Comparing brain activation for the right biased participants, to the left biased and the participants without a preference, in relation to mirror neuron activation. It is possible that there would be a side difference in activation depending on the participant's lateralization. Unfortunately there was no time within the scope of this study to perform and include an fMRI post-test.

From the presents study's results it is interesting to note that the basal ganglia was not found to be activated during the watching of IM-based hand clapping tasks. The basal ganglia is a structure that previously have been found to be involved in timing (e.g. Cassidy et al., 2002; Nenadic et al., 2003). This might be depending on the fact that the stimuli in this study were in the millisecond range and the basal ganglia seem to mostly be involved in longer time intervals, in the range of seconds (Mauk & Buonomano, 2004). The cerebellum is another brain area that previously has been found to be involved in timing. But also this structure seems to lack activation in this study, even as the cerebellum has been found to be involved in millisecond timing (Buhusi & Meck, 2005). But in the same study Buhusi and Meck indicate that the cerebellum is involved in automatic motor control. This is not what was to be expected in the present study so that might be the explanation for the lack of activation in this brain area.

Gorman (2003) found that IM training can provide greater attention, mental processing and other cognitive abilities. Further Diamond (2003) concludes that using IM can be expected to increase the nervous systems efficiency and organization. It makes the brain's signal processing more efficient, and consistent. It seems likely that this is a possibility for the soccer players in the present study as well, since their motor timing and rhythmicity got improved as an effect of the timing training.

Limitations and future research

One limitation with the present study was that there was no time to include a post session of fMRI outcomes. It would of course have been interesting to see if there had occurred a change in brain activation due to the timing training in the IM training group, which is in comparison to the control group. Future research can also include a follow-up test to try to find long term effects of the timing training. With a long term test any permanent timing and rhythmicity changes can be found which was not possible in the current study. Another matter to consider is if and how differences in number of repetitions, types of tasks and tempos might affect the outcome differently. It is not clear from the present investigation what combinations that creates the most effective training. A reflection regarding the IM training is further whether better soccer specific (sport specific) tasks can be developed to better capture the appropriate areas that the participant actually wants to get better at. If the timing training includes more sport specific tasks it might be possible to better see if the training really can affect the participants' skills in their respective sport field. Though there is scientific support for motor learning even without motor training (Meegan et al., 2000). But still it would have been of interest to find out if more soccer specific tasks could have shown if the participants in the IM training group had improved their timing ability on these tasks, compared to the control group. It could also be of interest to so see if there is any improvement on soccer specific tasks as an effect of the timing training. Thus, by first testing the soccer players on some appropriate soccer tasks, for example cross-pass or shoot on goal, and then retesting them after the timing training period, it is possible to see if the training has any effect on something that has not been trained on, but is relevant for the athlete's performance. Becoming better at their actual sport is the real purpose, at least for the participants themselves. However this was not within the scope of this study. Finally, another consideration is how the presentation of the different beats during the fMRI affected the outcome. It might be of importance that the beats were only presented as videos without sound. During the IM training the participants listened to the different beats through headphones and got the feedback by audio. It is a possibility that the brain areas that are activated as an effect of timing differ depending on how the timing is presented to the person, if it is presented visually or auditory.

Conclusion

The present study showed a significant effect of SMT in form of IM training by means of improved motor timing in the elite female soccer players that received four weeks of training. It also revealed a significant decrease in the IM training groups variability compared to the control group, which is an improvement in rhythmicity. The timing training group significantly improved their highest in a row within ± 15 ms of the reference beat, compared to the control group as well. This indicates that the participants in the IM group improved their attention. An improvement in motor timing occurred after only four weeks of training. This implies that also other sport perpetrators or other healthy people might benefit from IM training to improve their motor timing and rhythmicity, and maybe also their sport specific abilities.

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