The Triple Code Model as a theoretical explanation of the effects of active mental practice in motor skills performance

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by

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Summary of Thesis submitted for PhD degree

by Jorge Heitor Carneiro da Silva Alvoeiro

on

The Triple Code Model as a theoretical explanation of the effects of active mental practice in motor skills performance

This project studied the Triple Code Model by Ahsen and how it can be used as a theoretical framework in the investigation of the effects of mental practice in motor skills performance.

The work is divided into four parts. The first part is a review of various theoretical models that have been used in explaining why mental practice can promote performance.

The second part is another review but of the areas where mental practice has been used. It pays particular attention to three areas: training, rehabilitation from medical surgery and execution of motor skills in games.

The third, is a collection of experimental work, using the framework of the Triple Code Model with active imagery, and it is divided into three sections. The first section looks at how table tennis strokes can become more consistent. The second section, at how rehabilitation and gait patterns can be affected via the Triple Code Model and active imagery interventions after remedial practice. The third section presents a new type of imagery modality instrument using high imagery keywords as stimuli. This

questionnaire was multi-cultural validated in two countries, England and Portugal.

The fourth part is a summary of what was found throughout the project with recommendations for further work.

The general conclusion of the project was that the Triple Code Model with active imagery is a promising framework in the learning or correction of motor skills performance, but that the imagery modalities of people should be identified before any mental practice exercise.

Contents

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Abstract

Until recently most models of mental practice, like the Symbolic Learning and the Psychoneuromuscular theories, have been unable to explain fully the evidence that mental practice can improve motor skill performance.

Recently, a new theoretical framework by Ahsen, under the title of the Triple Code Model, seems to be able to account for not only why mental practice affects motor performance, but also which components should be used during mental rehearsal in order to produce successful outcomes. This Model suggests that mental practice is made up of three components: The Imagery (I) of the act itself and the manner in which the individuals interact within the image as if they were acting in the real world; the Meaning (M), which refers to the way the performer understands how the motor skill should be done, and the Somatic response (S) the individuals have when they become aware of what is required of them.

In view of the fact that most work done on mental practice has been mainly in the areas of games and physical rehabilitation, the experimental work of this project also made use of these two areas in order to find out how competent the Triple Code Model is in explaining the impact mental practice can have in changing motor skills

activities. A review of present mental practice theories and work revealed that active mental practice, that is mental practice mixed with some of the actual movement activity, and interventions of periods of 3 minutes each, were the best procedures to use in the experimental work performed in this project in order to test the Triple Code Model.

The first two experiments tested whether accuracy of table tennis shots could be affected by active mental practice within the Triple Code Model context. These revealed a significantly greater accuracy and control of the ball in those participants using active mental practice than in control subjects.

Two further experiments, this time done in a rehabilitation context, investigated whether people who underwent arthroplasticity of knees could have their rehabilitation recovery modified via active mental practice in contrast with traditional rehabilitation procedures. The results from the first experiment showed that active mental practice provided a better progressive and continuous rehabilitation procedure than the traditional techniques. During this experiment visual analysis of gait activity, modified by active mental practice, seemed to indicate that active mental practice might also be able to modify the dysfunctional gait pattern resulting from the deformity of the participant's knees. A second experiment, this time a case study, using a dedicated and more economically affordable gait analysis system, confirmed the visual analysis of the previous experiment, in that active mental practice was able to correct distorted gait performance.

Throughout these four experiments the three components of the Triple Code Model seemed to be able to account for the results obtained with active mental practice. But, on the other hand, qualitative data obtained from the participants, in particular from those in the rehabilitation studies, seemed to show that the Imagery component of the Model needed to be refined in order to take into account the type of imagery modality people used during their imageries.

As most imagery questionnaires which claim to measure imagery modalities ask for imagery ratings of situations or objects which people may not have experienced a new instrument was developed which attempted to corrected this problem. This new imagery modality questionnaire used high imagery words as stimuli to activate people's imagery modalities and was validated using a criterion-related procedure in two languages and cultures, English and Portuguese. The criterion was motor skill performance, and the results obtained from both groups indicated that this new instrument to be sensitive in discriminating the modality people used during their imageries

To conclude, the experimental data gathered from the experiments in this project showed that the Triple Code Model is a good foundation as a theoretical framework in order to explain why mental practice affects human motor skill performance. It may be a more complete model than the ones used up to now due to its use of the three components - I, M, S. But the Imagery (I) component needs to take into consideration the imagery modality individuals are more likely to use during the activation of their imageries. This means that the Imagery definition provided by Ahsen should be changed to ' ... It represents the outside world and its objects so that the imagery modality individuals use in this interaction can determine the way they interact with the image as if they were interacting with a real world'.

Chapter 1: Theoretical Models

The use of imagery as a technique to learn new skills or to recall old information may be considered to be one of the earliest human skills. When we look at primitive paintings in a cave we have to subscribe to the idea that they could only have been done using imagination. Later on, in Greece, we come across Simonides (556-468 BC) who developed and taught imagery techniques as a way to recall stored information. The *'method of loci'* as it is now known, allowed actors and orators to remember their plays or their discourses by imagining associations between objects and keywords. An example for today could be a shopping trip to the local food shop. In order to remember what we want to buy we can imagine, at home, walking through the shop, and at same time imagine objects located in fixed locations, like freezers or tills, as being associated with the items we want to buy.

But the experimental study of imagery did not come into effect until Wilhelm Wundt (1896). He was the first psychologist to create a psychological laboratory where the main area of study was imagery, which at that time he called '*memory-image*'. For him imagery '*... is always suggested, whether by a sense-perception or a previous memory-image*' and that these two '*associate*' between each other. For instances '*... movement-sensations ... acquire an especial significance from the fact that the memory-image of a movement is apt at once to arouse the movement itself* (Wundt, 1912). That is there is an association between the imagery of a movement and the actual performance of the movement itself.

Wundt used introspection as the main research method, which according to him had to follow four basic rules: first the subjects have to notice what goes on inside their minds when unknown questions are presented to them. Second, subjects can not, at same time, become involved in a mental activity which requires strong attention and be aware of mental events going on inside their minds. Third, there has to be repeatability of the procedure a number of times with the same subjets and questions in order to protect the results obtained through the introspection procedure. Lastly, there can not be many variations of the questions to the subjects otherwise the experiment turns into a test of memory or recognition (Wundt, 1907). Thus, during an introspection experiment if participants were asked to describe a chair they would do so by contrasting the awareness they have about the object with the '*... idea aroused by it*' (Wundt, 1912). The procedure was repeated again but this time with another word of an object which had a similar shape like stool. Thus for him the whole introspection procedure was nothing more than the separation of the internal image of a stimulus and what the participant felt about it.

Not so for Titchener (1909), a pupil of Wundt, who claimed that any type of introspection, was intertwined with sensations which were connected with other ones. For Titchener, descriptions of an object would bring into consciousness images which had a certain quality, clarity and intensity. It was these sensations that the subjects had to brake down to their raw original state in order to find out what human thinking was like.

However, as pointed out by Pratt (1928), ' ... *Some of the ideias which accompany the act of thinking [or imagery] present sensory aspects. ... But there are persistent contents of thought [or imagery] which reveal no sensory stuff whatever*'. These controversies lead to strong disagreements between everybody studying imagery and so introspection as a psychological tool came under attack by American psychologists, like Watson (1913). For him the study of human behaviour should be restricted to what a psychologist could observe and analyse. What was important was the study of human reactions to specific stimuli, and then the examination and measurement of these reactions.

For a period of time imagery, and all its derivatives, were shunned and very few people even wrote the word in their articles, even though some of their descriptions, like fractional anticipatory goal responses of Hull (1931) or the cognitive maps of Tolman (1948) were nothing more than descriptions of imagery. Nevertheless, as European psychologists were very dubious of the behaviourist theoretical model they carried on with the study of imagery and some of them, like Piaget, used the concept of imagery in their work, as well as Bartlett (1932) in Britain.

As time passed, psychologists started to realise that behaviourism was unable to explain how people represented internally the outside world in areas such as language, reasoning, memory, thinking, attention and so research in cognitive psychology, which imagery is also one of the areas, was reawakened. Also, with the development of technologies that could measure human internal activity, like the electroencephalogram, the electrocardiogram, galvanic skin response and others, researchers again become interested in the study of the relationship between the brain and the body and what part imagery played in this interaction. This move started with a book by Miller, Galanter and Pribram (1960) and later on by Richardson (1969) which were among the first attempts to explain what imagery is and how it could be applied to the way motor skills were learned by people. Nevertheless the problem, which still goes on today, is over the interaction between mental and physical activities. This is because mental activities can occur in any environment without being subjected to physical laws. On the other hand physical events, like motor activity, have to obey physical laws. For instance, when a person says that he/she has pain in one part of the body which is not there, as in the case of amputees, it becomes rather difficult to explain such events using physical terminology. But this work does not dwell on philosophical explanations, like epi-phenomenalism, which declares that body activity can cause mental activity but not the other way around (Huxley, 1894), or the parallelism of Leibniz (1934), which supports the notion that physical and mental activities run in parallel, or even the more recent interactionism approach by Popper & Eccles (1977), which assumes that there is an interaction between physical and mental processes. Instead, the present project will assume that in order to acquire a motor skill a human being needs a mixture of automatic and controlled processing. This means that a person, when confronted with a new task, has to use controlled processes in order to learn how to perform it. But as the skill gets internalised and easier to execute, it becomes automatic and requires very little controlled processing.

Since the 1960's imagery has been used in the most diverse fields. Two of the most popular are as a technique to recall known information (Bower, 1972) or as remedial intervention in cognitive-behavioural therapy (Meichenbaum, 1977). In this project imagery, also known as mental practice, is going to be used as the major intervention people can use of in order to learn and/or correct motor skill activity.

This particular area of research has another problem in that people can use different terminology even though they all have the same meaning. As was pointed out by Shebar (1979) in cognitive psychology the type of language one uses is very important. Therefore, words like imaginary practice, or mental training, refer to the same topic under study, that of mental practice.

Mental Practice and Imagery

Suinn (1983) indicated that the covert act of practising an act mentally can take many forms. Generally it refers to the way people think, talk or describe to themselves the movement being practised. He said also that mental practice refers to the initial learning stage of a new motor skill with the aid of mental imagery rehearsal. On the other hand, 'psyching up' should refer to the moment an individual is mentally rehearsing the act when it is already known. In this project mental practice refers to the internal mental act an individual uses in order to rehearse a new or known motor movement or skill. This means that a table tennis player, when carrying out mental practice of a stoke, can imagine a mixture of senses like visual pictures, and/or the kinaesthetic impression of the movement, and/or any sort of auditory noise like the ball hitting the bat.

In describing the concept of imagery the tendency is to think of visual imagery. However, there are other types of imagery. It is possible to say that imagery events can be based on any of five human senses. Richardson (1983) defined imagery very clearly as ' ... *all those quasi-sensory or quasi-perceptual experiences of which we are self consciously aware and which exist for us in the absence of those stimulus conditions that are known to produce their genuine sensory or perceptual counterparts, and which may be expected to have different consequences from their sensory or perceptual counterparts'.*

This type of idea may be the first clue as to what imagery is like and why recent research, using modern brain analysis techniques, like regional cerebral blood flow (rCBF), magnetic resonance imagining (MRI) or functional positron emission tomography (fPET), has shown similar activated areas of brain during imagery as when the same person actually uses the senses or motor acts in real life. For instance, in a recent article by Le Bihan et al (1993), MRI techniques have shown that areas of the brain that are active during visual perception are also functioning during mental imagery of the same stimulus.

In another article, Goldenberg et al (1991) tried to find out if there was any rCBF difference between acoustic and visual imagery. They found that there was an increase of rCBF in the hippocampal and the right inferior and superior temporal areas of the brain during acoustic stimulation. Whereas during visual imagery the only significant increase was found in the left thalamic region.

The work done by Decety (1990,a) and her co-workers, on the other hand, may be considered pioneering because she was one of the very few who pointed out the importance of these new techniques in the understanding of imagery and its relation to motor behaviour. In another article Decety et al (1990,b) described an increase of rCBF during imagery of motor activity in brain areas that are thought to be related to motor activity. This research of Decety follows from early work done by Ingvar & Philipsson (1977), who were the first to measure rCBF during actual activity and during motor imagery. They found that their normal participants showed that their sylvian region of the brain had an increase in blood flow both during imagery and actual performance of an open-clench hand movement. So, the implication of this research, using such techniques, is that areas of the brain used during mental practice are also involved in actual practice of these same activities. This new evidence is also important because it seems to substantiate previous research which has indicated that mental practice of motor movements may affect the learning, correction and performance of new or old motor activity as implied in the definition of mental practice mentioned above.

Mental Practice and Motor Activity

An article by Vandell, Davis and Clugston (1943) may be considered the first to associate mental practice with the learning of motor skills. They cited two other articles, Freeman (1931) and Shaw (1939), which showed a correlation between muscular activity and mental practice. But the work of Vandell et al used three methods to teach two motor skill tasks: dart throwing and free throws of a ball to a basket. Group one only practised on the first and last day. In group two the subjects did physical practice throughout the whole testing period. Group three practised the task physically on the first day, and then used mental practice from the second to the antepenultimate day, and then used only physical practice in the last day of the testing period. In the dart throwing type of task they found that group one had a 2% decline in performance, group two improved 7%, and group three showed a 4% enhancement on the task performance. On the ball to the basket task, group one produced a 2% improvement, group two 41% and group three 43%. On a more mature group of participants, which may suggest a more experienced group of people at throwing darts, they found that group one type of intervention did not improve at all, group two showed a 23% improvement, and group three improved by 22%. They concluded that mental practice of the skills under study improved the physical performance of the participants to such an extent that it was as good as actual physical practice and that mental practice of a motor skill seemed to have a higher impact when it is done on a continuous basis as well as more influential at the end of a training period .

At this time Sackett (1935) also published a study on mental practice. But this experiment lacked the rigour of the study by Vandell because the mental practice was done without experimental control, as the participants in the Sackett group were asked to mentally practice the task in the evening away from supervision of the experimenter. It can be said that the subjects in the project by Vandell could have also mentally practised the task at home but as he did not ask for such activity his group of individuals may have been less prone to do any sort of mental practice away from the laboratory. Another major difference was that the task in the Sackett study was related to the learning and recall of a finger maze rather than the learning of a open physical skill task as in the Vandell project. Nevertheless, the results obtained by Sackett showed that those people who did mental practice of the task were more likely to memorise the maze than those who did not. An interesting finding from this study was that mental practice of this task performed once a day over a seven day period was more beneficial than three or more practice sessions a day. Sackett was unable to explain this effect as the experiment was not set-up in order to test such particularities.

Like anything that is new, and perhaps controversial, and as these experiments were done during the dominant period of behaviourism, most of these reports were left unnoted for quite some time. The next article referring to the effects of mental practice on motor skills was not published until 1949 by Twining. He wanted to find out if mental practice could influence the acquisition of a new motor activity.

The task for his experiment consisted of throwing rings of metal at a vertical wooden peg ten feet away. There were three groups performing similar interventions as those in the experiment by Vandell. The participants who were asked to mentally practice the task and simultaneously to become aware of all sensory sensations during the intervention had a 36.2% improvement in task performance but the group. The respondents who performed the task physically throughout the training period showed a 37.3% enhancement. The control group, which did nothing during the twenty two days of practice, had only a 4.3% improvement. From these results Twining concluded that *'...physical and mental practice are both means of facilitating the learning of motor skills'*.

Some qualitative data from this experiment showed that, after five minutes of mental practice, the individuals became bored in performing the mental task.

A whole series of experiments then followed. Among them was a study by Stell (1952). His article points out that most of the experiments on mental practice were done with very few participants. So Stell decided to use a group of sixty-five participants of school age in order to find out if mental practice could affect the learning of a motor skill task. In his conclusion Stell not only confirmed the results found by Vandell and others but may have been the first investigator to remark that *' ... the group doing this 'mental' practice is, ..., actively assisting the integrative action of the central nervous system and reinforcing the effects of reminiscence.'*

With this comment Stell may have been the first to point out that mental practice activated brain structures. This, in turn, may activate brain cell arrays which could allow the individual to recall, learn or perform a specific motor task.

Brain cells arrays is a term used in this project to refer to a grouping of brain cells which due to each particular mode of excitation may represent in the brain the object or the activity one is imagining. This idea is based on two theoretical models. One, is the '2½ *dimensional sketch*' theory of vision as explained by Marr (1982). He said that when light strikes the retina, it does so in different intensities. This light provides information to the brain, about the physical surfaces a person is looking at . This enables each brain cell to be activated in accordance with its specific feature as explained by Hubel & Wiesel (1979)

When each brain cell activates its excitatory state, it starts to develop axons which connect to other activated brain cells thus making a brain cell array recognition pattern of the object. That is, the brain cell array '*understands*' the orientation of the stimuli, but it fails to *'understand'* depth information, thus lacking the full 3D sketch.

One problem with this idea of brain cell arrays forming models of objects under observation is presented by Kosslyn (1983) who said that if there were such arrays, then rotation of an image of a known object should proceed at the same rate in a back to front or clockwise or counter-clockwise motion. This is because every face and corner of the object would be represented in memory. But, according to Kosslyn, this is not the case because it takes longer to do a back to front rotation as there is a need to retrieve from memory faces and corners which were not mentally visible during the rotation.

On the other hand, an alternative explanation, could be that, even though the brain cell array is in the brain, the person doing the rotation needs to activate its different intermediate states in order to have the full rotation. This idea has been supported by a study by Metzler & Shepard (1974) who found that when they flashed intermediate orientation rotated figures to subjects, there was no time recognition differences between the flashed intermediate figure and the whole rotated imagined picture.

The above interpretation on why brain cells arrays become active during imagery is, nowadays, becoming the most prevalent explanation on why mental rehearsal may affect or change the performance of a motor skill performance. Research cognitive psychologists who work in imagery, like Kosslyn, (1980) and connectionists like Trehub (1991), are using expositions based on such psycho-neurological data in order to explain how human imagery or mental practice can affect behavioural performance. Their research is showing that there are a number of brain cells arrays activating during imagery, which by interacting with different parts of the brain can have an effect in the control of motor activity.

Definitions and Theoretical Hypothesis of Mental Practice

The first attempt at defining mental practice and its effects on human motor performance was by Richardson (1967,a). He stated that mental practice involved the '... *symbolic rehearsal of physical activity in the absence of any gross muscular movements*'. Richardson added that, up to 1967, most articles that used mental practice interventions concentrated in three broad areas: on the *'acquisition'* of a new motor skill, on the *'retention'* of a movement, and also on those occasions where mental practice was used just before the performance of a motor task.

He also pointed out that most acquisition studies followed a test-intervention-test procedure. That is, each participant is tested on a specific skill, then does some mental practice, and then is tested again. As far as the subjects from the control group are concerned, they follow a similar procedure to the experimental participants, but rather than doing mental practice they are, usually, advised to perform intervening tasks like counting backwards, or thinking about something different, such as telling a story, or else reading a short text.

This review article by Richardson is particularly interesting due to the mention of mental practice work where the experimental groups did mental practice interspersed with physical practice, like the study by Whiteley (1962), who used three interventions. One group did physical practice only for ten minutes, the second mental practice only for the same amount as the physical practice, and the third group mental practice with physical practice. This last group was divided into two sets. One set of participants practised mental practice for a period of five minutes and then five more minutes of physical practice. Thus ten minutes in total. The second set did mental practice for ten minutes and then another ten minutes of physical practice. Whiteley found that the group with the shortest practices, that is the group that carried out five minutes of mental practice with five minutes of physical practice, was the one which improved best, followed by the one which mixed the physical and mental practice for ten minutes each. The group that practised physical practice only came third best, with the group that carried out mental practice only in fourth place.

Another important point mentioned by Richardson in this article was that people learning a motor skill improved also when they interchanged periods of resting with periods of physical practice. Nevertheless, it is unclear as to what the participants were thinking in the rest periods. The Buxton (1942) study, for example, stated that those who thought about past performance improved. But he did not enquire as to whether the people were mentally practising the task, or using any sort of imagery interventions.

In relation to the effects of mental practice on retention of motor skills Richardson refers to two articles. The first one was the study by Sackett, as described above. The second one, by Rubin-Rabson (1941), deserves some close attention because it involves mixing physical with mental practice and also uses set periods of 4 minutes of mental training. The procedural set-up for this experiment consisted of three groups of skilled pianists. One group did five physical practice trials, followed by four minutes of mental practice, followed by physical practice of the task until there was no performance error. The second group did just physical practice throughout the whole period up to errorless criterion followed by four minutes of mental practice. The third group did physical practice up to the errorless criterion followed by another four minutes of physical practice. Rubin-Rabson found that the skilled pianists, who used the first procedure, showed better retention of the learned piece of music than any of the other groups, even though they all learned the music task up to errorless level. Nowadays, with the knowledge we have about brain activity as measured by the new brain scanning techniques, it may be proposed that the first five physical practice trials in this experiment may have given to the brains of these pianists the points of reference they needed in order to construct the brain cells arrays which were then further reinforced during the mental practice. The connections of these cells could then have been further strengthened by the physical performance up to the criterion level. But at this moment this suggestion is still rather speculative as there is not enough information to substantiate such brain activity.

With reference to mental practice just before motor performance, Richardson cites two articles. The first was an unpublished dissertation by Waterland (1956) which compared physical practice with mental practice. In the physical practice group the participants just followed standard bowling action practices, whereas in the mental practice group they were asked to mentally practice the task and recall the *'feel'* the movement as experienced during mental practice just before the ball was thrown down the bowling alley. The results indicated that the mental practice group not only showed an higher score but their movements were much smoother and faster. The second study by Abelskaya & Surkov (1959), asked high jumpers to mentally go through the action of jumping before taking off. The study showed that those that did this sort of mental practice improved their jumps in comparison with those who did not do this type of intervention. Nevertheless, Richardson pointed out that the sample for this experiment was very small, two subjects for each group, and that the observed improvement was not immediate as it took some time to become noticeable. At the end of this section the article by Richardson finishes by saying that '... *it may be that MP procedures derive part of their value through establishing an appropriate set to the task'*. From this statement it looks as though he was already becoming aware of the importance of knowledge of task demands and their relevance to mental practice execution.

In this report, Richardson also reviewed those projects which concentrated on individual differences. All the 10 variables under study showed a mental practice effect. The ones that showed most mental practice effect were abstract reasoning, games ability, intelligence, selective attention and quality or controllability of imagery. This last one is perhaps the variable that deserves special consideration. This is because a study by Start & Richardson (1964) found that those subjects who measured high on both vividness and controllability of imagery performed better than subjects in the other conditions.

It may be appropriate to point out that the idea of controllability is closely associated with optimal length of time for mental practice. This was, in fact, one of main points that a number of delegates who attended the 8th World Congress in Sports Psychology (1993) raised. As already pointed out above, if a person does too much mental practice one may become bored. One of the clearest studies on this idea was done by Schick (1970) on women performing a range of volleyball skills which indicated that a 3 minutes of mental practice was effective in enhancing their performance.

Theoretical Hypothesis of Alan Richardson

In his second article, Richardson (1967, b), tried to explain why people applying mental practice to motor skill tasks improved. He cited two types of interpretations: a symbolic learning and his psychoneuromuscular explanation.

For the symbolic learning Richardson cites the work by Sackett (1934, 1935) and Perry (1939). Sackett, in fact, declared that the improvement of the motor skills after mental practice could occur mainly on '... *those skills in which a symbolic control of movements is involved, ... It seems doubtful that there is this control in the case of such skills as ball tossing and mirror drawing.'*

This theoretical model will be discussed at greater length later on but it may be relevant to point out that the open skills, as mentioned in the above quotation, and used in the study of Twining (1949), are also improved after mental practice interventions.

The conclusion proposed by Richardson in relation to the symbolic learning explanation was that when a person is learning a motor task there has to be a mixture of '... *symbolic, perceptual and motor components... All motor learning, as distinct from motor action is perceptual-motor learning'.*

This is what psychoneuromuscular theory is about. For Richardson, the study of mental practice should be directed towards perceptual-motor tasks, like throwing darts, a ring or a ball to a target. The participants should have vivid and controlled visual and kinaesthetic imagery of themselves when they are throwing the objects to a visually imagined target. As the participants do this type of imagery, there will be '...

minute, inervations of relevant muscles.' Thus, as far as Richardson is concerned, it is this kinaesthetic feedback from the mental practice, that is, the awareness of the movements and position of the body coming from voluntary muscles of the body, that enables people to identify the position of their bodies in space. This physical recognition state may facilitate the activation of stored visual images of the movement. This sort of information could then be used by the person during mental practice thus enabling correction of the motor action at the next imaged motor act. As the person becomes more accurate at the execution of the motor act, co-ordination and performance are facilitated.

The explanation just given is the one most frequently cited in discussing the theoretical model of Richardson. However, Richardson goes on to state that all experiments based on his model are dependent upon four classes of independent variables: '... *clarity and control of visual and kinaesthetic imagery, magnitude and location of muscle action currents, accuracy of anticipated outcomes and degree of task familiarity.'*

These four variables are very similar to the Triple Code Model by Ahsen (1984), which states that imagery is a product of three parts: the Image, the Somatic response and the Meaning of that image. For Image, Ahsen explains that '... *It possesses all the attributes of a sensation but it is internal at the same time. It represents the outside world and its objects with a degree of sensory realism which enables us to interact with the image as if we were interacting with a real world.'*

This explanation can very easily be applied to the '... *clarity and control of visual and kinaesthetic imagery...'* variable of Richardson.

For the Somatic response, Ahsen said that it corresponds to the psychoneurological changes in the body, that is, skeletal, proprioceptive and/or kinaesthetic activity or internal body functions, such as heartbeat, which coexist with the imagery of an object or action. A very simple example would be in situations where a person is imagining stroking a dog he/she may imagine the touch responses produced by the texture of the fur of the dog on the skin of the hand. Again, this idea is partly similar to the second independent variable of Richardson which stated that there should be '... *magnitude and location of muscle action currents...'*.

Lastly, the aspect that some people have pointed out as being unique in relation to the Triple Code Model and that has been ignored by the other models, like Murphy & Jowdy (1992), is the meaning the image has to the person doing the imagery. For Ahsen every image has an unique meaning or significance to an individual. When a person tries to explain a certain imagery event to another individual, the imagery process of the person describing the event will never be the same to the other. This is because each individual brings his or her unique history or experiences into the imagined process. Again this explanation could also be used for the '... *degree of task familiarity.'* independent variable of Richardson.

These two last variables may also be linked to another recent theoretical model which attempts to explain how imagery can affect human behaviour. The bio-informational model of Lang (1979), as it is called, uses information-processing explanations. This model proposes that there are two sort of languages during imagery. Stimulus propositions, which refers to language which people use in order to describe an activity and which can affect their understanding of the act. For instance the description of the way a table tennis stroke is performed. The second type, response propositions, is language used in describing the way individuals can respond to imaged environments. For example the type of language used in imagery scripts which orients individuals to imagine physiological responses such as the feeling of leg muscles during running, or the pressure of the keys on a keyboard during touch typing. All these statements are already stored in the brains of people, which are used during actual behaviour. These two types of responses are fundamental to the model of Lang. For example, an experiment by Lang, Kozak, Miuer, Levin, & McLean (1980) found that subjects were able to evoke stronger physiological responses when imagery descriptions were full of response propositions than descriptions of imagery which contained many stimulus propositions. Instructions which contain stimulus propositions directed the attention of their participants towards the clothes they were wearing, their colours, the people around them and so on. Whereas response propositions oriented the person towards the feelings of the body, like leg muscles, the pressure of the clothes on the skin, the feelings coming from the feet resting on the floor and so on.

The importance of the language people use during performance and mental practice of a task has also been emphasised by Paivio (1985). He, rather than describing his ideas as the influence of language structures on task performance, stresses the familiarity of tasks which, according to Paivio, is dependent upon the type of language used during the performance of the task; what can be remembered, and also what is known about the task. For instance, in tasks that have moving targets it is important to know, or have some means of predicting, where the target goes to. Even within moving targets there are tasks where the performer is stationary, like baseball or cricket, but in football, tennis or hockey there are moving targets and moving performers as well. That is, they are total open skills activities On the other hand, there are tasks which do not require the performer to react to specific targets, like running, gymnastics, weight-lifting and so on. More akin to close skills tasks. These sort of tasks may be much easier to mentally practice than tasks that have moving targets and performers. From this explanation it looks as though Paivio follows a symbolic learning theory perspective because this theoretical model seems to predict that mental practice will be more effective in closed skills activities.

As far as language is concerned, Paivio pointed out the importance of how language can orient or instruct performers during mental practice. This is fairly clearly demonstrated in some experimental work which instructs people to do tasks that may be detrimental to their performance. This type of work urges subjects to use mental practice in order to produce poorer performance of the motor activity under study.

There are relatively few studies which show that mental practice of negative outcomes can produce wrong performance. Nevertheless, studies like Powell (1973) and Woolfolk, Parrish & Murphy (1985) clearly show that imagery can produce negative effects. The study by Powell compared two kinds of mental practice, negative and positive, in which two groups of subjects imagined poor and good performance respectively, in a dart throwing task. He found that those who did positive mental practice were significantly more likely to get better results and task learning than those in the negative mental practice condition. Powell stated that those who performed negative mental practice '... *led to no improvement at all, with even a slight negative trend'*. He actually thought that there would be some improvement from the negative mental practice mainly due to the '... *experience of actual throwing'*. But even this small physical practice seemed to be displaced by the negative mental practice exercise. One comment that can be made to this experiment is that the mental practice intervention could have changed the expectations of the subjects during actual performance. If this was the case just the innate intent of throwing good darts during actual performance should have changed the goal of the mental practice. But it looks as though this was not the case. The negative mental practice procedure seemed to be strong enough to carry on to the actual performance thus creating inferior performance.

The Woolfolk, Parrish & Murphy study used a similar procedure as the Powell study but their participants were required to putt golf balls into a cup 8.5 feet away. They found that those who carried out positive mental practice had a 0.4% improvement in their performance from a baseline of 5.2 successful putts out of 10. Whereas the negative imagery group showed a 21.2% decline of their accuracy from a similar baseline to the positive imagery group.

With regard to the role of memory during mental rehearsal, Paivio pointed out that those people who are highly skilled may have more difficulty in improving their performance if they do not change their type of language, orientation or methodology. With these skilled people the use of film or video to point out problems and possible corrections, could be interspaced with mental practice so that the performer can become aware of any inaccuracies in their performance and so change the mental practice exercise accordingly.

For those performers who are just learning a new skill, as Minas (1980) has pointed out, the use of mental practice may be very ineffective in tasks where performers have no idea of what to do. On the other hand if this new task has some known movements, mental practice may have some effect as this scanty knowledge may provide some hints on how the skill should be performed. Thus, the subjects, even though they do not have a complete mental model of the task itself, nevertheless, can make use of what they already know in order to create or develop a new one. For instance, research by Corbin (1967a, 1967b) has shown that some experience of the task is necessary when doing mental practice interventions. In his first experiment, Corbin tested 120 subjects on the use of mental practice on the learning of a new motor task. He found that mental practice was useful only when those using it already had some previous knowledge of the task itself, and that this type of intervention was most effective when combined with overt practice.

In his second study Corbin used a questionnaire in order to find out impressions of participants when they were using physical and then mental practice in comparison with just physical practice. He found that all subjects, but one, did find a greater self-esteem level after practising mental rehearsal, and this was an important factor in improving the task performance. They also reported that they were more successful when they performed a mixture of physical and mental practice than just physical practice. After this experimental work Corbin suggested an overall conclusion on the use of mental practice. He said that: ' ... *Mental practice seemed to be better utilized when based on experience and when actual practice preceded performance of the skill.'*

Finally, the fourth independent variable proposed by Richardson, the '... *accuracy of anticipated outcome...'* is, in fact, one that very few people have evaluated or described in their studies. In it, as was already mentioned, Richardson declared that the ' ... *accuracy of anticipated outcomes should correlated with task familiarity'*, that is the more familiar the participants are with the task the better they are at predicting what comes next during performance of the task. This may enable faster learning and probably the reduction of *'on the job'* type of training. Work by Vartiainen, Teikari & Poyhonen (1985) found that those subjects who did mental practice during their learning period produced significantly fewer errors than the control group in particular during the last training trial. They concluded by saying that the group of people who did mental practice ' ... *had better internal models and thus a better image of the goals* *and the strategies to reach it. They could plan their work better, because they had more free cognitive capacity in their use ... Learning is thus made steadier. This increases safety in two way: first, there are less accident-prone situations because of training outside real work, and second, as a result of this training, anticipation makes the working methods of a trainee safer'.*

This article is the only one up to now which tested this specific suggestion of Richardson.

Critique of Richardson's Hypothesis

One comment that most people who subscribe to the symbolic learning model (Murphy 1990, 1992, Feltz & Landers 1983), and also observed by Richardson, is that the reason individuals who use mental practice combined with physical practice are superior to those using physical practice is because during the imagery period the participants are resting. Fitts & Posner (1967) said that to develop a motor skill much faster, frequent physical rests should be introduced during training. It may, in fact, be fairly difficult to perform an experiment in order to find out if physical resting periods have the same effects as mental practice interventions. Current technology cannot reveal cognitive activity, such as thinking or recall of specific activity, during physical resting periods, and mental practice of a task can occur without people being aware they are doing it. Thus, until such technology is available, the research on mental practice will be under the shadow of ambiguousness and on the fringe of cognitive psychology.

On the other hand, there is some important research which does provide some insight as to whether mental practice is more than simply providing physical rest periods during motor skill learning. For instance, McKenzie & Howe (1991) performed an experiment to find out the effects of mental imagery practice on tackling skills in rugby. They found that a mixture of physical and mental practice was the most effective training method. A post-hoc analysis of their results also showed that, overall, those subjects who thought that mental training could improve their tackling performance exhibited a significantly greater improvement than those that were less likely to think that mental practice would have an effect on their performance. This finding could substantiate the idea that mental practice is more than a spaced resting period because those who were sceptical about mental practice, even though requested to do mental practice, may have not done so, or may have imagined something unrelated. On the other hand another explanation for this result can be provided by the self-efficacy theory of Bandura (1986). He stated that there are three dimensions in the measurement of self-efficacy. First, there is the *'level'*, which refers to the amount of success the performer expects to achieve during performance of the task or skills. Second, the amount of confidence, also called *'strength'*, the individual has in achieving the type of performance in mind. Lastly, *'generality'* which relates to the number of other disciplines the performer feels confident with in being successful. So, going back to the work of McKenzie & Howe, it may be said that those who were less self-confident in the use of mental practice as a good strategy in the learning of motor skills could have a lower *'level'* and *'strength'* certainty in this technique than the others in the group. This set of thinking can provide an explanation as to why there was lower desire to use mental practice, but would still not indicate whether mental practice was less efficient at improving the skill under study, as these people did not perform the mental practice of the task as the other individuals in the investigation.

A more recent study by Kohl, Ellis & Roenker (1992) actually tested the effects of rest *(silent reading)* and physical practice versus physical practice and mental practice on the acquisition and retention of a pursuit rotor task. As far as acquisition was concerned they did not find any significant differences between actual practice and the actual practice with imagery. These two interventions were nevertheless superior to the group which did physical practice with rest. In relation to retention, they found that alternating physical practice and mental imagery was superior to any of the other groups. This means that during those periods where the subjects did mental practice they were not just resting but were actually activating their mental learning processes as when during the actual practising learning periods. The mental practice intervals reinforced or had an effect like actual training.

Another interesting study was done by Cooper (1985). She wanted to find out if those who did mental practice with physical practice were more likely to retain a learned gymnastic skill than those who did just physical practice of the same skill. She found that two years after the initial learning skill experiment, those who had gone through the mental and physical practice interventions had higher retention scores of the gymnastic skill than those who did just physical practice. Thus suggesting that the combination of mental and physical practice have a longer decay period.

Another study by Crocker & Stortz (1982) analysed the effect of mental practice on storage of a motor skill in long-term memory. Their rationale was that if mental practice of a skill is prevented, there should be poorer storage of movement information in memory than when mental practising is allowed. Crocker & Stortz found that the mental practice group showed a superior retention of movement skill than the no-rehearsal, as well as the blocked-rehearsal interventions.

The Crocker & Stotz article relates to findings found in contextual interference effects (Batting, 1966) and mental practice. This particular effect in learning suggests that if subjects, in a practice session, practice a series of skills in block, that is practising the skills in a sequential manner, it will lead to a faster learning of the skill. On the other hand if the order of the skill is randomised the learning process becomes longer but there is a higher retention and positive transfer effect of these skills. One of the first studies to test the contextual interference hypothesis was by Shea & Morgan (1979). They had two groups of subjects practising three different tasks within a predetermined sequence. One group practised the tasks in block. That is, all tasks of condition A were done before going into task B, which was completed before going into task C. The other group practised the trials of the three tasks in a random sequence. Thus they both had the same amount of practice, but they only differed in the order in which the tasks were presented. They found that, at first, during the acquisition phase, the subjects who did the blocked sequence were more effective in their performance than those who performed the random sequence. Nevertheless, 10 days later those people who performed the random sequence during the acquisition phases, could remember more than those from the blocked group.

As far mental practice is concerned, could a similar effect be found in the acquisition and retention of a motor task in the same way as found in a random physical practice? In order to answer this question, Gabriele, Hall & Lee (1989) carried out a study where four groups of subjects did four patterns of arm movements each. Each one differed from each other only in their spatial composition. Even though each group did physical practice interpolated with mental practice, they differed in that one group did blocked physical and blocked mental practice, another random physical and blocked mental practice, another blocked physical and random mental practice, and the fourth group did random physical and random mental practice. Two experiments were undertaken by these authors. In the first one they investigated if random mental practice produced a similar effect on acquisition and retention as found in random physical practice. Gabriele et al found that as far as acquisition of the task was concerned, physical practice had a greater effect on the learning of the task than mental practice. They also found that all those groups who used some form of blocked physical interventions reached the criterion level in fewer trials than any of the other interspersions. As far as an imagery effect was concerned, the trials which used a random imagery had their most disruptive impact on the trials which were interpolated with blocked physical practice. According to Gabriele *et al* this result may indicate a strong dominance of cognitive role over motor activity. This finding is very significant because it can provide further support for the outflow - inflow hypothesis discussed later. In relation to retention they found that the group that did both random physical and random mental practice, produced better retention of the tasks than any of the other groups.

They also tested the effects of scores from high imagery versus low imagery subjects. These scores were obtained by their subjects filling in the Movement Imagery Questionnaire (Hall & Pongrac, 1983). It was found that there was no difference between the two on an immediate retention procedure, but on the delayed one, the high imagery subjects had better retention than low imagery subjects.

In the second experiment, Gabriele et al investigated the benefits of random mental practice in comparison with random physical practice. They also wanted to throw some light on what type of processes were used by the subjects during the first experiment which facilitated retention. Lastly they wanted to find out why interference introduced during acquisition in a random practice sequence did not depend upon similar tasks.

They had five groups. A blocked physical practice group, a random physical practice one, another random physical practice but with rest, a random physical practice with similar mental practice, and the last one was random physical practice with unrelated imagery practice.

For acquisition they found that the blocked group required fewer trials, followed by random practice with rest, then random practice, then random practice with similar imagery, and lastly random practice with unrelated imagery.

For retention, with a delay of two weeks after the initial testing intervention, the best condition was random physical with rest, followed by random physical with similar imagery practice, followed by random physical practice, then by random physical with unrelated imagery, and lastly the blocked physical practice.

These findings not only supports the above study by Kohl et al, but also that it is important to know what the subjects do during rest periods. This is because the participants during the resting periods in this experiment may have been doing some form of mental practice. That is, the group that did random physical practice with a rest interval showed similar high retention scores as the group which did random physical with similar imagery practice. In contrast the group with unrelated imagery practice got a lower retention score.

The conclusions proposed by Gabriele et al for this second experiment were that unrelated random imagery interventions could cause as much interference as random physical practice. Also that the benefit of random physical with similar imagery practice in retention was as good as random physical activity.

The Symbolic Learning Theory

The symbolic learning theory by Sackett (1934,1935), also known as symbolic perceptual hypothesis (Denis, 1985), is still referred to by some researchers, like Murphy (1990), but fewer authors now cite this theory. The theory is mainly based on two propositions. First, it is based on the idea proposed by Fitts (1962) who declared that, in the early stages of learning motor tasks, people use mainly cognitive procedures. He declared that when people are learning a new skill they have to go through three phases. First, a cognition phase which is characterised by analysis and verbalisation of the skill being learned. This phase consists of being aware of what is required to do during the motor activity, and what sort of errors people usually associated the task with. Secondly, a fixation phase, which refers to actual practice and continuous correction until the skill is performed without any errors. Finally, the autonomous phase, which involves an increase in the speed of performance and hardly any errors. This phase shows also that people are able to do the tasks without too much interference from any outside interference. Fitts goes on to say that neurological evidence at that time showed that, during this stage, people start to be more dependent upon their proprioceptive rather than their visual feedback, and that the lower part of the brain takes over the control of the acts. As the next section of this chapter will show, this suggestion is not completely correct, in that the area of the brain which controls motor activities, like the pre-motor and the supplementary motor cortex, is still involved even after individuals know how to perform tasks quickly and without errors.

The symbolic learning theory has also indicated that mental practice has its greatest effects during the early stages of learning a motor task. But, as the studies by Corbin described in the previous section have shown, such an effect is not confirmed.

The second, and perhaps the most important, suggestion is that mental practice is most effective in activities which have a high cognitive content and close skill. This notion has been mainly supported by the influential meta-analysis study by Feltz & Landers (1983). Their main conclusion was that the effects of mental practice were ineffective in open skills and absolute motor tasks than in symbolic activities because on the former they were like '... *digit substitution* ' which they summarised as '... *cognitive solutions to the unique requirements imposed by the task before the correct motor response can be executed'.*

Nevertheless, recent research, based on the symbolic learning theory has shown that the cognitive content of a motor skill can be influenced by mental practice, but not to the extent as was purposed by Feltz & Landers. At a recent Congress of the North American Society for the Psychology of Sport and Physical Activity a paper presented by Kim, Radlo & Singer (1994) stated that the effects of mental practice were more significant on tasks that contained motor elements. In a follow on from this first experiment they found that in a comparison of high level, median level and low level cognitive demand tasks the retention scores for the subjects in the low and median level were enhanced with mental practice. The subjects in the high cognitive demand task did not benefit from mental practice. The authors concluded by stating that '... *The* *present studies do not support the symbolic learning theory, that performance in tasks having a high number of cognitive elements are enhanced more with mental practice than those containing a greater number of motor elements.'*

The Outflow <-> Inflow Hypothesis

The latest research that investigates physiological activity of the brain during imagery has recently reported that mental imagery is due to both a form of the symbolic learning conception and psychoneuromuscular theory. The claim is that the findings from this research show that the success of mental practice is based on a mixture of an outflow system, in the same lines as the symbolic learning theory, as well as an inflow, similar to the psychoneuromuscular theory.

One of the most respected researchers who advocates this idea is Decety and her co-workers. Decety & Ingvar (1990) explain that the neuropsychological hypothesis seeks to explain mental imagery of any activity by using neural brain structures as the main factor of information processing. They declare that in order to explain the reasons why ' *mental simulation of movement* ' affects motor performance, people have to include not only the *'top-down approach from cognitive psychology'*, equivalent to the symbolic learning theory, but also the ' *bottom-up approach from neuroscience* ', derived not only from the psychoneuromuscular theory but also from psychophysiological research. But then the article becomes rather less clear as they declare that '... *mental practice seems to be more efficient for skills which do not require a permanent sensory feedback information like athletics, diving, swimming, gymnastics, which rely primarily on a so-called outflow processing, i.e. a skill which emanates from the brain and follows a preplanned complex motor sequence'*

With this statement Decety & Ingvar seem to imply that there is *'closed skill'* perspective very much in line with the symbolic learning theory as discussed in the previous section.

In the same year Decety & Boisson (1990), published another study which reached a similar conclusion. They timed mentally executed movement activities of patients with gait problems. Their findings were that the hemiplegic patients, that is patients with paralysis of one side of the body, showed a significant increase in the amount of time they took to perform a task mentally than either tetraplegic or paraplegic and normal subjects. Their main conclusion was that their' *...observations are compatible with an outflow processing underlying motor imagery'*. So the question then is where was the *'inflow processing'*?

In order to try to answer this question, there is a need to examine more carefully this report by Decety & Boisson. This article described also the verbal reports given by the subjects during the performance of the task. All the patients declared that they had experienced some effort in imagining the movements. In fact some of the hemiplegic participants said that they felt they were falling at various times when they were imagining hopping around the room. These qualitative reports could denote that these patients performed their imagery interventions in accordance with what the state of their bodies allowed them to perform. If so, it seems reasonable to speculate that they obtained different kinds of information from their bodies during the execution of the task, and this was probably due to the different genre of inflow information coming from their muscles and movements.

As was discussed above, in Gabriele et al's first experiment, the random imagery condition was more disruptive during the blocked physical practice. This result, in accordance with the outflow - inflow hypothesis, could indicate that the inflow of information coming from the sensory motor areas was not the same as the mental imagery practised during the intervention. Also, as was pointed out, during the second experiment those people who did random physical practice with rest intervals, had the largest retention score probably because they did some correlated mental practice. That is, as far as the present model is concerned, the inflow of the physical practice was in agreement with the outflow of cognitive procedure. Thus, the verbal reports of the participants in the Decety & Boisson's study, which corresponds to the '*outflow processing*', seem to indicate that there was '*inflow processing*', coinciding with the difficulty in individuals performing the task, which these authors seemed to fail to point out in their discussion.

A more recent report by Jeannerod (1994) does point out that motor imagery relates to the representation of a person in action, '... *with the subject feeling himself executing a given action, whether this involves the whole body ... or is limited to a part of it*'.

This representation is not just external but internal as well. For instance, when performers are learning a new movement, the course of watching the act itself allows the creation of internal imageries, even though they are not executing the motor skill. Also, just the act of observing a person performing any motor task, seems to induce physical feelings in the observer, which appear to aid the perceptibility of the mental imagery.

This process of internal representation when a person is watching an activity is based on some animal research performed by Di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolati (1992). They found that a group of neurones in the rostral part of the inferior pre-motor cortex of a monkey tended to show increased activity before and during a precision grip movement. This discharge is related to the act of the hand movement and not to the side or orientation of the hand. They also reported that these same neurones fired when the monkey saw one of the experimenters doing the same movement.

A rather similar experiment has also been performed in humans. Jowdy & Harris (1990) tried to find out the relationship between muscular responses, as measured by the EMG, and skill level of jugglers. They proposed that the higher the skill level of these participants the higher the muscle activity during mental practice. They found that the measures taken from the biceps of both high skilled and low skilled did not show any differences. Nevertheless, based upon just observation they noticed that , the high skilled jugglers used less movement variation and they also used different muscles in comparison with low skilled jugglers. The latter tended to flex their forearms and make use of their biceps more to juggle. In contrast the high skilled tended to use their wrist flexors more.

They also asked their subjects to describe their experiences during juggling.

The content analysis done on the verbal reports of the participants, showed that some of the higher skilled subjects claimed that they saw the '... *balls in front of them as opposed to feeling their arms move and the balls contact their hands'*. On the other hand, the low skilled subjects found the imagery technique effective helping them learn and perform the motor skill. As one subject put it, '... *It makes me want to follow the imagery. It's like copying the image so that I maybe can do it without having done the activity'*.

Overall, the jugglers who preferred visual modality mental practice, that is those that used visual imagery during their mental practice, also showed that their EMG gain from resting state was lower than the subjects who reported that they could not see clearly the balls but could feel their arms moving. This could indicate that there may be a close association between the modality they used during their imageries and the way the participants mentally rehearsed the task. So that those who were aware of their movements in space, kinaesthetic activity, would exhibit a higher EMG gain than those who were stronger at visual modality.

A more recent study performed by Yue & Cole (1992) cited evidence which shows that the strength of a muscle increases very rapidly just before it is exercised, as can be clearly measured with the aid of EMG analysis. This EMG measure is also accompanied with an increase in muscle reflex, with the greatest increase of strength localised on the trained body joint angle. But, as was described by Sale (1986), the training of that joint is also correlated with an increase in strength of the contralateral untrained muscle. The explanation for this effect is that '... *early strength gains may depend on changes in the central programming of a maximal voluntary contraction'.* This implies that whenever people make a new movement using a particular joint action, there will be not only an increase in local muscle tissue but there will also be an increase of brain cell interconnection which can be related just to the performance of the movement. The results of Yue & Cole's experiment showed that the group that just imagined the movement increased its abduction force by 22% from the initial stage. The group that performed physical contraction training only had an increase of 30%. The mean increase for the control group was just 3.7%.

An interesting finding from this project was that even those joints which were not receiving direct mental practice did, nevertheless, show an increase in their maximal abduction strength. They found that there was a significant increase in the abduction force in the untrained joint of 14% for the contraction trained group, and of 10% for the imagery group. Whereas the control group just show a 2.3% increase.

These results possibly imply that imagery practice of a movement can affect the development of hypertrophy of muscles. This could suggest that even though there is hardly any EMG activity during mental practice, the small amount produced by the muscle during the intervention may increase some form of muscle strength from its initial stage.

The explanation for these results given by Yue & Cole was that mental practice of the movement affected the '... *programming or planning levels of the motor system,* *most likely involving nonprimary cerebral cortical motor areas'*, like the basal ganglia, whose principal function is the development of movement co-ordination and cognitive functions, and the cerebellum, whose function is to turn slow, recently developed movements into rapid and well-practised acts (Kalat, 1992). This is clearly almost like saying that there was an outflow system processing. An inflow system processing may be implied when Yue & Cole say that Roland, Larsen, Lassen, & Skinhoj (1980) have noticed that when their subjects imagined a sequence of finger movements there was an activation of the supplementary motor area. This area tends to respond to activity which has sensory information, as was suggested by Roland (1984).

This explanation also implies that, if the mental practice of the activity is performed from an internal point of view and with some of the actual movement, the learning or correction of the movement would be reinforced in every possible way. The subjects would be performing an internal orientated imagery process, which would produce a sensory response. These two would be reinforced with the actual activation of the muscles, suggesting that the learning process of the movement would be highly concentrated and dynamic.

In order to substantiate the above explanation, research has to be found which shows sensory differences between internal and external oriented type of mental practice. This type of work was first introduced in a study by Mahoney & Avener (1977). In this study they found that, in a group of the highly skilled gymnasts, those who were selected for the Olympic team reported a high frequency of internal type of mental practice. Those who were not selected did more external imagery. Mahoney & Avener explained that '... *in external imagery, a person views himself from the perspective of an external observer ... Internal imagery ... the person actually imagines being inside his/her body and experiencing those sensations which might be expected in the actual situation'*.

Thus, the external imagery is in fact a visual type of imagery, very much like watching a movie. In internal imagery the modality can be predominantly kinaesthetic because the person is rehearsing the task from an inside body point of view, that is feeling the movement. Since this study most studies that investigated this area of mental practice showed a mixture of support and failure for the internal type of mental rehearsal. For instance a study by McFadden (1985) on hockey goaltenders found no difference between the groups that used internal or external perspective mental practice. On the other hand, a study by Mumford & Hall (1985) on novice and senior skaters found that the group that did internal visual and the group that did external visual demonstrated the least amount of improvement, whereas the group that did internal kinaesthetic imagery showed the most improvement. They also found that senior skaters were better at kinaesthetic imagery than novice. These results could imply that modality used by these individuals may be more relevant for the performance of the tasks than imagery perspective.

On the other hand it could also be that the way an individual performs mental practice is dependent upon the type of task a person is executing. For instance, a study by Jowdy, Murphy & Durtschi (1989) suggested that imagery perspective changes during mental rehearsal. In a run, the performer sometimes orients his/her viewpoint to what happens outside him/herself, but then changes to an internal orientation to check if his/her body is all right. Thus, each mode of mental practice provides different types of information which in term depends upon the type of mental rehearsal orientation of the individual. This then could mean that, during the performance of an activity, the way mental practice is performed can change in accordance with the type of information the individual is trying to get at.

As far as active movement mixed with mental practice, that is performance of , if not completely, some of the motor skill a person is trying to change with the mental rehearsal of that same movement at the same time, the studies are even harder to find. This may be due to the original definition of mental practice, as defined by Richardson. As was mentioned above, mental rehearsal should be done without any active movement. Nevertheless there are some studies which used simultaneous physical and mental practice. One of those was a pilot study by Meyers, Schleser, & Okwumabua (1982), which tried to find out if a combination of relaxation, visualisation with physical performance could affect two women basketball players who have been having problems with concentration in free throw shooting situations during a game environment. In order to find out if the difficulties the participants were experiencing were due to game situations or to the actual performance of the movement, Meyrs et al compared the percentage of good free throws during practice and during game appearances. They found that during practice these subjects had a rate of 75% good throws but only 40% during games. These two subjects were then put through the mental practice procedure but one of them received interventions in order to intervene on free throws type of skills, whereas the other subject on field goals. The subject performing free throws improved her game performance from 41.3% to 54.8%, but on the other hand her field goals did not change. The second participant improved her field goals percentage from 36.7% to 52.2% whereas her free throws did not show any improvement.

A later study by Meacci & Price (1985) replicated the above study with a larger sample of participants. But these authors called body rehearsal the active imagery as defined above. The task consisted of putting a golf ball in a hole. In this project the authors divided their seventy seven subjects into four groups. One group did Relaxation, Visualisation and body Rehearsal (R.V.R.) of the task. The second group just performed the putting of the golf ball twenty five times. The third group did Relaxation, Visualisation, body Rehearsal and repetition. The fourth group was a control sample, which received none of the above interventions. The visualisation exercise lasted for three minutes, and consisted of visualisation of putting a golf ball into the hole. The body rehearsal involved a mixture of visualisation and physical rehearsal of twenty five putting strokes. They found that the groups that used R.V.R. interventions, as an aid to learn a new motor skill, performed as well as the group which carried out physical repetitions. The subjects on this type of intervention were better than the R.V.R. at the end of 15 sessions, but by the end of the 30th session, the R.V.R. group was better than the physical repetition group. The group that did RVR with repetition was as good as the physical repetition at the end of fifteen sessions and better still than the RVR group at the end of thirty sessions.

As far as mental storage of the motor task was concerned, the subjects who practised any type of RVR mental practice were better in recalling the procedure than the subjects who performed repetition only. But, although it was not statistically significant, it may be worth to point out that the group that did RVR with repetition deteriorated more rapidly than the RVR or the physical repetition groups.

A more recent paper presented at the North American Society for the Psychology of Sport and Physical Activity Congress by Kim, Radlo, Singer, Chung, & Kim (1994), found that self-enactment of a movement before actually doing it, was significantly better than just imagery on the acquisition and retention of a new task. They concluded by saying that the mixing of these two techniques '... *increased the vividness of the imagined task as well as enhanced motor coding and kinaesthetic awareness ...'*.

The active mental practice method, nevertheless, may have the awkward aspect that one may not be able to perform the whole movement, if this movement involves jumps or 'body fly' activity. This was what Hanrahan & Salmela (1990) found with ballet dancers. They selected three dance movements, *'relevé'*, which requires the performer to raise onto the tip of the toes, *'développé'*, where one has to unfold the leg by bending and then straightening the knee as the leg comes up from the floor, and lastly the *'battement'* which is just a high or low kick. They found the active imagery was effective only in the *'développé'* movement. When the authors asked the participants to explain their feelings about the interventions, one of them, who did not improve the *'battement'* movement, said that she actually *'got into'* the active imagery and did not pay attention to the height of her leg.

On the other hand, a very interesting suggestion of active imagery for movements with jumps is given by Orlick (1990). As gymnastics is a sport in which the performer is always in movement. Orlick suggests that a skilled gymnast can go through the whole floor routine by doing kinaesthetic mental imagery and at the same time walk '... *across the floor doing slight arm movements, body gestures, turns, and pauses'*. Thus, the practice of some of the actual movement would reinforce the inflow - outflow of the mental practice. According to Orlick this mixture '... *can speed up and enhance the learning process'*.

The Triple Code Model

Even though there was a short explanation about this Model in this chapter in the Psychoneuromuscular Theory section, there is still a need to fully explain what this Model stands for.

The article where the Model has been described does not, up to recently, stand out like other imagery theories, such as the Dual-Coding of Paivio, or the Functional-Equivalence model proposed by Shepard and expanded more recently by Kosslyn. These latter theories have been described in almost every book of Cognitive Psychology.

Nevertheless, after going through the article, it is quite clear that the author, Akhter Ahsen, is very well versed in almost anything that deals with imagery. This could be due to the fact that the author of the Triple Code Model has been the editor of the Journal of Mental Imagery for some time and is the President of the Image Institute in New York, USA. Thus, seems reasonable to suggest that these positions may have allowed him to read and correct a fair number articles and books, as well as do practical work in the area of imagery.

Another reason why the Triple Code Model may have not received the sort of attention as the other imagery theories is that this Model has not introduced any new perspective from what was already known up to the publication date of the report. Its importance derives from the fact that the Model, for the first time, describes in a clear and an elegant way, the three most important facets of an imagery activity, the Image, the Somatic and the Meaning responses. Thus this Model should be looked upon more like a framework people can use in order to explain or research this area of cognitive psychology rather than a theoretical explanation of what is mental imagery.

The article, in its Summary, says that the Model is '... *superior to other models* ...' because the others like the Dual Code Model of Paivio (1979) concentrate mainly on the link between Imagery and Meaning leaving out the Somatic response. The reason for leaving out the Somatic response is due to the cognitive background of the Dual Code Model which is based in ideas put forward by people like Bruner (1964), Piaget (1973) and Binet (1966).

The explanation given by Bruner on how imagery develops is of a developmental type and it proposes that children can only construct images when they are at a stage when they can represent abstract acts. As these acts do not have concrete motor schemas, the child has to start using language and so the link between the imagery and language is established.

Piaget not only supports the explanation given by Bruner on how imagery develop but he also goes on by suggesting that it is this interaction between images and words which enables children to understand the world around them. This gives rise to the concept that imagery provide meaning to individuals.

The contribution of Binet derives from his conclusion that imagery, like visual images, do not have personal or subjective responses because imageries tend to be abstract mental formations.

Thus, in view of such explanations, Paivio proposes that imagery tend to develop from concrete into abstract because of the development of language in individuals as their language tends to evolve into the construction of more abstract concepts. As Paivio says, people create ' ... *mature imagery* ...' as they grow up.

It is at this point that Ahsen attacks the Dual Code Model because '... *This pursuit of the abstract has been the main counter-influence against discussion of psychophysiology at the level of model building.*' and so the Model cast aside the ' ... *physiological factor.*'. He goes on by saying that it is wrong to disregard this factor because every child is first a Somatic and Meaning individual and the abstractions come afterwards.

The claim of Ahsen for a Somatic factor in imagery is further substantiated by pointing out the work of physiologists like Pribram (1971). He says that the brain is a collection of neurons which excite when there is stimulation of receptors on our body, and that people use this information in order to know how to perform in an environment. For instance, the visual sense is used by individuals in order to provide information on how to behave in a situation. If there is a change in the way the information is received by the visual sensors, like in experiments where visual images are distorted or inverted by special glasses, people in time would learn how to act in this new situation, by allowing them to move and manipulate the environment. This lead Pribram to suggest that what people are doing is to develop plans of action which they use in order to know how to behave in the world at large.

Ahsen then asked whether there was any evidence which showed brain connections between the motor and the visual areas of the brain. This would provide evidence that when people perceive an object they do so by using sensation, cognition and motor activity all at the same time. He claims that Hebb (1968) has, in fact, demonstrated that there is a brain connection between sensation and motor areas, and that the work by Nauta (1964) has indicated that an area of the brain associated with imagery, the inferior frontal lobe, has many connections with the limbic system, which is an area that controls emotions, as well as the hypothalamus and the pituitary gland which has a regulatory effect on the body.

Ahsen then uses psychophysiological evidence in order to provide a close relationship between imagery and somatic stimulation. He cites the work of people like Schwartz (1971) and Lang, Kozak, Miller, Levin, & McLean (1980) who carried out research on heart rate, and a review of the area by Sheikh & Kunzendorf (1984) which ' ... *once and for all buried the epi-phenomenalist argument under magnificent laboratory work*'.

This contempt towards epi-phenomenalism is further expanded by Ahsen by reporting an experiment he did which showed that imaging of the heart beat could cause a change on the vividness of imagery and a stronger physiological response.

In this experiment Ahsen used two groups of people who differ in their imagery vividness, as one group low and another as high. Each subject was presented with a colour photograph and asked to report what the experience was like when looking at the picture. Then the participant was asked to look at the picture again, imagine that the heart was beating faster and report what the feeling response seemed to be in relation to this new situation. Lastly the person was asked to make a judgement on the vividness and colour detail of the picture when imaged with and without heart beat. His results showed that the low vividness group was able to report increased colour and picture vividness during the increased heart beat condition to a level very similar to that experienced by the high vividness group during the same conditions. This finding, according to Ahsen, is a clear example where the vividness of imagery people do can be affected by autonomic processes like heart beat.

But, he goes on by stating that even though there could be a difference between people in their quality of imagery, this does not affect their recall of the stimulus itself. That is, memory for an event '... *is less dependent on the imagery function itself than on the operational function that is involved in the creation of an autonomic effect such as increase in heart rate.*' Thus when the low vividness participants were asked to imagine an increase in heart beat during the imagery intervention, the results obtained were solely due to an improvement in the quality of imagery and not because they improved their memory. To conclude '... *The main and central function of the imagery phenomenon is not recall but enactment*' of the imagery itself.

An interesting aspect in this article is the mention of how difficult it is for people to imagine parental figures being in front of them and then ask these people to switch them over. Ahsen explains this finding (Ahsen 1977) by saying that '... *these images* *are strongly localised in the brain and that their spatial relationships have a specific neurological representation*'.

Recent work using PET analysis, which was explained during the '*Mental Practice and Imagery*' section of this chapter, does tend to support such claim. That is, when people imagine an action they tend to activate those areas of their brain which they use during actual performance. The same could be said of people who become used to seeing their parents in a specific left-right position and then they tend to imagine this position in the same way.

After this explanation on why imagery should include a Somatic factor, Ahsen proposes then an alternative explanation for imagery process. He states that it is the interaction of Image (I), Somatic response (S) and Meaning (M) which when combined activates imagery in people. These three aspects tend to be exhibited in six variations which are the result of specific image experiences. Thus for instance the ISM represents an image which is summoned by a visual image, followed by a somatic response and then meaning. An IMS represents an image where there is first an image, followed by meaning and then the experience of a somatic response. The others four are the MIS, the MSI, the SIM and lastly SMI.

Now, if imagery is the interaction of these three factors, what does Ahsen say in relation to those people who imagine things without real substance, such as mythical beings or stories which no one can have experienced. Ahsen responds by saying that every imagery is a result of past experiences and imageries. A new image ' ... *builds a* *new future out of the dead past*'. Thus, all those stories that children heard during childhood as well as video games, television programs and others, are used to create new imageries more fantastic and more powerful than previous ones.

The question now is whether the above explanation given by Ahsen, that every imagery is based on Image, Somatic and Meaning responses, can form the basis for the theoretical model for this project. Would mental practice which uses interventions of the three IMS components produce satisfactory results during the performance of motor skills activity?

Conclusion

From the above review the research suggests that:

1 - The subjects should perform their mental practice from an internal point of view so that they can experience kinaesthetic feedback from the mental imagery of the task. This would also enable a person to activate the outflow <-> inflow mode of processing.(Decety & Boisson, op cit.)

2- The effect on the motor skill is stronger if the mental practice is combined with physical practice - active mental practice.(Orlick, op cit.)

3 - Mental practice should be done for a period of not more than 3 minutes. (Meacci & Price, op cit.)

4 - The task should be one that the participants have already experienced. (Corbin, op cit.)

5 - The procedure should consist of test - intervention - test. (Richardson, op cit.)

6 - The control group should be doing some activity similar to the one under test (Surburg & Turner, 1991, op cit.).

7 - The interventions throughout this project are going to make full use of the three components of Triple Code Model by Ahsen, that is I for Imagery, M for Meaning and S for Somatic responses (op cit.).

Up to now most research and implementation of mental practice has been done in games, sports or sports-related motor activity, like ballet. This is not surprising due to the fact that the performers within these areas, after reaching a certain level of performance, find it very difficult to improve. As the law of practice says (Snoddy, 1926), the improvements are very rapid when one starts learning a new skill, but then they plateau. The corrections they have to do to their movements are very small and cognitive interventions like mental practice seem to be able to provide the desired improvements. But, how about corrections in other forms of motor skills performance like in physiotherapy and skills training? Would the proposed active mental practice based on the Triple Code Model framework be as good as, or even better, than the procedures now used in these areas?

But before trying to answer such questions there is a need to find out in which areas of motor skill performance mental practice has been used. This is what the next chapter is going to concentrate upon.

Chapter 2 - Applications of Mental Practice

Mental practice is a cognitive procedure which has been used in the most varied ways. As was described in the previous chapter its earliest use was as a technique to recall stored information. But since the 1940's mental practice become an important aid in the learning and correction of movement. This implies that nowadays mental practice is becoming very influential in almost any skill which requires some form of motor activity. Therefore, as every human being uses some form of muscle activity almost all the time, mental practice is important as a cognitive intervention procedure in three main areas: training, medicine and games.

Mental Practice in Training

The use of mental practice in training is perhaps the weakest area of research on this topic. Training here refers to ' ... *the goal of improved performance at some specific task.*' (Patrick, 1992). Thus, if the objective of training is to improve performance, mental practice could be thought as another tool at the disposal of those who give training, and more so on tasks which require some form of motor skills guidance. For instance, Patrick comments that

> *' ... Further research should address this intriguing topic which is of both theoretical and practical importance to training'.*

He cites a study done by Prather (1973) who studied how effective mental practice was in the training of low-experienced student pilots in the landing of aeroplanes. Thirteen pilots listened to tapes which gave instructions in how to land an aircraft. When they listened to the tape they had to imagine and perform the motor actions required when actually landing. Prather found that those who received mental practice instructions mixed with actual practice received a better rating scale in their landing tasks than those who had not received any mental training. Qualitative data from the pilots that did this type of active mental practice showed that this type of intervention helped them to perform better during flying. This author concluded by saying that

> *'... The use of mental practice may be an effective, low-cost adjunct to any training program that normally depends on costly actual practice of the skill being learned.'.*

Even though the above article gives a positive outcome to the idea of using mental practice in training publication of more research in this area did not emerge until

1982.

During this year there were two articles which studied the effects of mental practice in driving. The interesting factor in these articles was that they focused on two completely different types of population. In one study, Lewin (1982) looked at how mental practice could affect changes in established drivers. On the other hand Sivak, Hill & Olsen (1982) examined the way mental practice could improve driving performance in people who had brain damage.

The Lewin study is important because he compared people who received mental practice interventions with those who received personal communication pointing out their errors, that is, this group was evaluated in a driving situation and observers noted and recorded driving errors. These errors were described in a letter and sent to those who performed them. They found that 20 to 50 % of those drivers corrected their mistakes. This improvement was still recognisable after a three month period but it started to decline after six months. The mental practice group on the other hand was asked to remember situations were they nearly had an accident. After having their driving analysed, these people were instructed on the type of movements and changes required in similar situations. The group was asked to imagine these corrections everyday for a period of six weeks. The author found a great improvement in the mental practice group, in that they corrected their motor skills in the order of 50% overall. He also found that these people were less likely to forget their motor skills corrections than those who received personal communication via a letter. Lewin concluded his article by saying that

> *'... the results seem to be that both the defensive driving course and the technique of analysing near-accident events followed by mental (imagery) practice of the correct driving habits improve driving*

skills, and that there are some indications that the latter technique brings more improvement than the former'.

One problem with this experiment was that the participants who did mental practice were asked to do their interventions at home, away from the control of the experimenter. So, it may be difficult to accept the conclusion given by this article without a replication of the study under laboratory conditions and more information on the number of times the mental imagery practice group performed their interventions.

On the other hand the work done by Sivak et al is described in a small report of a project done in a group of people who had brain damage in particular to the right hemisphere. They used a series of perceptual/cognitive tasks whose goal was to improve performance in tasks such as visual scanning, visual imagery, imagery, pattern discrimination and visuo-constructive skills. The conclusion given by the article was that these training techniques were able to improve driving performance of brain damage people with just eight hours of training. They further stated that the improvements of the group that experienced the perceptual/cognitive tasks were

'... comparable to the improvements of the control subjects who were presented with standard driver-education audio-visual material'

In 1988 Bird & Wilson published a study which not only used a population which very few people would associate with research in the area of motor skills performance but they also looked at psychophysiological correlates of the skills used. Using a group of pupils of music conductors, they measured their HR, EEG and EMG, as well as two imagery tests in order to select the imagery abilities of their participants: the Creative Imagination Scale (CIS) by Barber & Wilson (1978, 1979) and the Movement Imagery Questionnaire (MIQ) by Hall, Pongrac & Buckolz (1983). The CIS is a rather unique instrument as it allows users to use their self-induced type of imagery strategy, whereas the MIQ is more peremptory and less permissive because it uses specific type of imagery script statements. There were two trials: during the pre-trial subjects were asked to mentally rehearse conducting a series of beats to the bar. After eight weeks of actual training the subjects were asked to repeat the task again, this was called the post-trial phase. First Hall et al found that there was no correlation between the scores from the MIQ and CIS. This, as they pointed out, suggests that each test measured different aspects of imagery formation. The psychophysiological data indicated that heart rate was the only measure which significantly increased from base line. This was found both during the pre-trial and post-trial. In relation to temperature, there was a significant decrease only during the post-trial. The EEG, on the other hand, did not show any change between the trials. The article describes also intra-individual psychophysiological measures between actual movement and mental practice tasks. The EEG data showed a very close pattern between the two tasks. This was more predominant in the top performers in the class and in the instructor. The EMG results were less clear, but three of the subjects who got top grades during their course displayed similar EMG wave trends between mental practice and actual movement. Hall and co-workers concluded that, as these conductors became more proficient, the mental practice tasks activated physiological systems used during actual performance. Thus, as the EEG patterns of actual and mental practice become more similar the EMG patterns were also more like the two tasks. This effect was more significant in the instructor data.

The most recent article using mental practice as a learning strategy in training was published by Doheny (1993). She wanted to find out how mental imagery could affect the learning and performance of a standard motor skill in nursing students. First Doheny used the Vividness of Movement Imagery Questionnaire (VMIQ) to identify high and low imagery ability participants. The task consisted of giving injections to people. The performance of these subjects was judged by three members of the faculty where the subjects were training and, by using a performance checklist. The performance correlation rate of the agreement among these members were in the order of 0.91. The imagery script followed an internally oriented procedure so that the subjects could rehearse their task from a first person point of view similar to simulating task performance. Doheny found that subjects with high imagery scores performed only significantly (p=0.051) better than those with low scores.

Qualitative data from a questionnaire indicated that high imagers tended to be more abstract in their way of imagining, whereas low imagers were more logical and concrete. One problem with this study was that the author did not control the amount of time the subjects practised the mental practice strategies. The article mentions also that another problem with the research was that the VMIQ questionnaire uses mainly descriptions of activities which can predispose people to image them as being done by someone else, like a movie film, such as '*Sliding on ice*', or '*Riding a bike*', in particular if they have never experienced the activity. Thus those subjects who were rated as low imagery could have used a different imagery modality during the procedure of the intervention and so the data and results may not show a true effect of using mental practice on the performance of the present task.

Nevertheless Doheny concludes by saying that the use of mental practice during learning or performance of motor skills

> '*... has implications for nursing education ... [*mental practice*]*
> *conveys a process to learning that may benefit some students*'.

Thus, the above articles seem to show and agree that mental practice is a useful and an important strategy during the learning of tasks in a training environment. On the other hand, mental practice is a procedure which, due to its recent growth, still has not developed a sufficient strong following among those people involved in training in order for it to become a standard practice in their interventions.

Mental Practice in Medicine

The use of mental practice in medicine is a very recent perspective. It is mainly used in rehabilitation cases, for example in patients who have undergone some form of bone or muscle surgery or in those who have suffered a physical injury.

Even though a study by Rosenstiel & Roth (1981) was the first work to mention the use of mental practice as a positive '*anticipatory cognitive activity*' by people who had a trauma type of accident, the article by Fansler, Poff, & Shepard (1985) may be considered to be the first description of a project which used mental practice as a method to help people rehabilitate from physical problems. They focused their work on the elderly and their problems with balance by pointing out that postural sway goes up with age and that this is one of the main causes of falls in this age group. They investigated whether mental practice could affect balance control. The authors used their own type of mental practice, which requires imagery of perfect body movements mixed with awareness of bodily feelings. They divided their group of participants into three sub-groups. One group did physical practice with mental practice, another physical practice with relaxation and the third did spaced physical practice sessions only. They found that, overall, those participants who used mental practice coupled with physical practice improved their control over their balance whereas those using the other two interventions show no significant improvement from the original balance control skill performance. On the other hand, they also found that there was no significant improvement on the walking balance between those people who used physical practice with mental practice in relation to the other two procedures. They commented that this result could have been due to the fact that each group consisted of twelve subjects, which, according to the authors, is a rather small group of participants for their experiment. The writers also pointed out that one of the participants had to be removed from their results as her improvement was in the order of 758% when practising balance control with a mixture of physical practice and mental practice. This sort of result, according to them, would have skewed positively the results of this group in the order of 142% .

After the above article, a review article of forty nine papers on the area of mental practice and its implications for physical therapy by Warner & McNeill (1988) can be seen as the first step in the use of mental imagery by physical therapists. As far as physical therapy is concerned, this article cited the above article and overall gave a very positive point of view concluding that

> *'... The use of MI and MP by physical therapists in their patient practice has many positive implications, including that of immediate implementation. ... Mental practice allows patients to visualise themselves performing physical movements in real-life situations, to practice with ease, and to envision perfect outcomes ...'*

A year later an article by Linden, Uhley, Smith & Bush (1989), replicated the work done by Fansler et al, cited above. They also examined the effect of mental practice in walking balance of an elderly population. But this time they tried to find out not only the effects of mental practice in walking balance but also whether four sessions of mental practice could affect the walking balance of their participants. They found that, overall, there was no significant difference between control and experimental groups. That is, four sessions of mental practice did not significantly improve walking balance of their participants. Nevertheless, there was a significant difference in the way the subjects controlled the equilibrium to their upper body when they carried objects with their hands. This, they claimed, was probably due to an increase in '*proximal tone*' and the '... *subject's grasp and the fixed position of their arms and forearms*' during walking with articles. The reason for such non-significant main results was claimed to be due to the tape dialogue that did not orient the subjects with the walking speed the subjects were prepared to do. These cited ' ... *that their personal visualisations were consistently ahead of the mental practice tape*'. They also pointed out that the group that did mental practice become less interested in what they did as they become rather exhausted of repeating the same procedure over and over, and that this group of participants were 'suspicious' of mental practice type of interventions because of their lack of acquaintance with it. The authors concluded by saying that further work in this area

> *' ... should incorporate different ways of administering the mental practice techniques ... should use different populations ... used ... in conjunction with traditional treatment methods of rehabilitation and activities of daily living training and within home programs'.*

As an add-on, the sort of behaviour shown by the participants in the Linden et al project has been pointed out by Bandura (1977) in his self-efficacy theory. He argues that, in order for people to behave in a specific way, it is not sufficient to have learned the behaviour or even that they think they know how to do it. There is also a need for these people to be motivated to perform the act. The problem with the taped description of the assignment and the lack of understanding of what the task was about may have resulted in lowering the interest of the individuals from performing the task.

After the Linden et al article, Surburg (1989) published a review where he suggested areas of motor performance where mental practice could be used. One of the most interesting areas suggested was its use with moderately mentally handicapped people. A study Surburg carried out with this type of population in order to enhance the performance of reaction-time movements found that those who used mental practice facilitated their performance whereas non-handicapped subjects did not show any difference. He finished the article by suggesting some aspects to which a researcher should pay attention when implementing mental practice interventions. For instance, Surburg points out that attention should be given to the type of motor skills the participants in the experiment are going to perform, in particular whether the type of language used during the intervention orients the subjects to image more understanding than motor content tasks, or vice-versa. It is this sort of subject matter that can determine the end result of the mental practice procedure. For example, in projects which have mentally handicapped participants, imagery scripts which orient these individuals to understand what to do may be more beneficial than scripts which use just motor content activity. Also what any person says before mental practice activity, can have an effect in the imagery practice. For example, can the dominance of instruction language in one modality influence the way the subjects perform the task? Finally, the duration of the mental practice intervention can be an important influence on the outcome of the intervention

The next article that made use of mental practice in motor rehabilitation describes a study involving physical exercise in the elderly. Riccio, Nelson & Bush (1990) asked an experimental group of 15 females with an age range of 62 to 96 years to perform reach-up and reach-down exercises and to mentally rehearse the exercise at the same time. They found that this group performed the exercises more times than the control group who did not do mental practice. Qualitative data showed that those who imagined the activity '*psyched*' themselves up with statements like '*My apple tree is plentiful*' or '*I will have to go to another tree when I finish here*' whereas the control group would say to themselves '*This is silly*' or '*I'm not tired, but I want to stop*'. They concluded by mentioning the work of Fidler & Fidler (1978) who suggested that the use of mental practice in motor activity results in giving purpose to action as well as being the result of motor action.

The article by Riccio et al is followed by a review by McKenna & Tooth (1991) on how mental practice can be used in occupational therapy. The major contribution of this article to the work already described is its style of review which categorised the different aspects which should be used when doing mental practice interventions, the different areas of application, and how much relevance mental practice techniques have when applied to occupational therapy. They concluded that mental practice could be effective in the retraining of tasks which are already familiar to those requiring this type of therapy; that it could be used in rehabilitation strategies in those who have a high level of fatigue and low activity tolerance; in those people who are confined to bed, and those who have problems with sitting balance and anti-gravity movements. The technique may also make individuals more involved with the therapy, thus resulting in a greater sense of personal responsibility. Mental practice may also enable people to develop their motor consistency and functional activity. It may increase mental concentration and enable people to overcome their depression and apathy which is very common in people who experience illness. Finally, mental practice may enhance the completion and formation of goals during the therapy. The authors finished their article by saying that

> *'... occupational therapists need to consider this technique when designing a treatment programme which fully taps the individual's potential.'*

By pointing out that mental practice could provide a methodological procedure for people to elaborate their own motor rehabilitation procedures, McKenna & Tooth, have identified a strong inducer to perform motor activities, that of intrinsic and extrinsic motivation. Intrinsic motivation is derived from the fact that people do things because they like what they do and so it arouses them to go on. By doing this, these people become more competent at performing the task which can then be reinforced by extrinsic motivating factors such as peer approval or incitement. This could then encourage people to use mental practice again as their main technique in developing their own amelioration strategies.

A more recent article by Fairweather & Sidaway (1993) made use of mental imagery with body awareness. This methodology, which was introduced in the above study of Fansler, Poff & Shepard, requires subjects to imagine perfect body movements mixed with awareness of bodily feelings. This type of mental practice, also called 'ideokinetic imagery', was used in the treatment of people with spinal problems like low back pain and postural misalignment. They found that those using this kind of mental practice improved their lordosis - inward curvature of the spine column - and kyphosis - too much outward curvature of the spine - angles. Also a questionnaire which asked subjects to rate their sleep problems due to back pain showed that, during the initial phase of the study, the subjects reported an increase in low back pain. But later on this pain disappeared and their sleeping habits were greatly improved. After this initial study the researchers did a further study in order to find out if the results obtained were due to just an increase in relaxation or to the ideokinetic imagery. The results of this second study clearly showed that only those subjects who were put through the imagery interventions improved their spinal angles and decreased their low back pain.

A very recent study by Porreta & Surburg (1995) described a follow up to that done by Surburg (1989). They wanted to find out if mental practice with physical practice could enhance the performance of an anticipatory task in young people with a small amount of mental retardation. They found that the group who did mental practice with physical practice not only were more accurate in the accomplishment of the task but also more consistent in their performance. It is noteworthy to point out that these authors write that

> *'As many individuals with mental retardation typically have lower self-confidence, imagery practice may motivate (them) ... since imaging ... requires persons to think about themselves successfully performing the skill.'*

In conclusion, mental practice seems to be, and is becoming more and more, an useful strategy in medicine. It has a great potential for those people who are not capable of actual movement as it enables them to rehearse the task mentally without actually doing it. This appears to provide the patient with a greater interaction with the therapy and at the same time it may enable patients to notice or to think about their motor errors. Mental practice may also help infirm people to correct their anomalous motor acts and perform more times their rehabilitation procedures, and it may also boost their attitude, confidence and mental processes like concentration.

Mental Practice in Games

Games may be considered the area where mental practice has had its most influence. This is not only because most articles and projects are based in sporting and gaming skills but also because it has a long history. A fairly large body of knowledge on the effects of mental practice in the performance of motor skills is closely associated with the work done in sports and games with players. Therefore the following may be considered as a kind of a major findings section. It will dispense with theoretical and review articles as these may be considered more with the effects of mental practice in motor skills generally rather than just games.

The first article that mentions the use of mental practice in games was that of Vandell, Davis, & Clugston (1943). They made use of two activities, that of throwing darts at a board and throws of a ball at a basketball basket. There were three groups of subjects. The first group practised just on the first and last day, that is 20 days later. The second group did physical practice every day. The third group did physical practice on the first and twentieth day, with mental practice of the tasks every day between the second and nineteenth day. Vandell et al found that this third group, physical with mental practice, performed as well as the physical practice group. Another important aspect about this article is that it may have been the first one to suggest the use of mental practice as an aid to learning professional skills, in this case typing. From what was discussed above in relation to the use of mental practice in training the suggestion proposed by this article was not taken in consideration until the 1970's.

The next project that deserves to be mentioned here was published by Twining (1949). His project was important in two areas: first, he tried to find out the statistically significant difference between control and mental practice groups. Most studies up to this study tended to look at the effects of mental practice on single subjects (Shaw, 1939) or else looked at percentages, as in the study by Vandel *et al.* Secondly, this was the first experiment where the experimental subjects had to experience and visualise all body sensations during the intervention. The task consisted of throwing rings to a peg to encircle it. Twining found that those who performed mental imagery improved their performance by 36% which according to him was a highly significant result. This article was also the first to mention that qualitative data obtained from subjects in the experimental group showed that the participants were capable of maintaining mental practice procedures for about five minutes. The participants experienced difficulties in sustaining mental imagery, for longer than five minutes.

After the work by Twining there is an interval of about thirteen years where the topic of mental practice, and most of cognitive psychology, was at a virtual standstill due to the dominance of behaviourism. Nevertheless, an article by Start (1962) needs to be pointed out as an important step in the way mental practice can affect motor skills in games. The aim of this study was to find out which factors, in mental practice interventions, were important in order to improve motor skill performance. The study concentrated on the amount of '*games ability*', or the '*knowledge of the individuals*' in the games of hockey, football, cricket and basketball. Thirty five students were allocated to three groups: group A had a very good understanding of all games, group B about average and group C the least knowledge. Start found that, overall, all people who were put through the mental imagery intervention were significantly better afterwards. But what was important was that those who knew more about their games were also much better at performing them than any of the other in that group. Therefore the knowledge, together with experience of performing the task, enabled people to mentally rehearse the skill in such way which was more beneficial for them during actual performance than those who knew much less. This finding is nowadays becoming an important factor for almost any type of mental practice research. The '*games ability*' a person has of a behaviour can determine not only the type of mental practice that person does but also the performance of the behaviour.

During the 1960's the importance of behaviourism theories and research started to decline and books as well as articles in mental practice in games started to appear with more frequency. In 1963 an article by Jones reported findings which are only now being used in mental practice work. Even though this article is not widely cited it was the first which tried to find out which type of directions should be given to athletes when they were doing mental practice. It was also the first project which mentioned the importance of kinaesthetic imagery in mental practice interventions. In this study, all groups of subjects were put through a two stage treatment experiment. During stage one, two groups received instructions on how to do a badminton task followed by mental practice of that same task. Afterwards, one group received '*directed mental practice*', which consisted of very clear and detailed instructions of the task read aloud to them, followed by mental practice of those instructions. This was achieved by a reading of a script of mechanical analysis of the task together with mental practice of those instructions at the same time, followed by mental practice without any instructions, finishing off with another mental practice of the mechanical analysis while it was read loudly to them. The second group went through an '*indirect mental practice*' procedure which was made up of the same script and mental practice being read to them, but, the mechanical analysis script, even though it was read to the participants like in the first group, the subjects here carried out mental practice of it three times without the script being read to them at the same time. Thus, overall all subjects did four mental practice interventions, but the first group did two of them while the mental practice script was read to the subjects and two without, whereas the second group performed all mental practice treatments without the script being read to them. After six sessions a benchmark test was conducted in order to see how many of the subjects learned the task so that they could go on onto the second stage. The results showed that the '*indirect mental practice*' group performed the task much better than the directed one. In the second stage of the experiment Jones introduced a physical practice variable in order to discover how physical awareness could influence the learning of the task. He found again that the group that received physical practice with an indirect mental practice procedure took less time to learn the task than the group with physical practice mixed with a direct mental practice. Jones concluded that

> *'... the reception and interpretation of information and the formation of the kinaesthetic image are the only essentials necessary in the initial learning of a gross body skill ... The advantage of indirected mental practice over directed mental practice, when applied to the theories of motor learning, seems to suggest that the formation of the kinaesthetic image is better achieved if the subject is first given the information and then allowed to try to form the complete pattern on his own, the different stimuli being organised by himself'*

With this comment Jones may have been the first person to cite the importance of the way imagery information is understood by the users of mental practice and how this can influence their kinaesthetic mental imagery. Nowadays, this idea has being taken by most researchers in mental practice when they cite the triple code model of Ahsen. The three components of the triple code model - I for image, S for somatic response and M for the meaning or the understanding the subject has of the task - are increasingly emphasised as important components of mental practice in the performance of motor skills. The interaction of these three components, in the formation and performance of mental practice and their effects on human motor skills activity, is very similar to what Jones claimed to be the best procedure back in 1963. In the above quotation, the formation of the imagery pattern, the kinaesthetic imagery and the interpretation of the instructions, seemed to be direct equivalents to the three components of the Ahsen triple code model as just described.

The next article reporting an important factor in the use of mental practice in games was published by Powell (1973). His was the first study which investigated whether mental practice can have a negative effect in motor performance. As Powell suggested in this article most of the work done in this area uses positive mental practice and does not test whether negative mental practice can be as effective as positive mental practice in the performance of a motor task. A dart throwing task was used and eighteen students with similar imagery capacities were divided into two groups. One group received positive mental practice, the other negative. The instructions given to the participants in the positive group suggested darts landing near the centre of the target. Whereas the negative group imagined the dart landing away from the centre. Powell found that those who did positive imagery interventions improved their target accuracy by 28%, whereas those participants who imagined negatively decreased they performance accuracy by 3%. This result was rather surprising in view of the fact that, as suggested by Powell, the action and the experience of actual throwing a dart at the board should have improved the performance of the people in this group. The article finishes by indicating that the way a person mentally practices a motor task '... *is liable to affect differentially later performance*'. Thus this article, for the first time, shows that the type of instructions or scripts a person uses during mental imagery may be an important variable in the way a person performs in a task when using mental practice interventions.

After the 1970's, and during the next decade the interest and the number of research articles in mental practice grew very significantly. The area became more established and the topics and questions under study were more specific and concrete. One of those questions was in relation to the type of imagery perspective an athlete should use. There are two ways of performing mental practice. One is from an internal point of view, where the subject has a first person perspective. Under this condition information coming from the kinaesthetic modality tends to dominate and the person is also prone to become aware of the muscles in action - also called proprioceptive information - during the performance of the motor activity. The visual modality is also active but the subject imagines seeing the environment and activity as when performing the task with eyes open looking out.

The second method is to do mental practice from an external viewpoint. Under this condition the performer mentally practices the skill using information coming mainly from their visual sensory modality. When athletes use this perspective they analyse their skill using a third-person perspective, as when people watch themselves on a video screen.

It has also been found that some people can do both procedures because they can imagine that they are looking at a screen when performing the task and then adapt their mental practice as if they are looking at themselves repeating the same movements they just saw on the screen

A study which looked specifically at the difference of performance between internal and external was done by Epstein (1980). The task consisted of throwing darts at a board. For this task she had three groups. One group did mental practice of throwing darts from an external imagery standpoint for fifteen seconds. The second group used an internal perspective for the same period of time, and the third group counted backwards aloud for the same period as the other two groups. Epstein found that even though the type of mental practice did not affect the performance of the participants, she found that there were gender differences on the way the males and females performed the task, with males being more accurate in their dart throwing at the target than females. The reason for such results was obtained by a questionnaire which asked the subjects to describe the type of imagery they performed during the procedure. The qualitative data revealed that 39% of the subjects used just internal perspective type of mental practice; 35.7% of the subjects switched from an external to an internal perspective at some point during the mental practice task; 12% of the people used both perspectives at the same time, similar to what people do when they are performing activities with their eyes open; 8% switched from and internal to external or from an external to an internal perspective; 3.7% used just external perspective, and 1.7% changed from an internal to an external perspective at one specific point in time during the mental practice. The questionnaire prepared by Epstein showed also that males who were much better at dart-throwing tended to use a larger number of sensory modalities. They tended to use not only visual and kinaesthetic modalities but also the auditory, and olfactory during mental practice. On the other hand females with high ability were more inclined to use a reduced number of imagery sensory modalities like visual, kinaesthetic and auditory . Thus the data seems to suggest that overall everybody used internal mental practice of some kind during imagery intervention. However external imagery was seldom used even during those periods when was required by the experiment. Epstein concluded by saying that this sort of behaviour could be due to the fact that

'... the existence of 'critical points' within images, where subjects frequently switched imaginable perspectives, suggests that imaginable perspective may not only be a function of the individual doing the imagining, but of the scene being imagined'

This inference goes along with the conclusion suggested above for the study by Start. The experience a person has of a task determines not only the type of performance of the mental practice intervention, as was indicated, but also the type of perspective the person uses during the procedure of that same mental practice. One criticism that can be made of this study is that the participants on this experiment did not perform what Epstein told her subjects to do. But looking at the above quotation it may be said that they did, only that half way through their mental practice, they switch over to their more traditional way of using their perspectives.

A study published by Ziegler (1987) has become very influential in the way mental practice can affect motor skills activity in games performance. The study concentrated on the three types of mental practice that can be used during imagery experiments and how effective they were on the performance of the task. One method, and the one that is used most frequently is passive imagery. During this type of imagery the subject is quiet, tries to imagine the scene as vividly as possible and finishes the intervention by imagining successful performance of the task. A less frequent type of imagery is passive imagery with physical practice. During this type of mental practice the participant performs as in the passive imagery, then tries to imitate physically the task imagined without full performance. This is very similar to simulating the motor action. This type of imagery, according to Ziegler, tends to be seen in athletes who want to focus intently just before the execution of the task. The third type of mental practice, and the method that is seldom mentioned or used in research in this area, is active imagery. During this type of mental performance the subject not only mentally rehearses the task but simulates it at the same time with actual physical actions. Ziegler used this type of imagery because of the psychoneuromuscular theory of Jacobson which claims that when a person does mental practice of a motor skill, it is accompanied by small muscle enervation of the muscles of the body, in particular those parts that the participants are going to use during actual performance. Thus, the rationale is that if the performers mix mental practice with actual movement there would be a stronger effect on the learning or correction of the motor action. This is because the muscle activity which is controlled by the brain area in charge of that motor activity, is reinforced with activation of the same area of the brain during the mental practice interventions. This creates a stronger outflow effect on the muscles and as well as the formation of a firm brain cell array of the task under practice. Also, the performance of the mental practice of the subjects performing active imagery will be very focused as there will be concerted mental and physical actions.

As a second variable, the study also examined the effect experience of the players has in the performance of the task. The task consisted of ten practice and ten test basketball foul shots. The results showed that the group using active imagery performed the best, followed by passive imagery with physical practice. In relation to the amount of influence experience could have on the task, Ziegler found that the group which had less amount of understanding about the task and the group that mentally rehearsed the task using active imagery improved the most. These results are still today rarely referred to by researchers who study or investigate the effects of mental practice in the performance of motor skills. Even though active imagery has been pointed out by people such as Ziegler and Orlick (1990) as the best strategy to use during mental practice, most present research still uses passive imagery as their experimental variable when doing experimental work in this area. It seems that, as was indicated by Ziegler, ' *The increasingly more complex levels of imagery ... are introduced ... (the) ... greater effectiveness in performance*', that is the enhancement of performance of players may be greatly strengthened if the mental practice interventions are of a greater complexity using a greater number of sensory modalities during its performance.

One of conclusions suggested by this study of Ziegler seems to go against the suggestion described in the previous work of Start, who reported that the group with most knowledge and using active imagery came out as the best at post-intervention. Thus a person reading this statement may think that the less knowledge that person has of the task the better at performing it after mental practice procedure. This may not be so. What seems to be important is to know enough about the task so that the person can rehearse it mentally without the need to learn the basic structure of the act under study. If a person is looking for the amount of skill retention then passive imagery rehearsal may be the best strategy rather than active imagery. Ziegler points this out in her conclusion by saying that ' *Perhaps in the area of long-term retention, prior experience becomes a significant factor in performance*'. Therefore, '*active*' mental practice may lead to better motor performance, whereas '*passive*' mental practice may produce a better cognitive model of the task

The most recent research on the way the brain behaves when a person is doing mental practice of motor tasks, introduces a new methodology which may allow a better understanding of the way the areas of the brain activate during mental practice and whether these areas are also engaged during actual motor practice. This new technique, called Positron Emission Tomogaphy (PET), consists of a large instrument made of arrays of crystals, which brighten up when they get ionising radiation through them. These PET cameras can detect the activity of the brain because when unstable radionuclides which decay by emitting positrons, travel a short distance through the brain, collide with electrons and split them into photons and so cause the crystals to illuminate. These are attached to photomultiplier tubes which detect these light variations. The output of these tubes is connected to computers which can provide pictures of brain activity. The radionuclides are injected into arteries which travel to the brain mixed with blood. Due to the energy requirements of the brain cells for an increased supply of blood when they become active, also called regional blood flow (rCBF), the concentration of these radionuclides is larger than at any other areas (Volkow, Brodie, Bendriem, 1991). This allows the PET equipment to identify these active areas of the brain and so provide information on how much activity the brain cell arrays in that area has in relation to the other areas during mental practice when compared with periods when subjects are resting. A short communication by Decety, Sjöholm, Ryding, Stenberg & Ingvar (1990) measured rCBF when people were imagining a motor task. The group used a three dimensional rCBF via a single emission computerised tomography, also called (SPECT) to measure the blood flow in the brain of fifteen people when they were at rest, during silent counting and mental imagery of a task. The motor task was a simple tennis training procedure which consisted of trying to hit, with a tennis ball, a target on a wall for a period of five minutes. The number of hits was recorded without the knowledge of the subjects. The imagery of the participants was also tested with two questionnaires, the Movement Imagery Questionnaire and the shortened form of the Betts' Questionnaire. The study also measured how much control the subjects had over their imagery training with the help of the Gordon test. This test showed that the participants had, on average an above average control of their imagery. They tended to score around 10.8 out of a top score of 12 and a reported test mean of 6. The other two questionnaires indicated that the visual and kinaesthetic imagery modalities of the subjects were very similar as they showed a mean score of 1.95 for visual and 1.99 for kinaesthetic imageries. The analysis of the rCBF of the brain for the subjects showed that the area of interest which displayed a significant increase in blood flow during mental imagery of the task was localised at the cerebellum area of the brain. The analysis indicated also that this increase was also significant in the amount of distribution of blood flow around this particular area. The silent count was able to significantly increase the distribution of blood flow but not the amount of blood in the area. When the subjects stopped counting and imagined the task the amount of blood flow was significantly increased but the distribution stayed the same. In order to explain these effects the authors commented that

> *'There is a general agreement that a rise of rCBF recorded during sensory and motor activation as well as during cognitive activity, is caused by an increased metabolic activity of neurones. This induces a dilatation of vessels which augments the blood flow locally in the brain (as suggested in the book by Ingvar & Lassen 'Brain Work', 1975). The rCBF increases reported above thus represent local augmentations of cerebral neuronal work'*

This can be extrapolated to indicate that when the subjects carried out mental practice of the tennis task, the amount of blood flow around the cerebellum went up whereas when performing other activities, such as silent counting, there was an increase in the distribution of the blood flow around the area. The cerebellum is quite well known for its function in motor learning. Ito (1984) has explained this factor by remarking that the cerebellum works like a learning modulator of all motor activities in the central nervous system. The results obtained in this experiment by the rCBF technique suggests that the cerebellum is also active during mental practice of the tennis task. Therefore according to the Decety group it seems reasonable to assume that

> *'... both mental and motor functions are largely using the same processing methods and to some extend the same functional units, including the cerebellum'*

The question then is how much can a person rely in these new techniques? Are they providing such clear cut results as they seem to be doing or are they just another *'fad'* that tends to occur when new technology appears on the market? As was suggested by Sergent (1994), there are extraneous factors such as circadian rhythms of the body, nicotine, fatigue or anxiety that can have an effect on the cerebral activity of individuals and thus provide unreliable data. Also rCBF data is derived from brain cell activity. But this technique is unable to show whether the brain area under study is in an excitatory or inhibitory state. Thus, as pointed out in this article '... *not all peaks of activity can reflect a direct contribution to the realisation of the function*'. Even though it is reasonable to assume that an increase in rCBF is correlated with the amount of neuronal activity, it may be inappropriate to assume that this activity is due to the performance of the task. This is due to the fact that the more proficient a person is with a task the less rCBF activation. When there is no change in rCBF it does not imply that there is no change in cerebral activity because rapid increases and decreases in brain cell activity with an area of interest can cancel themselves out and the technique is not sensitive enough to detect this rapid change. The Sergent article points out also that the rCBF technique involves the subtraction of one slide of brain activity doing a type of task with another slide when the brain is doing a different task. This is dependent upon various assumptions - for example; the analysis of information is basically serial and it is organised in a system of layers; that the subjects perform just what is told them to do during the experiment; that the rCBF change corresponds exclusively to a single aspect of the task under study and that this is constant and it is not affected by some other aspects that may be included on the task. The problem with such assumptions is that the brain works in parallel and interacts with different areas, and that there are neuronal areas, such as the cerebellum, which work with more than one type of modality. As was explained by Kalat (1992), damage to the cerebellum can result in not only difficulties with motor movements but also with speech, sense of direction and problems in linking in a smooth sequence of individual motor acts.

Nevertheless rCBF has a great potential for the study of the effects of mental practice in the performance of motor tasks. What seems to be important is not to rely in one specific technique but to combine rCBF with EEG, EMG, EKG and GSR, as their results can provide some information about the physiological responses of the participants during mental practice interventions. Also, as was explained above, these methodologies have to be accompanied by scripts which describe motor tasks which can be well understood by the individuals during the performance of the experimental study as well as the type of modality they are more likely to use during the performance or learning of those tasks, as proposed by the Ahsen's Triple Code model.

Overall the three areas of study discussed above seem to be more likely to benefit from mental practice interventions. Two of those, medicine and games are those that this project is going to give particular attention.

Chapter 3 - Active Mental Practice on Accuracy of Ball Placing in Table Tennis

Since the 1930s, mental practice training has increasingly been put forward as a technique to improve the performance of motor skills. As was pointed out in Chapter one, a possible explanation on why mental practice can affect motor activity is the psychoneuromuscular model of Richardson (1967) also accepted by Corbin (1972) and by Schmidt (1988). This model has a long tradition that goes back to the work of Jastrow (1892) who noticed that people would produce non-deliberate movements when they were doing mental operations. Later, Carpenter (1894) reported that participants in a motor skill experiment would produce a reduced muscular activity during mental practice which was very similar to that produced by an actual motor movement. However, it was a series of experiments by Jacobson (1930, 1931 I, II & 1932) that became the basis for the psychoneuromuscular model. The most relevant article was the one published in 1932, which starts by saying that his main point of interest was

> *'... to learn something about what takes place in the nervous or neuromuscular system specifically for various forms of mental activity, and so far as possible to measure the processes in physical terms.'*

Then Jacobson goes on to describe a series of experiments where he finds that his galvanometer would display muscle activity every time a subject imagined contractions of the right arm, and also contractions when people recalled lifting a 10lb weight. An interesting result was when a participant without a left forearm and hand was asked to imagine doing a task with this part of the body. Even though the subject said that he was able to imagine everything with his left hand that he could do with his right, Jacobson found that every time this subject imagined bending his left hand there were galvanometer measures not just from the stump-biceps muscle but as well as activity from the muscles that were in charge of flexing the right hand. This subject declared in the end that when he did something with his right hand the left seemed to duplicate the performance, but that '... *My imagination of bending the left hand is but a shadow - a duplicate of what the right hand is imagined to perform.*'. Thus, from this early research and also from the more recent projects based on this model, the use of mental practice in motor activity seems to produce muscular activity which can affect the way a person learns to perform a task. Nevertheless, this model fails to accommodate recent MRI and fPET research which shows that motor skill learning is centrally related rather than peripheral.

The other model that is still supported by some researchers, (for example Murphy & Jowdy, (1992)), is the symbolic learning hypothesis. As this perspective has already been discussed in the first chapter, the only further point that may be added to what was already described is that recent research investigating the physiological activity of the brain during mental practice of motor skills does seem to show that mental practice of movements activates areas of the brain specific for the sort of activity a person performs in normal circumstances. However, a major problem with the symbolic learning model is that it dismisses the idea that mental rehearsal produces peripheral activity. But as the research discussed above, and in the first chapter clearly shows, there is muscle activation, as measured by psychophysiological interfaces, every time a person mentally rehearses motor skills.

A more recent model is based on the observational learning theory by Bandura (1971). Even though the modelling theory introduced by Bandura is used mainly to explain the way people acquire and develop behaviours and social skills, he also said that when people model what an individual is doing they are using attention and are thus learning. Following on from this idea an article by McCullagh, Weiss and Ross (1989), proposes two elements: one is the '... *impact of the observer on what is perceived in the demonstration and how this information is rehearsed*', and secondly the '... *action perception, which focuses on the perception of human motion*'.

In relation to the first element, they point out two types of issues: one, the type of characteristics the observer must have in order to find the relationship between the model and what should be performed, and two, the effects of what the individual is learning by observation on the psychological characteristics of the observer. For the first question the paper points out developmental factors of the person, like cognitive and physical development, as well as the motives the individual may have in order to reproduce the model actions. In relation to the second question, the researchers point out that observation can affect memory development when those that are doing modelling learn about the labelling, rehearsal and organisation of the modelled motor skills.

As far as action perception is concerned, the authors pay particular attention to '*the demonstration*' factor. For this they say that there are three aspects that can influence the level of performance. One is '*augmented information*', second the '*cognitive task elements*' and finally the '*model characteristics*'. Augmented information refers to any sort of information that does not belong to the task but that can give some information to the learner. The modality a person may use to learn a skill is such a case. They propose that an auditory 'demonstration' may be better for a 'demonstration' where there is a need for timing and sequencing. Whereas visual may be more adequate for spatial or qualitative aspects of a 'demonstration'. Another aspect could be the type of verbal cues a demonstrator provides when demonstrating a task. The authors cite the work of Roach & Burwitz (1986) who found that when verbal cues were added to the 'demonstration', the attention of the observer was enhanced and so was the performance. For cognitive elements, McCullagh, Weiss & Ross pointed out that when a person is imitating a model, the first act is to observe the action, then encode and rehearse, before trying to repeat the observed performance. In mental practice they claim that a person thinks about what they are going to do, then encodes and rehearses it before reproducing the act. They conclude that modelling may be seen as a form of '... *covert rehearsal* ...' producing similar behavioural patterns to those found during mental practice. This was precisely what Jeannerod (1994) found as explained in Chapter 1. As far as the characteristics of the model are concerned they point out that it is very important who demonstrates the skill, as well as what the model is saying and doing.

However, after looking at the demonstration of the task, the way these observers are going to perform the motor activity is dependent upon the type of mental practice technique they are going to use. For that, the authors suggest three strategies: the type of verbal code used during the demonstration so that the person doing the modelling understands what to do; second, the amount of knowledge the person has of the act so that mental practice can occur using the visual, auditory and kinaesthetic modalities, and lastly '*organisational considerations*', which include how often and when the observer should look at the model, together with variation of the number of responses during the demonstration. This last part of this theoretical model seems particularly relevant to this chapter and project because it not only has, to a certain extent, some similarities with the model presented by Ahsen, such as the type of verbal code used during the interventions, which is similar to the Meaning component of the

Triple Code Model, but it also supports various features of type of interventions which are going to be used in the present experiment.

The Triple Code Model by Ahsen (1982, 1984) proposes that the performance of a task is a mixture of psychological and physiological components. This model emphasises the interaction of three components in mental practice: (i) the Image itself (I) which represents the outside world; (ii) the Somatic response (S) which is understood as the proprioceptive changes which occur as a result of the activated image, and (iii) the Meaning or significance (M) of the image has to each individual. In this model, Ahsen suggests that each individual brings a unique history to the mental practice process and that this interacts with the mental practice instructions so that the same instructions will never produce the same image for any two individuals. This was well illustrated in an article by Murphy (1990) where a group of élite skaters were asked to imagine a bright ball of energy radiating energy inside their bodies so that they could feel peaceful and full of energy before competitions. Murphy found that some of these skaters created this image in a negative way, such as imagining the ball exploding inside them and creating a hole in the body, or that the ball was so bright that it blinded them, and so on. Thus, it was quite obvious that each athlete, when imagining the activity proposed by Murphy, brought into it their '... *own fears, anxieties, and preconceptions* ...'. Murphy concluded by saying that mental practice scripts used during interventions should be carefully created so that unexpected negative responses or images are reduced to a minimum. Therefore, the scripts must reduce the possibility of allowing the participants to create images which do not orient them to perform tasks they are supposed to perform. As Paivio (1985) has pointed out '... *language is an efficient and accurate way of activating the desired imagery content.* Each mental practice intervention generally has a specific language for the sport or performance under study. For example, Suinn (1984) has developed a series of verbal instructions for runners which enables them '*to run relaxed*' by orienting the imagery of the runner to those parts of their bodies which show signs of tenseness. He found that the heart rate of the runners decreased as well as their VO2, and that they kept the new running style in later events. Therefore, such instructions should serve the purpose of orienting the imagery of the athletes to those processes which are involved in optimising their performance.

The MRI and fPET brain analysis data illustrated in the first chapter suggests also that the more the subject performs the three components of the Triple Code Model the more '*automatic*' the response becomes. For instance, a study published by Decety, Perani, Jeannerod, Bettinardi, Tadary, Woods, Mazziotta and Fazio (1994), concluded that

> *'... consciously representing an action involves a pattern of cortical and subcortical activation closely similar to that of an intentionally executed action ... mental representations during observation of actions performed by others, and even more during simulation of one's own actions, share common neural mechanisms with other covert aspects of motor performance, such as planning and programming.'*

This quotation implies that the three constituents of the Model, the Imagery, the Somatic and the Meaning (ISM), create and maximise the formation of brain cell arrays which can determine the way a person performs a motor action. Thus, an implication of automating ISM components is that, if the mental practice is correctly performed, it should produce a motor skill which will become more effective and consistent.

Another feature of this project is the use of active mental practice. This is due to recent research in the field of motor mental practice which has shown that active mental practice leads to better performance than passive mental practice or physical practice alone. Active mental practice may be defined as a combination of cognitive and physical components of a desired movement, but without the normal product of the movement. Thus, a tennis player using active mental practice for a serve would both create a vivid image and physically practice a serve but without hitting the ball. Ziegler (1987) found that of three types of mental practice - passive mental practice, mental practice and physical practice, and active mental practice with kinaesthetic cueing - those subjects who used active mental practice with cueing performed much better than any of other types of mental practice. Also, a more recent experiment by Van Gyn, Wenger, and Gaul (1990), found that the group combining mental practice with physical activity performed better in later performances than those subjects using just mental practice or physical performance alone.

Thus, all the above suggests that active mental practice training, which incorporates instructions orienting the imagery of the participants to tasks which have meaningful relevant processes, also called guided mental practice, has the potential to enhance performance, and produce more consistent motor skills. The study presented in this chapter is an attempt at testing active mental practice within the framework boundary of the Triple Coded Model using the active motor skill performance of the game of table tennis. This type of sport seems to be a fairly effective way of testing the effect of active mental practice in motor performance as it requires consistent movements, fast responses and the accurate placement of the ball on the table with every stroke.

Method

Participants

There were 14 table tennis players, 9 males and 5 females. All had several years experience of playing table tennis, with the average being 3 years (range 2 - 15). No one had practised guided mental practice in the game of table tennis before, but they usually did '*shadow playing*' which involves acting out known stroke movements without the ball without mental practice.

Materials

The test was carried out using a standard competition table tennis table, and participants used their own regular table tennis bats and balls. The target area was a 15cm X 15cm square of thin cardboard placed on the table at the opposite corner from where the players were standing.

Design

The design for this experiment was a 2 X 3 (Groups X Sessions) repeated measures factorial. There were two groups, Mental Practice and No-Mental Practice, with 7 participants per group. Each group completed three assessments for accuracy. The design was as follows:

Experimental Group	**Control Group**
Baseline accuracy (out of 10)	Baseline accuracy (out of 10)
3 mins mental practice training	3 mins normal training
Accuracy score (out of 10)	Accuracy score (out of 10)
3 mins mental practice training	3 mins normal training
Accuracy score (out of 10)	Accuracy score (out of 10)

Procedure

After assessing whether each participant was a left- or right-handed player, the target was placed 45cm from the right or left side and 15cm from the bottom of the table respectively, on the server side.

The subjects were briefed before each trial on their task. The task began with the server doing a long serve and the ball being returned by the opposite player with a forehand drive towards the target on the table. The number of target hits, out of 10, was counted to establish target accuracy.

After this initial trial, the participants from the mental practice group then carried out a 3 minute active mental practice practice, which was suggested by Weinberg (1982) as the most effective period for mental practice interventions, of the forehand drive movement. For the first 90 seconds, the imagery of the player was directed to specific task-relevant areas of the body, like feet and leg posture, waist, chest and shoulder movement and arm and hand swing. During the second 90 seconds period, players continued with the movement but were also instructed to imagine the ball going from the bat towards the target.

At the end of the three minute period the players were tested again on target accuracy. After all 7 participants had finished their first test they were called again one by one to repeat the active mental practice and the accuracy test. During the waiting period the players carried on with their normal training.

The control group was also tested three times but did not do any active mental practice training. Each participant in this group was called from his/her normal training, carried the target accuracy task and then returned to their normal training. After three minutes each subject was called from their normal training practice and tested on their target accuracy again.

Both groups did not change any activities of their normal training practice periods, thus reducing the possibility of any training practice interference.

Results

The table 1 below shows the overall means values of the participants touching the target with the table tennis ball.

Table 1: Means for hit scores (out of 10 strokes) for the two groups.

	Mental Practice group	Control group
Baseline	1.857	2.00
Assessment 1	3.714	1.571
Assessment 2	4.143	2.143

The analysis of variance indicated a significant difference in accuracy between the groups ($F_{1,12} = 6.4$, $p < 0.026$). There was also a significant difference between sessions ($F_{2,24} = 3.82$, $p < 0.036$) and a significant interaction between groups and sessions ($F_{2,24} = 4.2$, $p < 0.027$) due to the improvement in accuracy in the Mental Practice group in comparison with the Control group. This interaction is also illustrated in Figure 1 below.

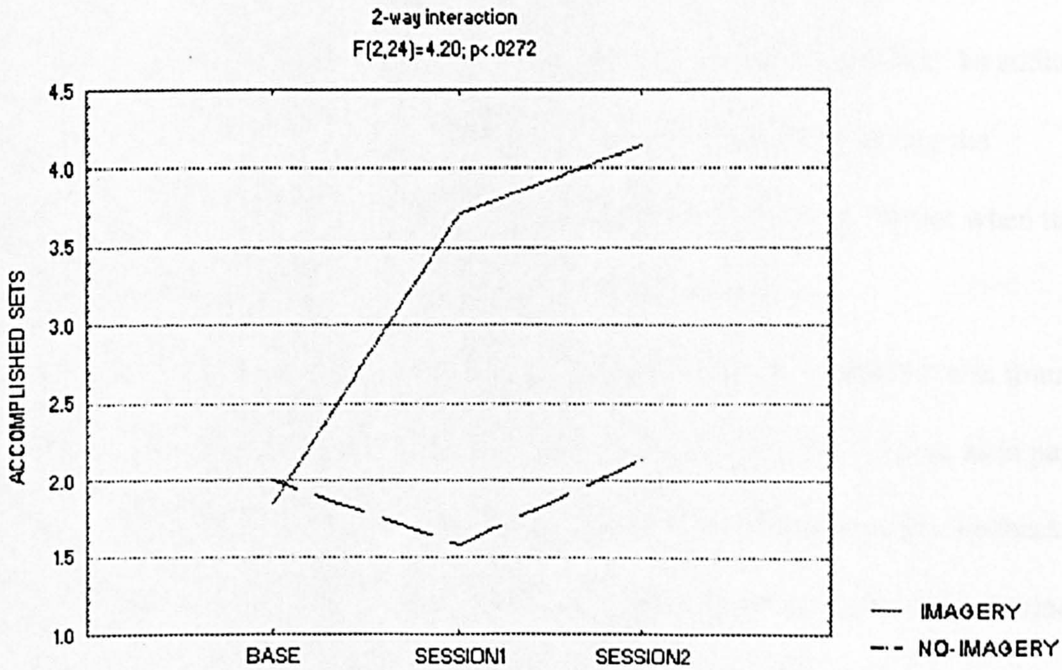


Fig:1 Means for Imagery-NoImagery and the three sessions

Discussion

The results from this experiment indicate that guided active mental practice seemed to improve the consistency of ball placing accuracy on a target in a table tennis motor skill task. This is clearly shown by the mean scores obtained between the base session and the first mental practice session. The players doubled their accuracy after their active mental practice training. However, it should also be pointed out that the results demonstrated little improvement between the second and third sessions in the experimental group which could have been due to the subjects reaching a '*plateau*'. As Singer (1980) has pointed out, as soon as one learns a new skill one tends to repeat it over and over, and there is a temporary reduction in the pattern of progress. The subject has reached a '*plateau*'. This lack of improvement despite mental practice intervention could thus be due to this '*consolidation*' process.

These findings confirm also the report by Suinn (1984) where he found that mental practice instructions which orient the imagery of the participants to the task processes have the potential of improving performance in comparison with those subjects who just practised physical interventions without mental practice. In addition, it also lends support to Ziegler and Van Cyn et al's findings that by having the participants perform mental practice dynamically the participants get better when they physically activate the muscles required for performing the task.

It has also to be pointed out that in a study by Ryan et al (1986) it was found that when feedback about performance is not given during mental practice, as in passive mental practice, participants require correct kinaesthetic and performance feedback and that mental practice with physical practice increases the consistency of the performed motor skill. In the present study, active mental practice and directing the imagery of the participants to different parts of the body may have been equivalent to a form of kinaesthetic feedback, in which there is an emphasis on the processes involved in performance rather than on the product or outcome of those processes. On the other hand such an emphasis could also involve both performance and consistency rather than just skill enhancement.

The active mental practice type of interventions seem also to be very relevant to all of the components of the Triple Code Model of Ahsen. As each participant is oriented to parts of the body during the performance of the motor skill task the Meaning or significance of the image that each participant can bring to the mental practice intervention is greatly restricted. Therefore, the subjects would be more likely to imagine what the experimenter tells them to do rather than imagine irrelevant activity. The Somatic response is very much made aware to each subject because the enervation of the relevant muscles that occurs during the mental practice is reinforced by actual movement of the arm and body. Lastly, the Image element may be more vivid as the other two elements enable each subject to become more involved with the mental practice task, thus forcing the participant to imagine only the motor performance.

Nevertheless, even though this study found an enhancement in target accuracy it still did not show whether there is an increase in motor consistency or performance. Therefore, the next chapter will explain an experiment which investigated whether active mental practice can also affect consistency and the performance of a motor task.

As in the present experiment, it will use a natural situation but this time rather than one single stroke the task will be composed of multiple strokes. This is much more similar to the competitive game of table tennis, so the results that are going to be obtained from this next experiment should provide a much more accurate indication of the effects of active motor and mental practice interventions on motor skill tasks.

Chapter 4 - Active Mental Practice Effect in Open Skill Consistency

The results obtained in the previous chapter indicated that interventions of active imagery can improve single stroke target accuracy in a table tennis task, confirming previous reports attesting to the potentially positive effects of imagery on the execution of motor tasks. However, as was pointed out, although a considerable body of evidence indicates that the use of imagery has the potential to enhance performance, particularly in combination with physical practice, much of this is based on '*closed*' activities. That is, on movements or sequences of movements which require relatively little modification once initiated. But, as most games activities are based on series of movements with large variation and range of motor skills it is necessary to test the extent to which active motor imagery can modify established motor practices.

Thus, this chapter will try to identify studies which are specific to one single sport and that may involve more than one activity. As the effects of mental rehearsal in specific sports with multiple skills represent a recent research activity, the earliest study was the work by Shick (1969) in volleyball. She found that mental practice in serving and volleying skills resulted in better results and that three minutes of imagery intervention was better than one minute.

However, after the study by Shick, and until 1985, most studies used single activities rather than a series of movements. The study by Mumford and Hall (1985) broke away from the one motor skill procedure in order to find out how internal and external imagery could affect the performance of a '*figure*' in figure skating. The subjects had to perform a figure of 8 moving from one foot to another, and the elements of the task had not been performed before by any of the subjects. There were three types of subjects standards; novice, junior and senior skaters. Each group of subjects was divided into experimental and control groups. The experimental group was also subdivided into an internal visual imagery group, where the participants listened to imagery instructions which oriented each subject to an internal visual perspective; an internal kinaesthetic group where each subject paid attention to instructions which oriented the subjects to internal kinaesthetic sensations, and an external visual imagery condition where each subject received external visual imagery instructions. The control group just watched figure skating films similar to the task. Each subject also completed the Movement Imagery Questionnaire (MIQ) by Hall, Pongrac and Buckolz (1985) before and after the imagery interventions.

Mumford and Hall found that there was no statistical difference between the treatment groups, but they found a trend which revealed that the internal and the external visual imagery groups produced the least amount of improvement with training, whereas the internal kinaesthetic imagery group showed the most improvement. They also found that seniors performed significantly better the figure than novices but that there were no differences between novices and juniors nor between junior and senior skaters. As far as the MIQ questionnaire was concerned, Hall, Pongrac and Buckolz data found that senior skaters were significantly better at kinaesthetic imagery than either novices or juniors. These same authors also found that those subjects who were instructed in the use of mental imagery continued to use these types of interventions in the future. These authors also found that 40% of the control group skaters did mental practice outside their normal training sessions. This may explain why there were no significant results between the two main groups. Overall this study seems to indicate that mental imagery interventions may affect multi task activities in figure skating; that good kinaesthetic imagery can influence the effectiveness of training procedures and seems to be an important component in the performance of a higher quality. Mumford & Hall finished the article by stating that mental practice helped the skaters in their skating performance, and that they would use it in the future. That mental practice

> *'... definitely increased their confidence in their ability to perform the figure. ... It appears that images of a successful performance can instill in an athlete a feeling of self-confidence'*

A later study, also in figure skating, by Rodgers, Hall & Buckolz (1991), extended the above study in order to find out whether imagery training can produce better results than other cognitive interventions, such as verbalisations. They based this study by citing the work by Magill (1985) who found that the use of useful or meaningful verbal descriptions of movements aided the recall and the learning of motor skills resulting in the improvement of motor skills performance. They used two instruments, the Movement Imagery Questionnaire (MIQ) so that they could identify individual differences during movement mental practice, and the Imagery Use Questionnaire (IUQ) in order to find out the comprehension of skaters during the performance of their movements and their use of mental practice images. The authors found that the group using mental practice was the only one which showed any change in the MIQ scores, with no changes for the group that used verbalisation training and the control group. As far as the IUQ test Rodgers et al found that, before mental practice training these skaters tended to use mental practice before competition but seldom during practice, that they used mainly visual modality imagery and that they practised an external visual perspective. After mental practice training the skaters started using mental practice during practice more often. They used kinaesthetic and visual mental practice imagery, and that they made more use of an internal imagery perspective. In relation to their performance, these researchers found that those skaters who became better at their visual imagery were also better during their performance and that those who improved their kinaesthetic imagery just failed to reach statistically significant scores in their improvement.

Table tennis, is a game activity where constant movement adjustments have to be made in response to strokes executed by your opponent. These players have also to have a good understanding about the sort of spin or speed the ball has as a result of special movements of the racket. For instance, the stroke called '*top spin*' looks like the ball is moving slowly towards the other side of the table of the opponent but this is misleading as the ball gains great speed after touching the table. Thus, table tennis players have to identify the nature of their opponents strokes, decide from a range of options and initiate and execute their own shots. In such situations, the task is not just one of executing a single action, but is one of maintaining consistency of performance through an ability to keep the ball in play by utilising a variety of strokes. Taking all this into consideration, a question which can be raised is whether the use of active mental practice can help in situations where a sequence of shots has to be played, very much like the execution of a '*game plan*'. The present experiment was designed to investigate this possibility.

Method

Subjects

There were 14 participants, 12 males and 2 females.

Participants were randomly assigned to one of two groups, Control (normal training) or Experimental (active imagery), with seven subjects in each group.

Two subjects, one in each group, had not participated in the previous table tennis experiment nor had any experience of guided imagery training. All had several years experience of playing table tennis, from two years up to fifteen.

Task

The experimental task required that participants carry out 10 table tennis mini-rallies (on a competition size table). Each rally consisted of three strokes: (1) a service, (2) a chop, push or block, and (3) a top spin or drive. A completed rally was one in which all three strokes were completed by the subject, and an incomplete rally was one in which the second or third stroke was not completed. A rally was repeated if the subject's partner failed to keep the ball in play, or if the subject carried out a faulty service.

Procedure

Following an explanation of the task requirements, each subject carried out 10 rallies in order to establish baseline performance levels. On completion of the baseline assessment, the imagery group carried out 3 minutes of active imagery of the sequence of three strokes. This involved the participants imaging the rally in real time and carrying out the stroke movements. Those in the control group continued with their normal training. After three minutes of training each subject was called back and performed 10 further rallies of the same three strokes.

Results

Table 1 presents the mean number of completed rallies for the two groups before and after intervention. Each set of 10 rallies is broken down into the average for the first 5 rallies and that found for the second 5 rallies.

Table 1: Average number of successful rallies

		Baseline			Post-intervention		
Rallies		1-5	6-10	Total	1-5	6-10	Total
Control	Mean	2.28	2.00	4.28	2.00	1.86	3.86
	SD	1.38	1.29		1.00	0.38	
Imagery	Mean	2.14	0.86	3.00	2.57	4.00	6.57
	SD	1.35	1.21		1.81	1.54	

The raw data was analysed by a 3-way ANOVA. This indicated a statistically significant overall increase in the total number of rallies completed following intervention (df 1,12, F=17.7, p=0.0012). A significant interaction between group and session (df 1,12, F=28.68, p=0.00017) indicated this to be due to the improvement in performance of the imagery group whose overall mean increased from 3.0 to 6.57 completed rallies. There were also a significant interactions between groups and sessions (df 1,12, F=5.88, p=0.032), and between groups, sessions and rallies (df 1,12, F=4.76, p=0.049).

The 2-way interaction between groups and sessions is shown in Figure 1, which illustrates the improvement in performance in the imagery group in comparison with the control group. Figure 2 shows the nature of the 3-way interaction between groups, sessions and rallies which shows that much of the post-imagery improvement in the experimental group can be attributed to improved performance in rallies 6-10 rather than in the rallies immediately following imagery intervention.

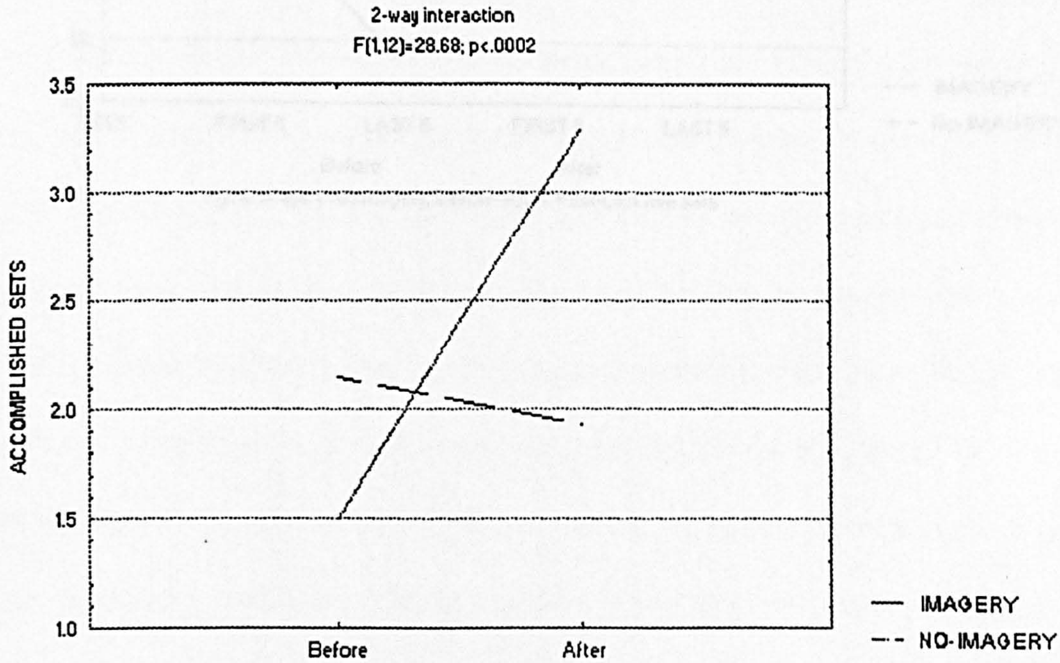


Fig: 1. Means for Imagery-NoImagery and Before-After sessions

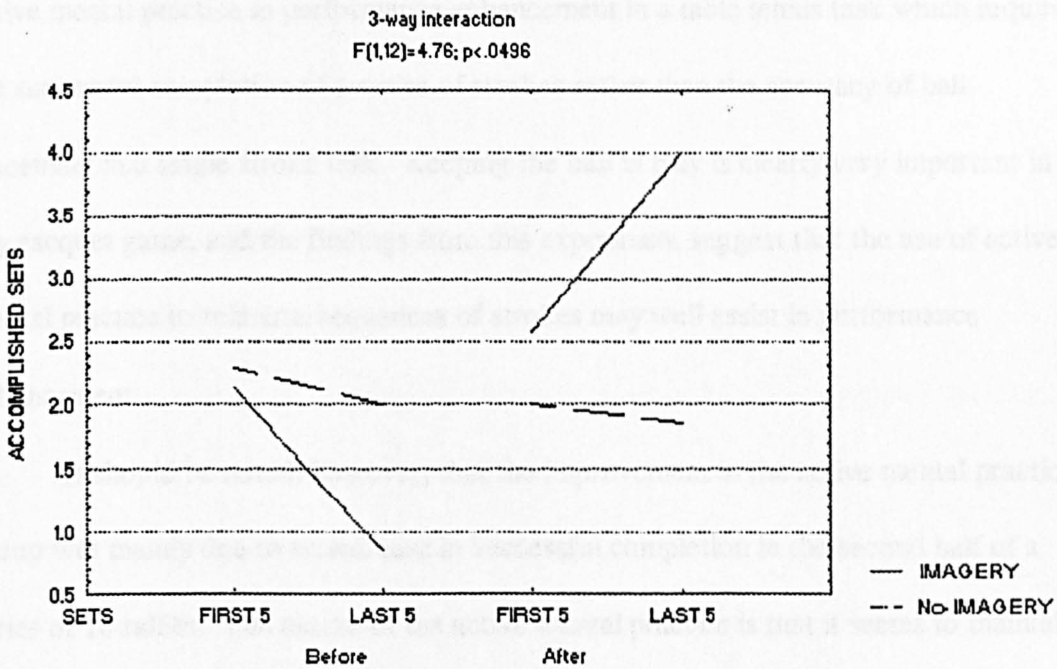


Fig. 2: Imagery-NoImagery, Before-After, First-Last five sets

Discussion

The results from this second experiment indicate the potential effectiveness of active mental practice in performance enhancement in a table tennis task which required the successful completion of a series of strokes rather than the accuracy of ball placement in a single stroke task. Keeping the ball in play is clearly very important in any racquet game, and the findings from this experiment suggest that the use of active mental practice to rehearse sequences of strokes may well assist in performance enhancement.

It should be noted, however, that the improvement in the active mental practice group was mainly due to an increase in successful completion in the second half of a series of 10 rallies. The nature of the active mental practice is that it seems to maintain the orientation of the participants on the motor processes involved so that they can carry out actions or sequences of actions. By doing this it may encourage the development of an accurate schema or mental representation of the motor skill. This idea goes in line with Decety (1991) who has proposed that mental practice '*involves an internal representation at a high level*', and also that the mental practice '*ought to take place in real time and as precisely as possible*'. Also Cox (1990) suggested that

> '...*Information that comes into STM from the sensory store is often new or original information. If we do not rehearse and memorise it quickly, we will forget it.*'

The data from this experiment suggest that one consequence of 3 minutes active mental practice is the development of a cognitive representation of the actions to be carried out. When the players return to the table, the first rallies may involve a comparison process during which the motor actions (shots) are matched against the mental model developed during the active mental practice period. Thus, one effect of active mental practice may be the development of a modified motor schema against which the participant may compare their motor activity, correcting the movements over time. As the movements become more like the schema or template developed during the active mental practice the physical activity becomes more reliable and more consistently accurate.

One implication of such an interpretation is that any application of active mental practice training should focus on the development of a correct motor schema, which can incorporate a range of sensory cues, such as those coming from visual and kinaesthetic modalities. The central theory of motor control proposed by Schmidt (1988) suggests that any motor activity is a consequence of a cognitive program resulting from the interaction between the body of an individual and the environment.

Active mental practice orients the mental processes of performers to focus on cues associated with the correct execution of the actions to be carried out. It appears that one effect of such a process is that active mental practice can not only serve to improve the execution of a single action, but can also result in an improvement in accuracy of the action over time. This suggestion seems to be supported by an assertion purposed by Magill (1989) which stated that in learning a motor skill there should be improvements over time and increasing consistency of performance.

Nevertheless there are three aspects which may require further studies on how much influence active mental practice has on the performance of motor skills and whether there are some important features of the Triple Code Model, the theoretical model this whole project is based upon, which require further investigation.

Two of these are in relation to the way the Triple Code Model influences human motor performance, which may need to be looked into more carefully. The first one is in relation to how long the improvement persists, and the second, whether physical movement dysfunction gained through a very long period of time can also be corrected via the use of active mental practice. The first issue is difficult to investigate within this project due to the time period required for such investigation, and the possibility of a large part of the participants moving away from the place of the research, as was the case in the table tennis projects. The second is more accessible because this type of work would require participants who, after undergoing some form of physical modification, had their performance of motor activity being changed by interventions of active mental practice.

The third aspect is in relation to whether the Triple Code Model can explain all the results obtained throughout the experimental work in this project. This question derives from the fact that some unrecorded qualitative data provided by some verbal comments from the participants in this experiment seem to indicate that there may be individual differences in relation to the type of imagery the subjects do during their interventions. Even though the participants are guided to orient their images to those parts of their bodies which they use during the performance of their task, they do so by creating images which use subjects's own specific imagery modalities. If this is so, there may be a need to identify the type of imagery modality people are more likely to use during their mental practice interventions so that the imagery modality language of the person doing the orientation does not conflict with the one created by the subjects.

Chapter 5 - Active Mental Practice as a Rehabilitation Procedure

The last two chapters described research experiments which concentrated on the use of active mental practice in games performance. Their results were encouraging as both of then showed that interventions of active mental practice in single and sequential motor movements can affect playing performance. The table tennis players were more accurate on the placing of the ball on the table and were able to complete a significantly greater number of table tennis rallies than before. But as was also pointed out the table tennis movements performed were learned by young people and, even though they were part of their regular playing game, they had not been used for a very long time span and are not part of normal human activity.

The question posed in this chapter is whether active mental practice can correct motor movements used by people over a lengthy time span or on a regular and continuous basis, for instance walking also called gait activity.

The way a person walks, also called gait, is probably the most visible of all human activities. The desire to move from one place to another is so powerful that it starts very early in life. The work of Gesell (1940, 1945) in early motor development has been very influential in explaining such activity. He suggested that motor development is basically dependent upon the maturation of the baby's central nervous system. This goes along according to two principles; the first is the 'cephalocaudal principle' where there is a progressive maturation of the muscles of the neck, the arms, trunk and lastly the legs. The second principle, called proximodistal, is where the muscle control of a new-born progresses from the body to the limbs. It is at this stage that the new-born starts to attempt to stand up. As this activity develops, others like the reciprocal kick reaction or the supporting reaction, all part of native reflexes, tend to disappear progressively. Also the brain of a baby during this period starts showing a higher amount of myelination at all levels, not only at the subcortical but also at the surface of the brain.

Nevertheless, recent research questions this theoretical model. For instance Zelazo (1983) does recognise that cortical maturation is very important for motor development but so is perception, cognition and experience. He found that, with practice, some primitive reflexes in a baby can progress straight into instrumental responses (Zelazo, Zelazo & Kolb, 1972). Thus, Zelazo declares that the loss of reflexive stepping is due to nurture activities which can limit opportunities for motor exercises rather than just cortical maturation. The innate motor reflexes in the new-born act as the underlying basis for later voluntary motor activity. Unfortunately the Gesell model fails to point out these aspects of learning or experience.

Normal Gait

Looking through gait analysis literature (Vaughan, Murphy, & du Toit, 1989) it is clear that gait has been studied for quite some time. Leonardo da Vinci has been cited as the first person to describe walking patterns in human beings. But real descriptions of what is nowadays known as the gait cycle were only described by the Weber brothers in 1836 (Whittle, 1996). They made very accurate measurements of human gait phases, the relationship between length as well as the duration of each step and the way a person walks and runs.

The gait cycle, as defined by Whittle (1991), is the '*time interval between two successive occurrences of one of the repetitive events of walking.*' The event he refers to is usually the moment the right heel makes contact with the floor. There are two phases in the gait cycle: the swing phase which is ascribed to the movement of the leg through the air, also referred to when the foot goes over the floor. The second phase is called stance phase and refers to the moment the foot is on the ground and the body goes over it.

This phase is again subdivided into three phases: the initial double phase stance which is when both feet are on the floor after the initial contact of the right heel. The single limb stance which is when the foot is on the floor and the foot of the other leg swings. During this period the entire weight of the individual is supported on that foot. Lastly the terminal double stance which is similar to the initial double phase but this time the initial contact of the floor is done by the contralateral foot. This phase finishes when the leg we are analysing is lifted off the floor for its swing phase.

Perry (1992), on the other hand, has described the gait cycle in rather expanded way. She claims that, up to recently, the way the cycle has been described was all right for amputees. But not for patients who showed paralysis or arthritis problems. Thus, she proposes that gait should be divided into three levels: the period level, which is divided into stance and swing; the tasks level, which is composed of weight acceptance, single limb support and limb advancement, and finally, a third level which she divides into initial contact, loading response, mid stance, terminal stance, pre swing, initial swing, mid swing and finally terminal swing.

The weight acceptance task, according to Perry, is the most demanding of the whole gait cycle. This is because the heel of the foot, which has just finished swinging, has to absorb the shock of its contact with the floor. At the same time, in order to preserve movement progression the whole limb receives the total body weight onto itself. This task is composed of two phases: the initial contact, which refers to the moment the foot touches the floor, and loading response which is the beginning of the double stance period.

The single limb support starts when the other foot lifts of the floor and starts swinging forward. During this period as the movement goes on the whole body weight is supported by one limb both sagittally and coronally. This task is made up of the mid stance phase, which is assigned to the swing of the other limb and the support limb advances over the foot by ankle dorsiflexion whereas the knee and hip extend. The terminal stance is where the swing limb is finishing its movement. On the other hand, the support limb rises its heel. The knee extends fully and it just begins to flex.

In the limb advancement task the leg and foot lift off the floor and go forward in order to start the next stance period. Unlike the old method that just described the swing as a single phase, Perry suggests a movement with pre-swing phase, where the swing limb increases its ankle and knee flexion, and the hip reduces its extension. This is followed by an initial swing, characterised by the advancement of the limb due to a hip and an increased knee flexion with the ankle with hardly any dorsiflexion; a mid swing, where the hip flexes even more, and the knee starts to extend together with the ankle going to neutral position. The final phase is the terminal swing where the hip keeps its mid swing flexion, the knee is fully extended and the ankle is dorsiflexed to neutral. During this time the other limb goes through the stance period.

Pathological Gait

Introductory gait analysis literature, like the books by Whitle and later on by Perry point out that gait abnormalities tend to be due to four problems. In one case the limbs have deformities. In another, the muscles of the legs are very weak. In another the individual lacks control of his limbs, and lastly the person experiences very strong pain which makes walking very difficult.

Gait impairment because of limb deformities is mainly due to body tissues which do not allow sufficient stride mobility. One of most common is contracture of fibrous connecting tissues that make part of leg muscles, ligaments or joint capsules. This is primarily found in people who are inactive for long periods of time, or have experienced large tissue scarring after injury. The amount of elasticity and rigidity of the of the new connecting tissues are the main causes of contractures.

A tissue that is rigid is more likely to resist stretching activity. For instance a rigid contracture on the knee inhibits the normal progression of the stance because the thigh has its advancement blocked. This results in a greater demand on the quadriceps muscle of the leg.

On the other hand, in over-elasticity the person stretches the leg muscles more than is required. For instances, during the swing period the movement of the leg is inconsistent because the individual lacks muscle sensory awareness.

Muscle weakness, on the other hand, is due to lack of muscle strength. This reduction is mainly the result of muscle atrophy because of lack of use. The cause of this disuse derives from muscular pathology like poliomyelitis, muscular dystrophy and other motor neuron diseases. But if the patient has a good kinaesthetic sensory recognition of the weak muscle, the correction of the gait cycle is very encouraging. On the other hand if the lack of muscle puissance is accompanied with a loss of proprioceptive consciousness, the patient does not know when to transfer body weight during the stance period and also at the end of the swing period the foot can hit the floor with extra vigour in order to recognise the moment of contact. That is, the person may not know the position of the hip, knee, ankle or foot during the gait cycle. This situation deteriorates if the person not only has sensory impairment but also muscle weakness. In this situation it is vital to assess the patient using standard proprioceptive methods, like reaction time of touched limbs or other parts of the body.

Lastly, musculoskeletal pain tends to be the result of extreme tissue tension. This physiological reaction normally occurs because of trauma or arthritis of joints due to deformities or muscular weakness. When a joint is swollen a person tends to minimise its movement. For the ankle the minimal amount of plantar flexion is 15°. For the knee there is an arc of between 30° and 45° of flexion, and for the hip a 30° flexion.

Pain conditions also tend to reduce activity of joints and body movements. As this lack of activity increases the muscles tend to become weaker and weaker. Thus when the joints are swollen the examiner that does gait analysis should expect less strength and the posture is more precarious.

In relation to a condition of over stretch, also called spasticity, the client usually shows brain or spinal cord injuries. This condition results in alteration of muscular control because of limb position and body alignment.

Traditional causes of spastic gait are due to strokes, multiple sclerosis, cerebral palsy and spinal cord damage. The most common display of this problem is the patient reverting to a form of primitive locomotion pattern. This is clearly shown when using mass flexion or mass extension instead of the traditional smooth transition from swing to stance periods. Mass flexion pattern occurs when the hip and knee flexes at the same time whereas the ankle dorsiflexes. In mass extension the hip and knee extensors as well as the ankle flexors work all at the same time. These patterns also do not allow the patient to develop muscle activity as in normal gait and so this could exacerbate weakness of leg muscles.

Mental Practice in Gait Rehabilitation

Until very recently, most research and articles on the use of mental practice were done with people who practice or who were learning some form of motor skill in games activity. Recently, as indicated in the second chapter, some articles have suggested other areas where mental practice can have an important role. One of those areas is physical rehabilitation.

The use of mental practice in situations where there is pathological gait in order to correct motor actions has never been used as a way in helping re-establishing walking patterns.

Orthopaedics seems to be the most obvious choice where active mental practice may have a strong influence. The main goal of this branch of medicine, in the same manner as in the performance of physical games, is to improve some aspect of motor skill performance. Thus the use active mental practice may be an important addition to standard rehabilitation interventions, such as in arthroplasty surgery of the knee.

Knees which show adduction (varus) and abduction (valgus) conditions are very debilitating and their development can start at very early age.

The varus condition is characterised by a medial tilt of the tibia and medial displacement of the foot relative to the knee. The alignment of the femur is also altered as the hip abducts in order to accommodate the displacement of the foot. In a standing position, the distance between the knees is larger than that between the feet.

The valgus knee is ascribed to an excessive lateral deviation of the tibia from the centre of the knee. This causes the knee to be displaced medially from the line between the hip and the ankle. During standing the distance between the feet is greater than at the knees.

These knee deformities can be the result of intrinsic congenital or developmental abnormalities.

As a person gets older, development of conditions such as osteoarthrosis of the knee, which is characterised by a progressive deterioration of the joint cartilage and bone, leads to an unbalanced body weight. This puts a greater load at the top of the tibia which can result in varus knees.

On the other hand, rheumatoid arthritis in the knees can have a great influence in the development of valgus knee contours as well as paralytic gait (Perry, 1992).

Any of these knee conditions give rise to a pattern of gait performance different from normal. People tend to accommodate their gait through their life span as the problem can increase with age. In those who display excessive varus knees, their gait is characterised by having problems when they swing their feet during walking, but more so during the placing of their feet on the floor, as they tend to put greater pressure on the lateral side of their feet. On the other hand, during excessive valgus condition, the problem with the gait cycle is shown when the foot is placed on the floor. During this period the medial arch of the foot makes contact with the floor, as well as the first metatarsal.

Later on, due to the pain that any of these leg conditions can give, the only solution is to have a total knee-replacement surgery.

After surgery, even though the shape and structure of the knee and leg are corrected, people still perform according to the pattern of walk they used previously. For instance, a study by Chao, Laughman, & Stauffer (1980) found that the main improvement in total knee replacement was only an improvement in knee motion. Also, a study by Murray, Gore, Laney, Gardner & Mollinger (1983), suggests that patients still show a deficiency in terminal knee extension after 24 months post-operation. Thus, this suggests that correction of bone structure is not enough in order to correct the way a person walks. Gait patterns that are developed along many years can take lots of effort and time to correct.

The most common complaint from those who are in charge of rehabilitating patients from these conditions, like physiotherapists, is the time it takes the patients to correct their gait performance. These patients tend to correct their gait when they have been told to do it but later on they tend to revert to their old pattern.

The situation is such that Simon, Trieshmann, Burdett, Ewald & Sledge (1983), have suggested a postoperative program with weightbearing exercises on the second day after surgery, followed by gait training on days eight to ten. After discharge, the patients still have to ride a stationary bicycle without resistance for a minimum of 20 minutes a day. Also, a more recent study by Skinner (1993) declared that even though arthroplasticy of the knees can free a person from pain, '... *previous gait problems ... seem to prevent most patients from regaining normal gait*'.

Taking into consideration all the above research, together with anecdotal evidence provided by physiotherapists through informal contact, it seems reasonable to conclude that the gait performance of people who have undergone knee arthroplasticity may not reach the sort of standard made possible by surgery. Also, it seems that although traditional gait correction techniques have an impact and are useful in rehabilitation, they do not seem to be effective at changing old gait patterns. This was indicated in a study by Andriacchi, Galante & Fermier (1982) who looked at how total knee replacement affected walking and stair climbing and suggested that abnormal gait after surgery could be due to various factors such as loss of proprioceptive control as well as to the incapacity of modifying their preoperative gait performance. A more recent article by Wilson, McCann, Gotlin, Ramakrishnan, Wooten and Insall (1996) confirmed the speculation by of Andriacchi et al. Wilson et al found that four years after surgery, spatiotemporal gait cycle produced by the transplanted knee was very similar to normal, but there were gait abnormalities which could not be explained via weakness of the muscle or dysfunctional knee action. This goes along with narrative communicated by physiotherapists, who have commented that the correction is maintained for the duration of the intervention at that time, and that these people need to repeat the procedure many times over. If the patients are not continuously reminded of these exercises they often forget them or else become bored and eventually stop doing them.

As was suggested by Schmidt (1990), '... *Rehabilitation tends to focus on muscle strength, neural control, bone strength and cardiopulmonary efficiency*'. This approach tends to leave out the perception the patients can have of what they want from the treatment. Thus, by introducing mental practice strategies, it may be reasonable to suggest that individuals under treatment can develop an active interest their own therapy which could result into the development of a personal cognitive model of rehabilitation, as was found in the work by Hall, Pongrac & Buckolz (op cit) study on skaters as described in the previous chapter. This would enable the patient to know what sort of movement they should perform after surgery, enabling them to have better control over the movement process, gait correction or any other motor activity.

The following studies that used mental practice in rehabilitation, have been concerned mainly with the improvement of balance and posture. They have also shown that the type of imagery each participant does might have an influence in the outcome of the interventions. Two of these studies used idiokinetic imagery. This type of imagery has been described by Sweigard (1974) as requiring subjects to imagine sensory and visual types of imagery movement so that they can become fully aware of their bodies.

One of these studies was by Fairweather &Sidaway (1993), which was concerned with postural development, and found that the idiokinetic imagery intervention was able to improve posture and reduce low back pain. An earlier study by Fansler, Poff, & Sheppard (1985), studied the balance on elderly women which is one of the major problems in people in this age range. They found that idiokinetic imagery together with physical practice improved significantly the time participants stood on one leg.

A more recent investigation by Linden, Uhley, Smith and Bush (1989) on walking balance of elderly people, found that traditional mental practice had a significant impact on the equilibrium reactions of these subjects only when walking and carrying an object in each hand, as described in the second chapter.

Another area in which mental practice has been shown to have some impact is in the encouragement of exercise practice in old people. A study by Riccio, Nelson & Bush (1989), in women between the ages of 62 and 96, found that imagery evoked more repetitions of reaching-up exercises than the control group.

One major problem with rehabilitation and its strategies is that a literature search done on Medical, Social Science and Science Citation Indexes as well as Psychological Abstracts on how pain and the feeling of pain interacts with the desire for physical exercises after surgery, and in particularly orthopaedics, has produced no articles at all. Anecdotal communication provided by physiotherapists seems to suggest that they tend to encourage their patients to carry out exercises via the use of arousing type of language. This type of intervention is also used frequently in games and athletics activity and Rushall (1979), one of main advocates of this technique, has proposed that the thinking or the verbalisation of '*mood words*', which have a direct connection with the appropriate movement, can provide the sort of attention orientation and the arousing desire to perform well during competition or demanding training situations. For instance, a series of studies with children by Meichenbaum & Turk (1975) found that a task was improved when the participants thought or pronounced the words '*faster, faster*' at the same time as they were performing the movement.

For mood words to have an effect, Rushall declares that they have to fulfil two conditions. One, they have to be appropriate to the performance an individual is doing, and secondly, they have to convey movement content so that they can elicit some emotional feelings in the performer. Thus, when gymnasts say '*I am able to do difficult tricks on the vault*' this would orient the attention of these people to what they are capable of doing but with the added benefit of creating a feeling of confidence in their abilities. More so when the above phrase is supplemented with statement like '*I am confident and strong*'.

On the other hand, when this sort of intervention is performed by physiotherapists in postoperative patients, it may not predispose them to generate cognitive mental strategies of what they have to do but they are used mainly as a way to overcome the pain patients are feeling during the period of time they are performing the motor exercises as described by the professionals. This may not be enough for these patients because they may not have an idea of what are the goals of the exercise. In a study by Samples (1987) on injured athletes, he found that it was important to inform them of the type of injury they had the method that was going to be used on their rehabilitation, and the problems they were going to encounter. Likewise, people who experience knee arthroplasticity may need to have similar information so that they can develop their own motor rehabilitation strategy.

The procedure the patients are going to use in learning such strategy will determine what sort of gait performance the patients are going to show later on. This is what is found when looking at performance curves, like those showed in Schmidt (1991), which tend to appear continuous lines without decrements. The learning slopes are smooth and going upwards when participants are learning motor tasks.

This study proposes that the use of active mental practice intervention on basic physiotherapy exercises during the rehabilitation period would enhance the development of rehabilitation strategies in patients who have been through knee arthroplasticity so that their knee flexion would act and react according to what is expected by physiotherapists after such operation. The performance of the flexion of the knee after arthroplasticity in those patients who receive active mental practice would be continuous and in a progressive manner. Further, the use of active mental practice strategies could then be used by the patients in order to correct their gait cycle performance and to produce better outcomes than those who do not go through the active mental practice procedure.

Method

Subjects

There were six participants in this experiment. Four females and two males. Their ages varied between 66 and 89 years old. All females had received operations to correct varus knees, whereas one male had varus and the other valgus knee.

In the experimental group, the two females had surgery on the left knee and the male on the right. In the control group, which received mood words, one female had surgery on the left and the other on the right knee and the male on the right.

Experimental group		**Control Group**	
Gender	Knee	Gender	Knee
Female	Left	Female	Left
Female	Left	Female	Right
Male	Right	Male	Right

It has also to be pointed out that one male in the experimental group and one female in the control group also had rheumatoid arthritis in the foot of the leg and were due to have surgery.

All subjects participated voluntarily in this project. They all agreed to perform the exercises and they did not show negative attitudes to the new intervention. They declared also that they never had practised any form of active or non-active mental practice during their lives.

One comment about the physiotherapists who helped with this experiment is that they had no knowledge of active mental practice interventions and that throughout the experiment they assumed a doubting attitude regarding the effects of what active mental practice could do to patients, in that they declared they did not believe that it could produce any effects on the rehabilitation processes.

Procedure

Before the start of the experiment the hospital rehabilitation team and the psychologist met in order to decide which exercises the patients were going to do during the rehabilitation period. It was decided that the measurements should be taken when the patients were exercising knee flexions. Of the various exercises used in knee flexion during rehabilitation, it was decided to take measurements during the exercise where the patients sit on the bed with their legs making a 90º angle. The subjects then had to flex their operated knee so that the foot goes under the bed (Clarkson & Gilewich, 1989), corresponding to the flexion-extension rotation on picture 1 on next page. The picture 2 below shows a physiotherapist helping a patient bend his knee.

Fig. 2: Patient bending his knee as instructed by a physiotherapist.

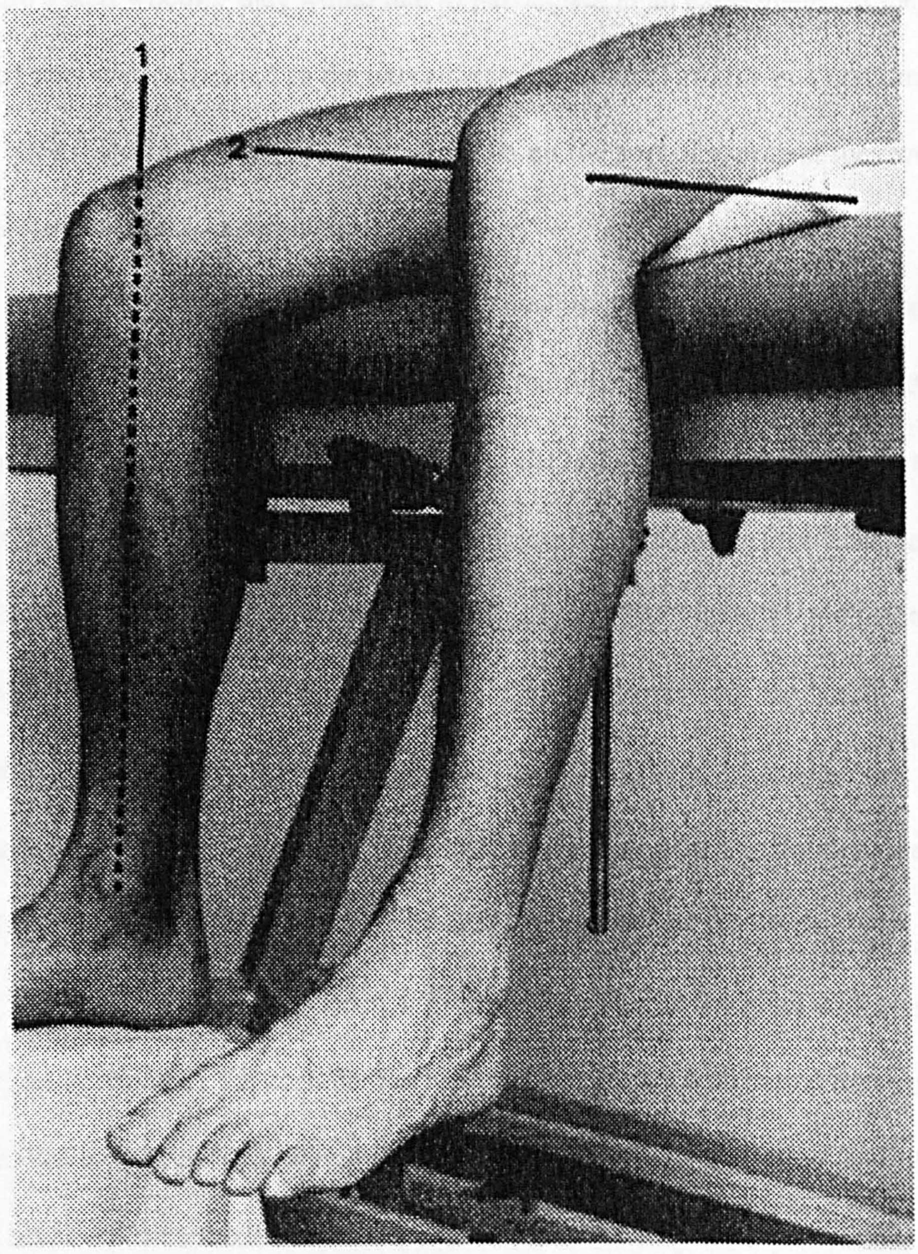


Fig.1 Knee Joint axes: (1) Tibial internal-external rotation; (2) flexion-extension rotation.

After surgery, and as soon as the patients had recovered from the anaesthetic, they were asked whether they would like to participate in an experiment. If they accepted they were allocated to the experimental or control groups in a random order.

All subjects received a short explanation on the sort of exercises they were going to do during the experiment.

After this explanation an experienced physiotherapist marked the leg that was operated upon with three marks. One mark on the top of the Greater Trochander, another on the top of the Lateral Epicondyle of the femur and the third one on the top of Lateral Malleolus on the foot. In order to measure the flexion of the knee before and after the interventions, the physiotherapists use a large 360º universal goniometer. The measurement was done by placing the axis of the goniometer over the lateral epicondyle, the stationary arm was pointed towards the greater trochander and parallel to the longitudinal axis of the femur, whereas the movable arm was pointed down towards the lateral malleolus and over the longitudinal axis of the fibula.

The subjects in the experimental group were asked to imagine, with eyes closed and for ninety seconds, the knee flexion movement together with actual movement. Each flexion took about ten seconds to be performed, which means that overall each patient did about nine flexions for each intervention. As they were performing active mental practice this group heard also mood words as explained by Rushall early on. The mood words were '*bend, bend*', and '*bend a bit more*' which provided information on the direction of the movement they were going to perform. These words were also similar to those used by the physiotherapist during her normal rehabilitation interventions.

In contrast, the control group performed the same exercises, at the same rate and time period, and with their eyes closed as in the experimental group but this time they were only encouraged to do knee flexion with the same mood words as in the experimental group but without active mental practice.

The measurements for each of flexion of the exercised knee were taken as soon as the patients reached the maximum amount of flexion during each intervention. Thus, overall, there were nine measurements for each practice period for each subject and for both groups.

Each subject stopped receiving rehabilitation training as soon as they could flex their knees up or close to 80º. Two of the subjects, because of their rheumatoid arthritis in their foot, received rehabilitation exercises up or close to 50º.

Results

The time to discharge the patients from the hospital were very similar for the control and experimental groups. The physiotherapist in charge of the measurements reported that four of the six participants were able to flex their knees to 80º as required by the standard physiotherapy procedure by the fifth day after the patients had started with their rehabilitation exercises. The other two, the male in the experimental group was only able to flex his knee on the sixth day whereas a female in the control group was able to do the required measurement by the fourth day.

On the other hand, looking at the way the rehabilitation went for each subject, a linear regression analysis on each individual knee flexion data for each day of intervention showed that the three subjects in the experimental group, that is, those who used active mental practice, had a steady and significant knee flexion increment, having analysis values of $F(1,3)=25.83$, $p<0.015$; $F(1,3)=38.1$, $p<0.0085$ and $F(1,4)=117.63$, $p<0.0004$, for the two females and male respectively, whereas the participants in the control group who heard only mood words, showed a larger variation in their knee flexion data values during their measurements as shown by the linear regression analysis of the data as $F(1,2)=6.48$, $p<0.125$; $F(1,3)=7.9$, $p<0.067$; and $F(1,3)= 6.13$, $p<0.089$ for the two females and the male in turn.

The graphs 1 to 6 represent the regression analysis on the variations of the knees for the experimental and control group, being 1 to 3 for those subjects who received active mental practice and the 4 to 6 for mood words.

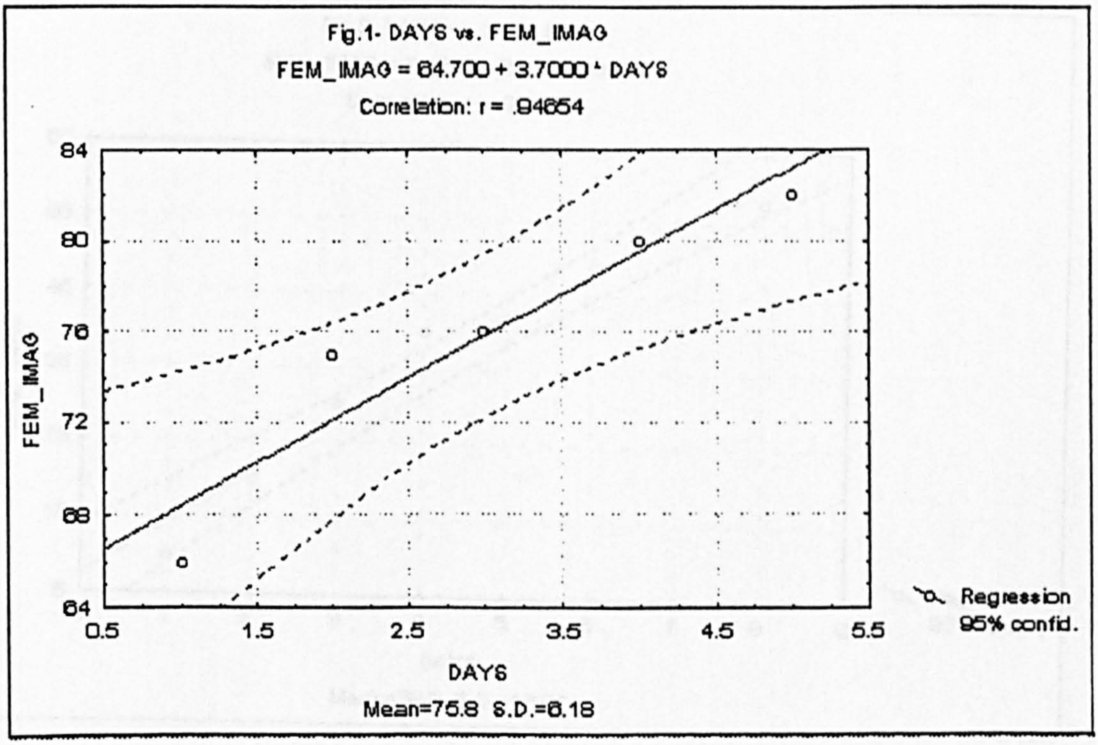


Fig.1- DAYS vs. FEM_IMAG
FEM_IMAG = 64.700 + 3.7000 * DAYS
Correlation: r = .94654
FEM_IMAG
84
80
76
72
68
64
0.5
1.5
2.5
3.5
4.5
5.5
DAYS
Mean=75.8 S.D.=6.18
Regression
95% confid.

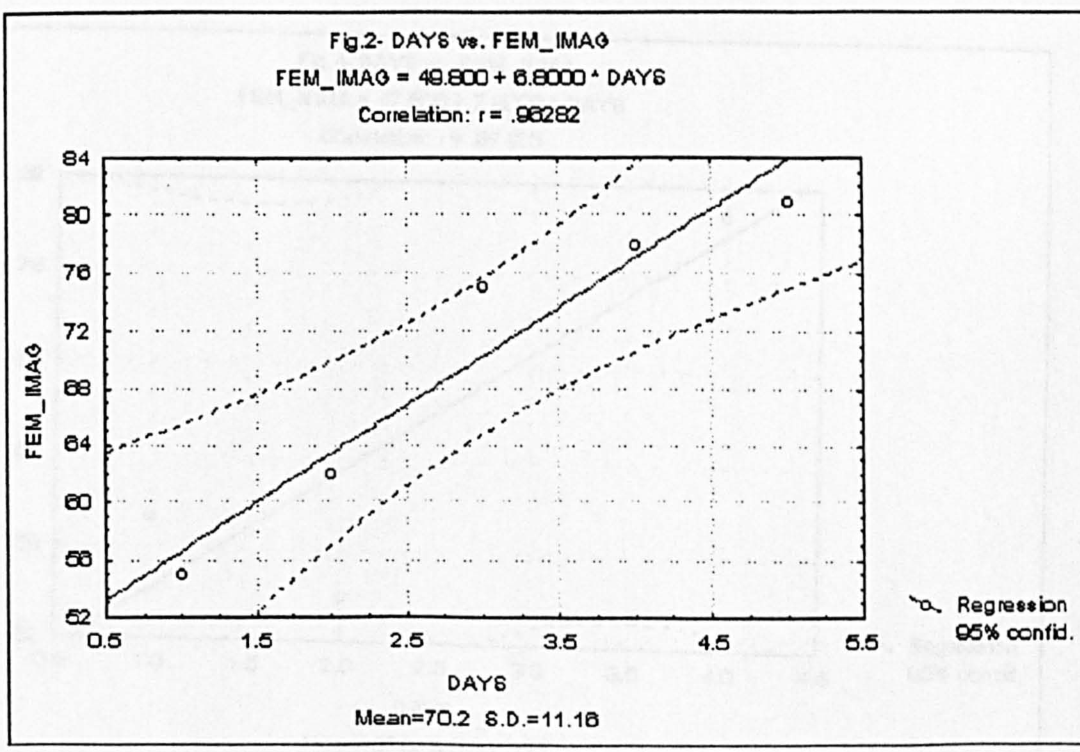


Fig.2- DAYS vs. FEM_IMAG
FEM_IMAG = 49.800 + 6.8000 * DAYS
Correlation: r = .96282
FEM_IMAG
84
80
76
72
68
64
60
56
52
0.5
1.5
2.5
3.5
4.5
5.5
DAYS
Mean=70.2 S.D.=11.16
Regression
95% confid.

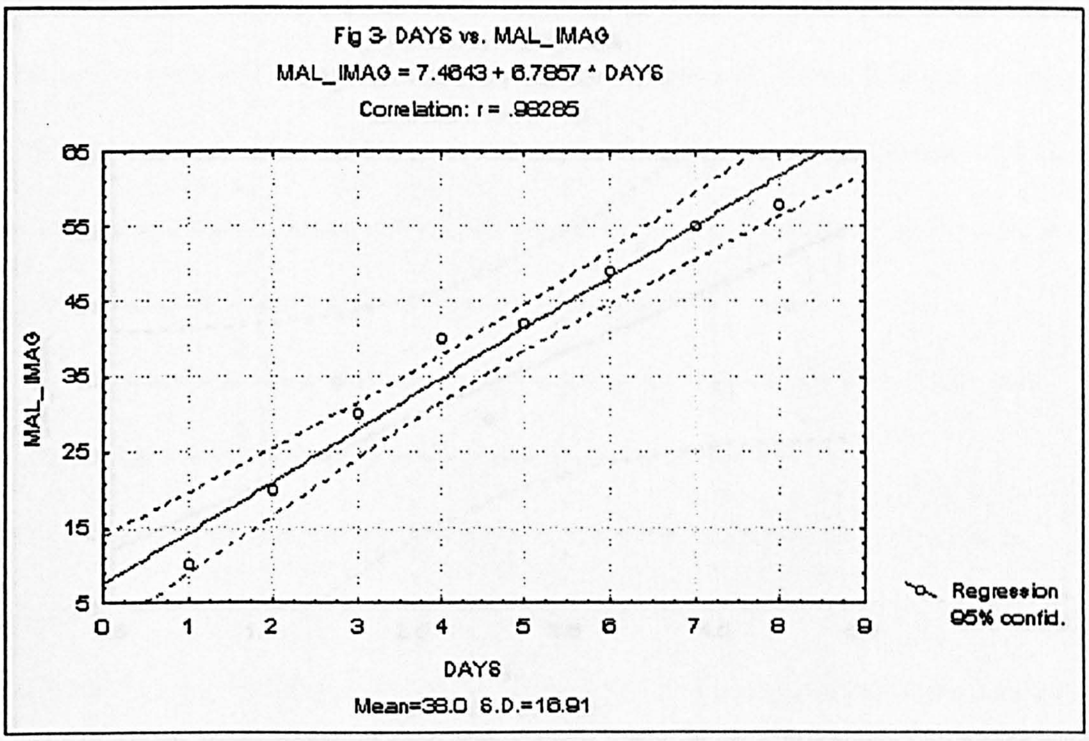


Fig 3- DAYS vs. MAL_IMAG
MAL_IMAG = 7.4643 + 6.7857 * DAYS
Correlation: r = .98285
MAL_IMAG
DAYS
Regression
95% confid.
Mean=38.0 S.D.=16.91

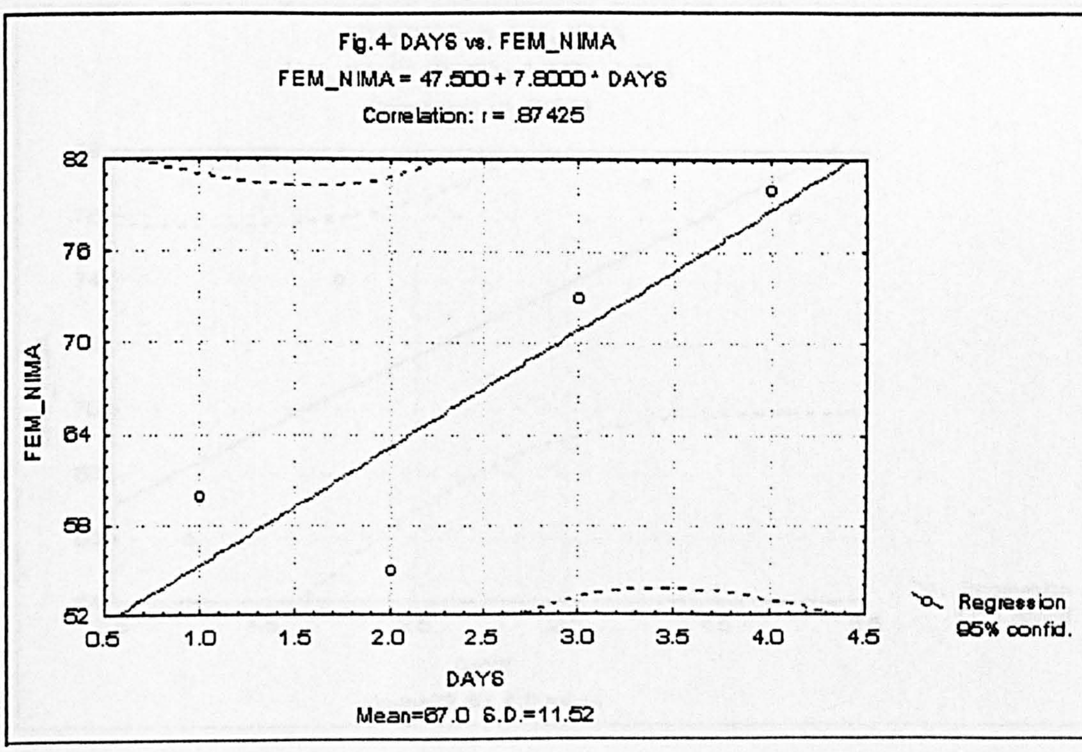


Fig.4- DAYS vs. FEM_NIMA
FEM_NIMA = 47.500 + 7.8000 * DAYS
Correlation: r = .87425
FEM_NIMA
DAYS
Regression
95% confid.
Mean=67.0 S.D.=11.52

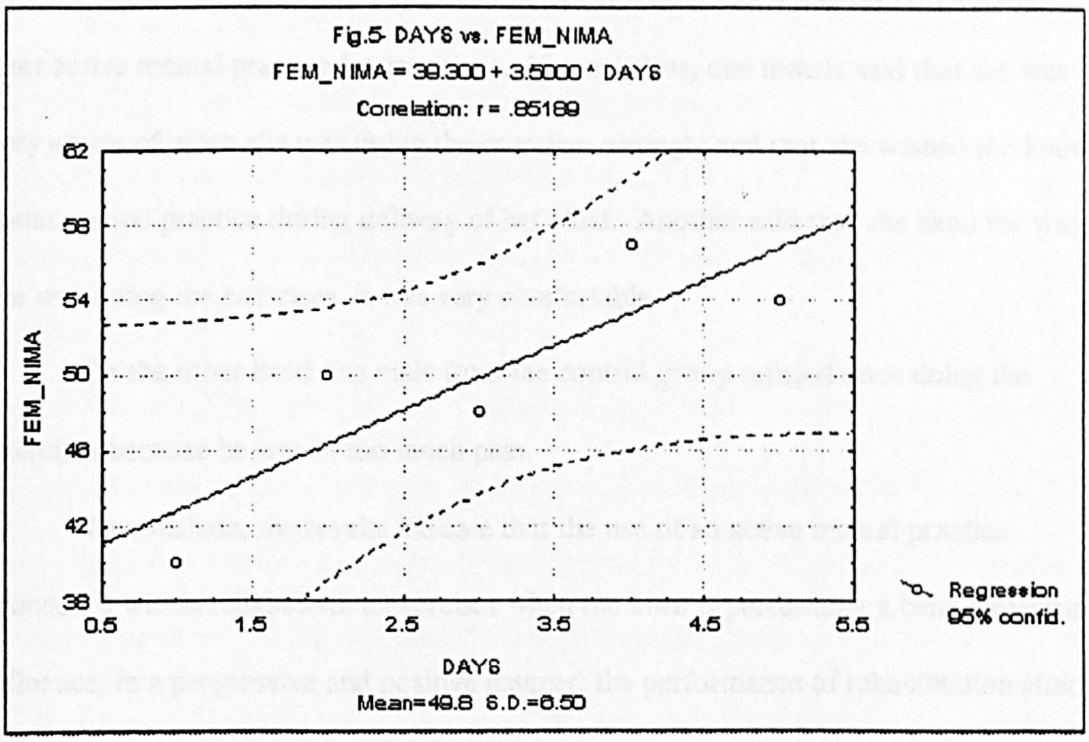


Fig.5- DAYS vs. FEM_NIMA

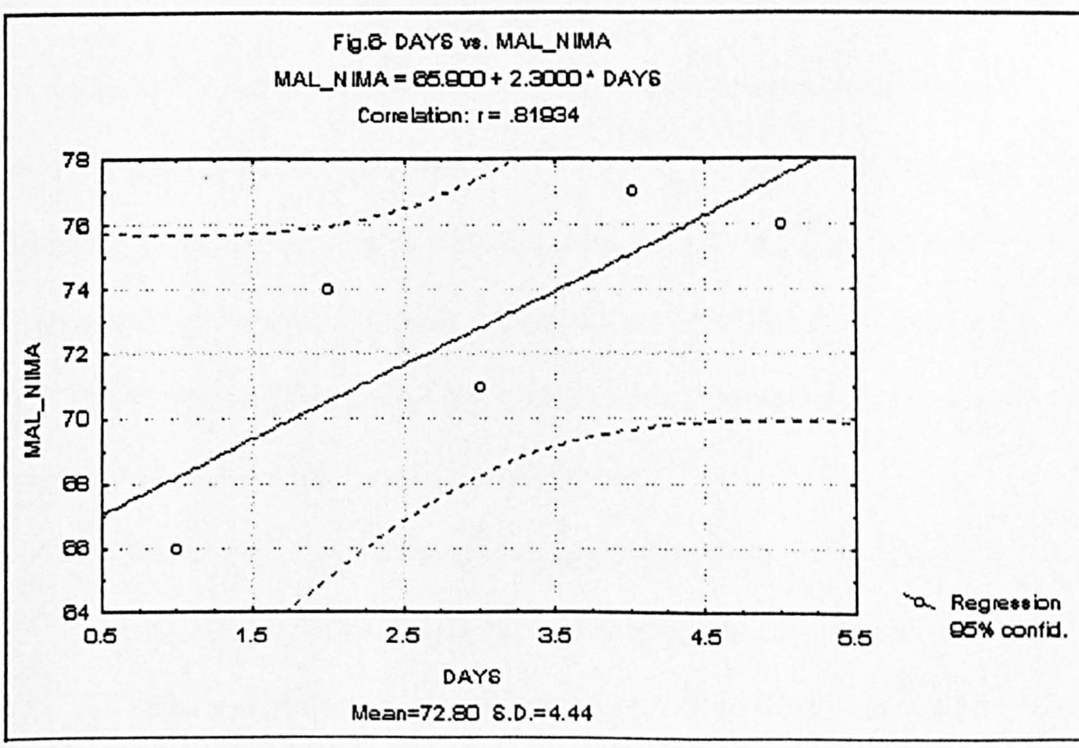


Fig.6- DAYS vs. MAL_NIMA

There were very few verbal comments expressed by the patients during and after active mental practice interventions. Nevertheless, one female said that she was very aware of when she was doing the exercises wrongly and that she wished she knew about mental practice during delivery of her child. Another said that she liked the way she was doing the exercises, it was very comfortable.

On the other hand one male from the control group refused once doing the exercises because he was in too much pain.

To conclude, the results indicate that the use of an active mental practice procedure within rehabilitation exercises when the knee is performing a bend move can influence, in a progressive and positive manner, the performance of rehabilitation after total knee arthroplasticity.

Discussion

The main result of this experiment shows that active mental practice can affect the way the recovery is achieved for patients after arthroplasticity of their knee. Those patients who were encouraged with just mood words during their knee exercises were not able to increase their knee bending in a continuous way like those in the experimental group.

The anecdotal verbal evidence from some participants seems also to suggest that active mental practice may have helped these people to focus on the task, and so they may have put more importance on the physical motor action. The active mental practice intervention may have enabled these participants to orient their cognitive processes towards the performance of the bend task rather than becoming aware of the sensation of pain that the participants from the control group may have been perceiving during the performance of rehabilitation exercises when they were hearing mood words. This suggestion is supported by an investigation done by Sanders & Hammer (1979) which tried to find out the reasons why imagery, as used in cognitive-behavioural therapy, is effective in pain treatment. They found that attention, motivation and expectancy are more important than reinforcement and conditioning. These last two being more akin to what mood words are more likely to be related to. An article by Green (1994) suggest that mood words, which he calls '*trigger words*', can be useful in associating them with mental practice. He says that

> *'The use of trigger words as imagery pegs that trigger a motor program before a play can be developed through mental rehearsal. By mentally rehearsing an instant ... via trigger words, the athlete becomes somewhat conditioned to think in that manner just prior to execution. Ultimately, the athlete attempts to eliminate as much self-*

talk as possible so that he/she thinks exclusively in images'.

Earlier on a study by Nigl (1982) found that '*the patient's abilities and skills in visualisation may be very important factors in producing a positive treatment effect*'. In a later book Nigl (1984) suggests that, when patients use imagery or visualisation techniques, they should '*actively imagine scenes during the session*'. It seems that active mental practice may do what he suggested because the patients during this experiment not only imagined the knee movement but it also allowed them to engage in a real motor task thus co-ordinating both the cognitive intervention which activates the brain cell array that controls the knee bending together with the activity of the leg muscles.

Looking back at the Subjects section we can find that one problem with this project was that, probably due to their age, there were more female participants than males, and that the females in the experimental group could have been better at creating active mental practices of the exercises than males. Females also found the active mental practice very useful to the point that, as soon as they were taught how to do the intervention, they would do the knee exercise only if they could use the intervention for all rehabilitation movement exercises. Also, the male from the experimental group was at first very aware of the pain coming from the knee and could not bend his knee, but he started bending it as soon as he started using active mental practice during the exercise.

As far as gait activity is concerned the physiotherapist, based on her visual analysis only, reported that those who did active mental practice looked different from when she saw them before any sort of active mental practice interventions. Overall, these patients tended to show gait problems like hip hiking, abnormal hip rotation and abnormal walking base. The man and one of the women in the experimental group had their gait performance corrected by the third day and the other female by the fifth day with going up stairs on the sixth day. On the other hand the use of standard physiotherapy strategies, which involved the use of just walking and pointing out the problems as the patients walked, were less successful in any of the three subjects by the fifth and sixth day. Even though they showed some corrections as they were walking they would go back to their initial movement performance the day after.

As the physiotherapist helping in this experiment was also involved during the periods where the participants received their active mental practice, it was decided to video tape the gait skill of the male subject before and after each session in order to have it analysed by another physiotherapist who had no contact with the experiment. The visual analysis of this video by the physiotherapist confirmed previous reports by the previous physiotherapist in that she agreed that active mental practice did correct the gait dysfunctions and that she did not notice any repetition of the same problem on the following day. Afterwards, both physiotherapists suggested that active mental practice could be effective at changing gait problems.

Even though the visual analysis of gait performance can be very precise, people still do tend to observe certain patterns and may leave others. As mentioned by Perry (1992) if the observation does not follow a precise methodology, there is a '... *natural tendency to focus on the obvious events while overlooking other, more subtle deviations, which may be highly significant.*' The alternative is to use a special type of equipment which is capable of analysing gait so that it can provide accurate measurements and deviations consistently and reliably. However, the technology that analyses gait is expensive and/or awkward to use. Thus it was decided to investigate whether the present computer and video power at our disposal may be able to provide a less expensive and easier way of analysing gait activity in humans.

Chapter 6 - Active Mental Practice Effects in Correcting Gait Performance

We can deduce from the previous experiment that active mental practice is capable of influencing the way individuals progress their rehabilitation and gait.

But, even though the physiotherapists did agree among themselves that the active mental practice was able to change gait patterns after looking at the patients or looking at a video, there was no quantitative data which would have allowed more secure conclusions to be made. Therefore there is a need to find a way to check sequences of movements before and after active mental practice interventions via some technical means. This methodology would provide not only a more accurate gait pattern analysis but also the possibility of replication and analysis of the same data by other analysts.

Instrumental Methods of Gait Analysis Systems

The use of instrumentation on gait analysis is done mainly in three situations. When there is a need to measure gait problems in people who have cerebral palsy in order to help identify which part of the body should have surgery or orthotic procedures. In patients with Parkinson's disease or muscular dystrophy so that the dysfunction can be monitored as it progresses. Lastly in people who have to go through orthopaedic surgery so that their gait patterns can be quantified before and after surgical interventions (Davis, Öunpuu, Tyburski & Gage, 1991).

Analysis of normal gait pays particular attention to the sagittal plane, which refers to a plane separating the left side of the body from the right side, and the motion of the ankle, knee and hip. During one gait cycle the ankle at the loading response phase starts with a plantar flexion of about 7°, then a dorsiflexion of 10°, followed by a plantar flexion of 20° and finishes in a small dorsiflexion and back in neutral position when reaching the mid swing phase of the cycle.

The knee at the initial contact of the cycle is flexed by about 5°. It then flexes up to about 18° during the loading phase, and extends to about 5° at the end of the terminal stance phase. It then makes a flexion of up to 65° at the end of the pre-swing phase, keeps extending during this phase until 2° at which moment the heel of the foot is placed on the ground, this position being called terminal swing.

The hip usually goes through arcs of motion during each gait cycle. It extends during the stance period and flexes during the swing. Thus it starts with a flexion of 30°, and goes to an extension of 10° at about 50% of the stride, finishing with a flexion of 35° at the terminal swing phase.

Overall, there are five measurements which can be made during device's oriented gait analysis. Two of them concentrate on the effect of walking on the individual. Of these, the first one tries to find out the type of stride the patient has in order to measure the walking capabilities of the patients. From this measure a second measure is obtained which can indicate the amount of energy the patient uses when walking.

The other three measures concentrate on the different parts of the gait cycle.

i- The weight bearing the individual puts on the foot, as during the stance period, which is measured via force plate instrumentation;

ii- The intensity of the muscles, repose and the time they take to perform one gait cycle which is measured via electromyography, also called EMG;

iii- Motion analysis, which is going to be used in this chapter, and which pays particular attention to the timing and angle range of each leg joint during walking.

Walking is very difficult to measure. Even though most of the arc joints happen on a sagittal plane, there is also very small activity in the coronal - front and back of the body - and transverse - upper and lower parts of the body - planes. Because some of these variations are the ones that disabled people tend to show, it is important to pay particular attention to the way the gait cycle is analysed. For example, if the gait is analysed just from a lateral view point and if the person does some internal rotation of the limb it is possible to underestimate the flexion of the knee.

The traditional way of measuring gait cycle is by placing a goniometer on the leg. This instrument serves to measure the angle of any joint in the body, and its size varies according to whether the measurements are done on fingers or legs.

The first electrogoniometer was made in such way that its two bars were strapped to the leg, one on the thigh and the other on the leg. The main problem with this set-up was that its original alignment with the leg deteriorated as the person walked along a path.

More recently there have been a few alternatives not just in the way the flexions and extensions of joints can be measured but also in the way these measurements can be taken.

There are still electrogoniometers being made and in use today. For instance, the parallelogram type is placed over the knee and ankle, or the triaxial parallelogram electrogoniometer that can measure non-sagital plane activity. But with the advent of very accurate strain gauges, parallelogram type of electrogoniometers are on the decline and nowadays it is possible to measure most walk planes by placing these gauges on the joints at different axis locations.

Even though this technology can provide accurate measurements, it can intrude on the way people perform their motor actions as people are aware of the instrumentation on their limbs. Thus, even though the analysis of the movement is accurate it does not correspond to actual movement in a real situation. In order to eliminate this problem the use of video and computer analysis of the video on gait analysis has become an acceptable alternative. Nowadays, this technology seems to be more feasible due to the lower price of computers, software and video cameras.

This type of technology is an extension of the kinematic systems which originally used movie cameras with a wide frames per second speed which ranged from 50 through 500 frames per second. This sort of speed allows clear and sharp gait measurements, as well as the possibility of having a group of experts analyse the motor skills performance of the patient. Nevertheless there are a few problems with this technique such as the time it takes to have the film processed and the capture of the data points from the film into the computer which requires special equipment in order to digitise each frame at a time, and the software to analyse each leg marker. The commercial programs are very expensive, as is the dedicated equipment, and so this requires a heavy investment from each gait laboratory.

In order to find out the arcs and the position of the joints one by one, we have to find out and agree on standard joint landmarks.

The most important skin surface marks for sagittal plane measurements are the hip, the knee and the ankle. At the hip, the marker is located at the greater trochanter. At the knee the position is located over the lateral epicondyle of the femur. On the ankle the skin surface marker is placed over the lateral malleous, and lastly a marker is also positioned laterally over the fifth metatarsal in order to measure ankle dorsiflexion.

For measurements done from a coronal plane the skin marks are located on the two anterior superior iliac spine positions, another at the middle of the patella on the anterior centre of the knee, and a third at the middle of the distal tibia for the ankle.

The most simple method to measure sagittal plane gait motion is to place a single camera at a right angle to the plane of motion. Also, it has to be placed some distance away from the subject so that perspective distortions are minimised. Later, in order to measure coronal plane motion the camera can be placed in front of the patient and at some distance away to reduce measurement inaccuracy, similar to sagittal plane motion analysis.

Before doing any kinematic gait analysis, it is advisable to look at the patient and do some eye interpretation of the gait so that the overall problem may be identified. There are already some standard observational gait analysis methods. One of them is the '*Full body observational gait analysis form*' from The Professional Association of Rancho Los Amigos Medical Centre (1989).

The video analysis of gait made by people should have, in general, a representation via a graph or picture so that the amplitude of the angles done by the major angles of the leg are shown for general examination. That is, angles of the hip, knee, and the ankle. This technique is appropriate unless the gait problem is clear and can be localised to a particular part of the leg. This section will describe a case study of a young girl with gait problems and the video analysis technique used to investigate her gait cycles. The hardware and software used in this project are readily available and affordable by any gait analysis unit .

Method

Subject

The subject for this case study was a Portuguese female aged 12 years old. She was submitted to the hospital for radiological and visual observation due to very strong foot pain particularly in the right foot. The analysis showed that her feet had a bilateral '*planus valgus*' and bilateral '*calcaneus valgus*'. After surgery, she did not experience any pain in the left foot, but the right foot was very painful which, in order to counteract the pain, made her develop an abnormal walking base with an excessive knee extension. Sixteen months later, even though she did not have any pain on the right foot, she still displayed a gait pattern similar to the one she had developed from the period when she felt pain. Traditional methods of gait correction, like feedback from mirrors, failed to produce any further corrections. The physiotherapist and the three rehabilitation physicians who helped with this project considered this person to be an ideal candidate for active mental practice intervention.

The control subject was a male physician who did not show dysfunctional gait patterns.

System Overview

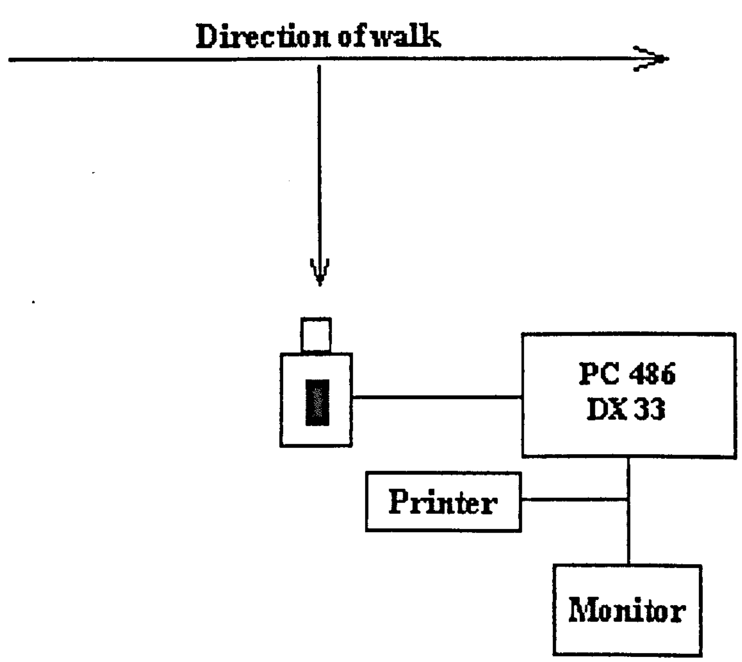
Hardware

The hardware for this case study consisted of two instruments. A video camera and a multimedia video capture card .

The video camera was a ready available commercial CCD model. Nevertheless the quality of the CCD was taken into consideration and the model selected was a camera which had a resolution of 1024x768 pixels, which is becoming a standard for every video recording system.

The video capture card was a '*Media Pro Plus*' made by '*Rombo Ltd*'. This company now goes under the name of '*Quantum Leap Software Ltd*'. This card has a 1024x768 resolution and 64,000 colours. It comes with its own software and it requires a normal PC computer and a VGA card with a Feature connector. When the card is installed inside the computer it takes over all its video functions. It can display normal pictures from any sort of software as well as being able to digitise all PAL (EUROPE) and NTSC (USA) video signals from any composite video sources in real time.

The picture 1 below shows a diagram of the hardware setup.



Picture 1- The diagram of the computer and CCD camera. The arrows indicate the direction of walk of the participants along frontal and sagittal planes

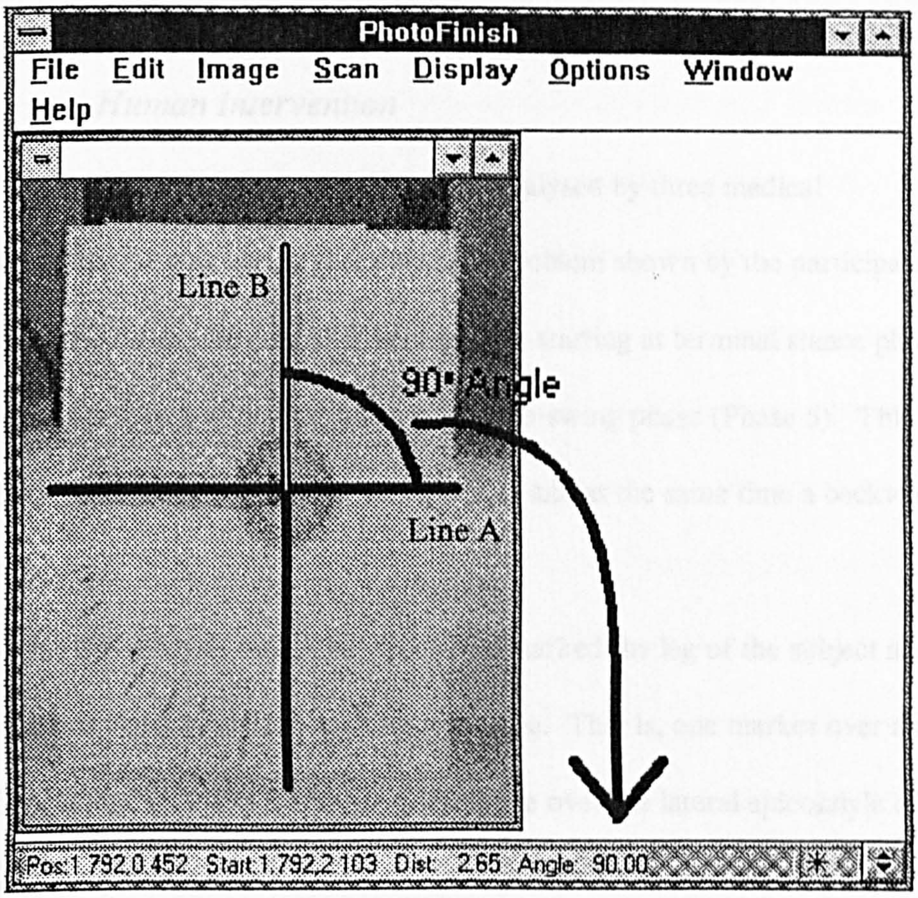
Software

Because most of the software used in dedicated commercial gait analysis is very expensive and oriented towards specific video and hardware equipment, the question then was whether the one supplied at no cost with the video capture card was able to analyse gait performance. Therefore, all the software used in this project comes with the video capture card, and consisted of two programs. One program is capable of capturing still pictures of the video made with the subject under study. The second piece of software is a program which can modify the capture pictures taken in the first program. This second type of software was found to be able to show angles between lines drawn on the capture pictures.

The first piece of software, called '*Media-Pro+*', is capable of displaying a video on the monitor of a computer. Then, by pressing the Space key, the image displayed on the monitor is captured to the memory of the computer. This is done in real time without stopping the video recording done during the intervention sessions.

The second programme, also called '*Photo-Finish*', is more sophisticated than the '*Medi-Pro+*' because, after importing the picture captured by the '*Media-Pro+*', it is capable of modifying or correcting any deficiencies of the captured picture, as well as showing various aspects of the picture like angles between two lines drawn on top of the object or figure.

The picture 2 below shows an example of four lines drawn on top of a test card with the indication of the 90º angle at the bottom of the picture.



Picture 2. Drawing lines over a cardboard with markers of various degrees.

As it can be seen the angle of the two lines, A and B, done on the piece of cardboard correspond exactly with the angle shown on the bottom of the picture. This finding was unexpected as some distortion was anticipated when the picture was displayed on the screen of the monitor. The accuracy of the software was such that it allowed a measurement accuracy of the angle as high as a hundredth of a degree.

Procedure

Human Intervention

The gait performed by the subject was analysed by three medical physiotherapists. It was agreed that the major problem shown by the participant was an Excessive Knee Extension (EKE) of her right leg starting at terminal stance phase (Phase 4) and finishing at the beginning of the pre-swing phase (Phase 5). This was shown by a lateral right rotation of the right foot and at the same time a backward push of the knee.

After this analysis one of the specialists marked the leg of the subject according to the standard leg skin surface marking technique. That is, one marker over the greater trochanter on the hip, another on the knee over the lateral epicondyle of the femur, and lastly over the lateral malleolus on the ankle.

The active mental practice was divided into two phases. On the first phase the right foot was held and the gait cycle movement was demonstrated to the subject. It was explained that when the foot when reached the moment of terminal stance it did not have to rotate; that the ankle could be bent, and that the foot could be lifted off the floor by bending the knee.

As soon as what was required during the task was clear to the subject she repeated the movement just shown to her without any further explanation from the experimenter. Afterwards it was explained to the subject that she was going to actively imagine the movement just explained. This active imagery consisted of the subject walking and simultaneously mentally rehearsing the movement with eyes closed. During the performance of the active imagery intervention the subject held onto the experimenter so that she could walk in a straight line. He, in turn, oriented the mental rehearsal of the task by suggesting to the subject that she imagined the performance of the walk using both visual and kinaesthetic sensory modalities. The active imagery intervention, that is the walk with her eyes closed, lasted for about 3 minutes.

After the imagery intervention the subject opened her eyes and would walk once more when her gait performance was video-taped for later analysis.

After this session the subject was asked to perform active imagery for three more sessions without further mental rehearsal orientation or demonstration.

The gait analysis performed on this subject during the active mental practice sessions was then compared with another video of a walk performed by the control subject, who did not display any walking problems. This allowed a comparison of the angles of the leg joints between the gait of a normal person (control subject) with the gait of the experimental subject in order to find out if the active mental practice interventions were improving the gait of the girl throughout the four sessions towards measurements shown by the control participant.

Gait analysis

The number of events within one gait cycle seems to vary between seven and eight. As was above explained, Perry (1992) describes eight events. But nowadays most textbooks on gait analysis follow the recommendations given by Winter(1987) who describes seven events. This study is also going to use seven events as this seems to be the most accepted and the one that the gait analysis experts suggested as the most appropriate.

Winter reports seven phases, which are very similar to those mentioned by Perry. The only difference is that Perry adds a further phase, the pre-swing, between the terminal stance and the initial swing phases, and also Winter gives different names to some of the phases. The following table provides a better description of the differences and the stages of the one gait cycle as explained by Winter and Perry. These phases corresponds to the seven details shown on picture 3 and 4 on next two pages.

TABLE OF GAIT PHASES FOR WINTER & PERRY

Phase	Winter	Perry
Detail 1	Heel contact	Initial contact
Detail 2	Foot flat	Loading response
Detail 3	Mid stance	Mid stance
Detail 4	Heel off	Terminal stance
Not Shown	Not Available	Pre-swing
Detail 5	Toe off	Initial swing
Detail 6	Mid swing	Mid swing
Detail 7	Heel contact	Terminal swing

The computer analysis of the gait cycle done on the normal and experimental subjects follows the seven details by Winter as shown above. The first picture shows the gait cycle of a normal subject when the video camera is positioned in front of the subject (Frontal Plane). The second picture shows the seven phases of one gait cycle when the video camera was positioned at 90 degrees in relation to the walking plane of the subject (Sagittal Plane).

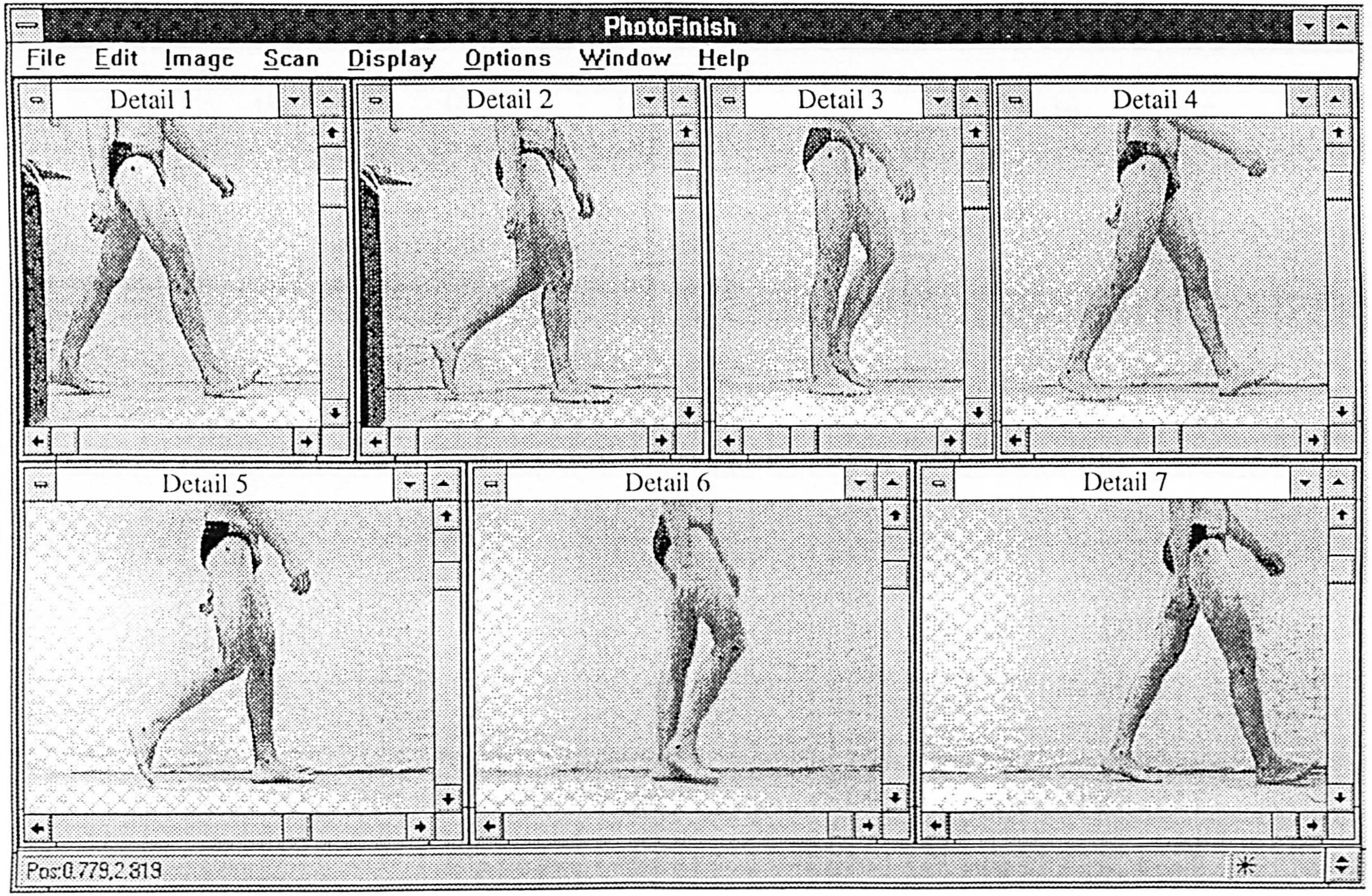


Figure 3 - Gait sequence of a normal participant. The picture on the top right corresponds to Detail 1(Heel Contact), and then the sequence goes from right to left finishing with Detail 7 at the bottom right corner. The black dots on the leg are the markers.

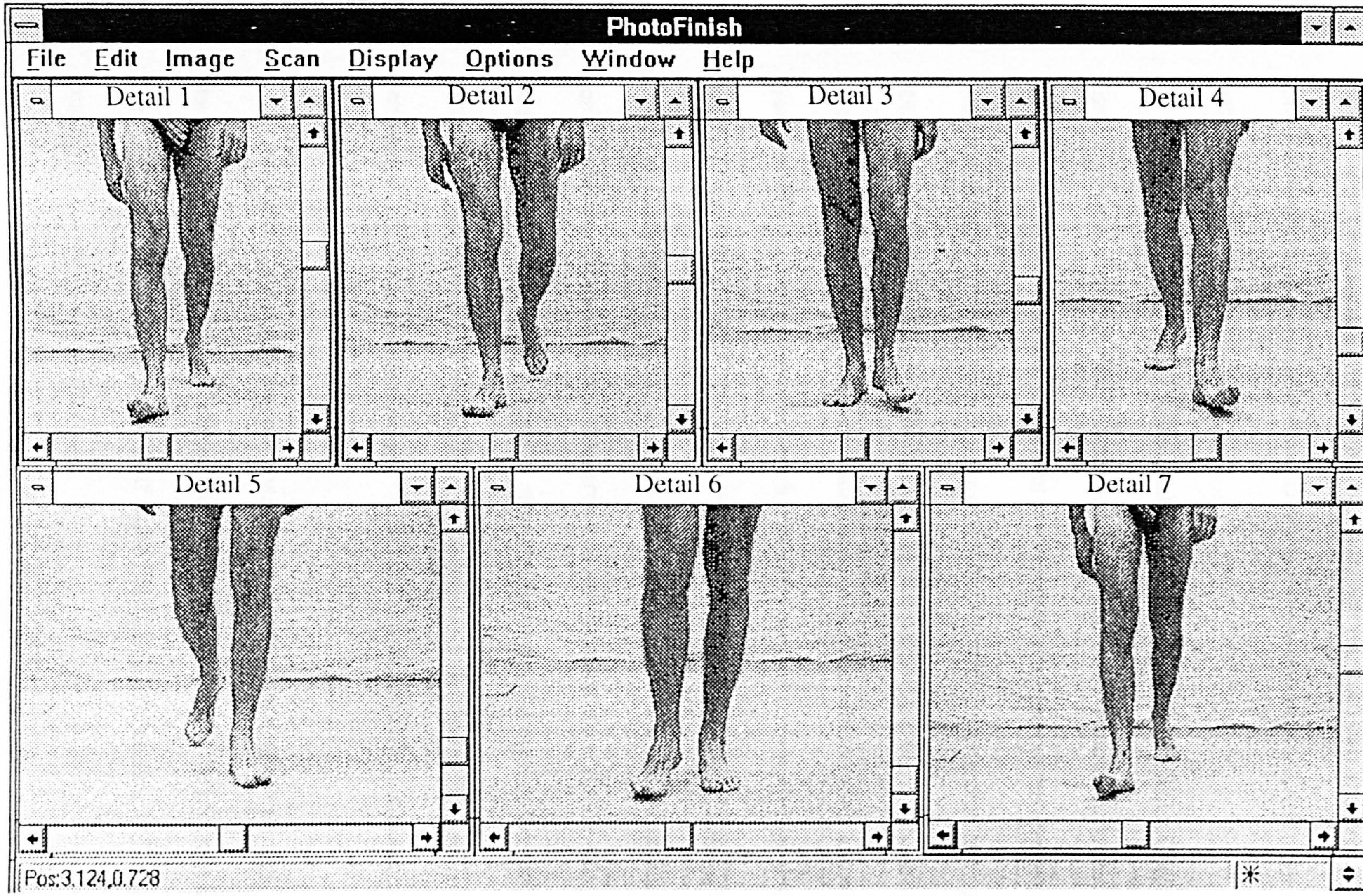


Figure 4 - Gait sequence of a normal participant analysed from a frontal plane. The first picture at the top left corresponds to Detail 1 and the one at the bottom on the right to Detail 7.

Results

The results obtained for this project are derived from two sources. The qualitative data from the medical specialists and the angle measurements from the computer analysis.

The qualitative data showed that the active imagery interventions performed on the experimental subject did, in fact, change the gait of the female participant. The three medical experts in gait movement who visually analysed the performance of the gait performance agreed between themselves that the subject corrected her right foot rotation and over-extension of the knee during the heel off phase. As the project progressed the physicians, from an initial sceptical position due to their knowledge that traditional methodology did not work in this case, became convinced that active mental practice was able to correct the gait performance of the experimental participant. They had never come across such a procedure through their professional training and meetings with other colleagues. Nevertheless they became interested in using this type of intervention in their therapy and in other similar cases. At present the staff of the hospital in Portugal where this project was done are compiling cases of people with similar gait problems so that this type of intervention can be fully integrated within the gait rehabilitation treatment program.

A more clear result was obtained by the computer analysis of the gait moment of the subject during the heel off phase. The pictures below show the moment at which the subject was performing the heel off phase during the first session and at the fourth session.

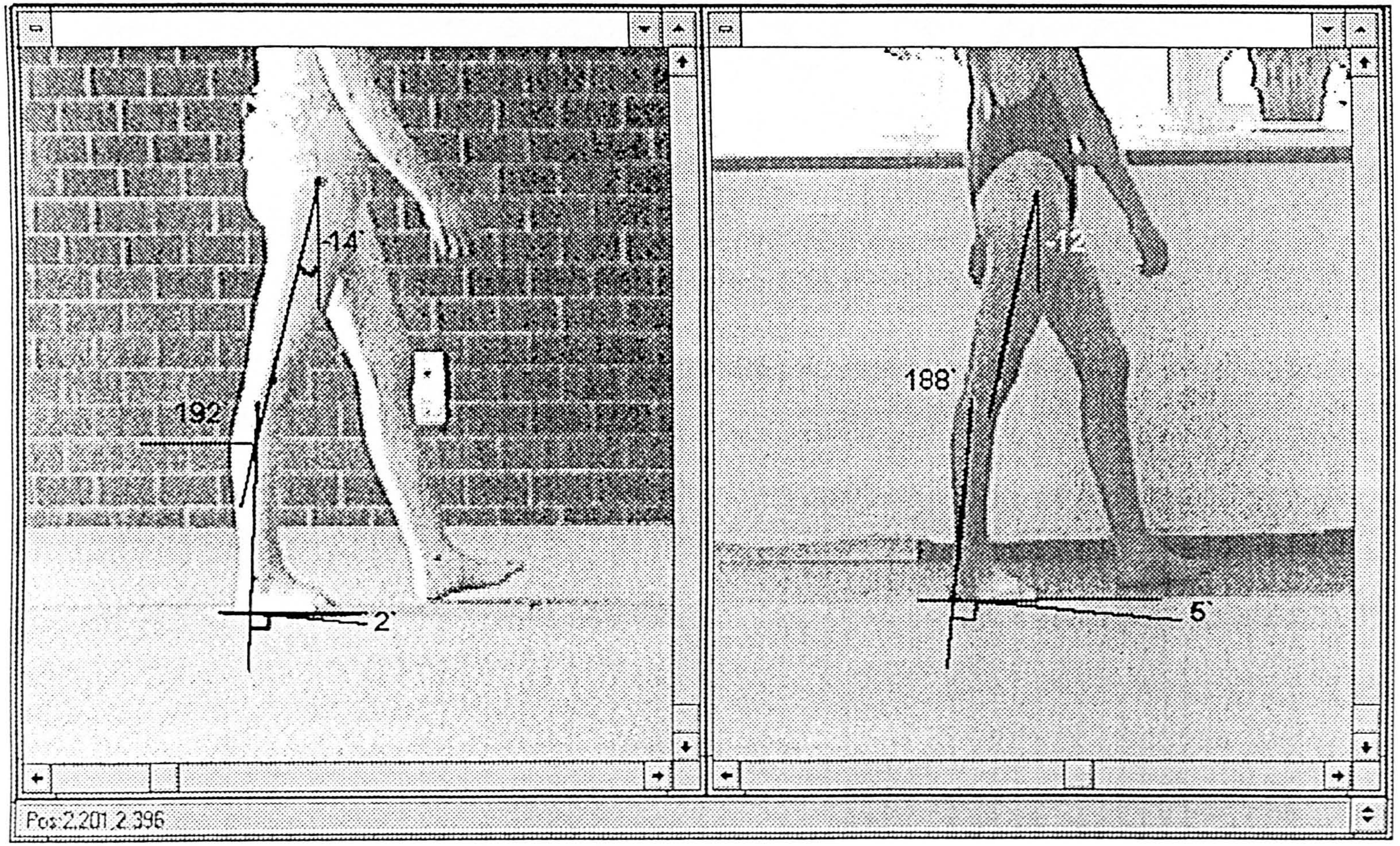


Figure 5- The picture on the left shows the overextension of the knee of the female participant during the first session, at heel-off phase. The picture on the right shows the same participant at the fourth session. The angle of the overextension between the knee and the hip was reduced from 14º to 12º. The angle of the knee between the foot and the knee was reduced from 192º to 188º.

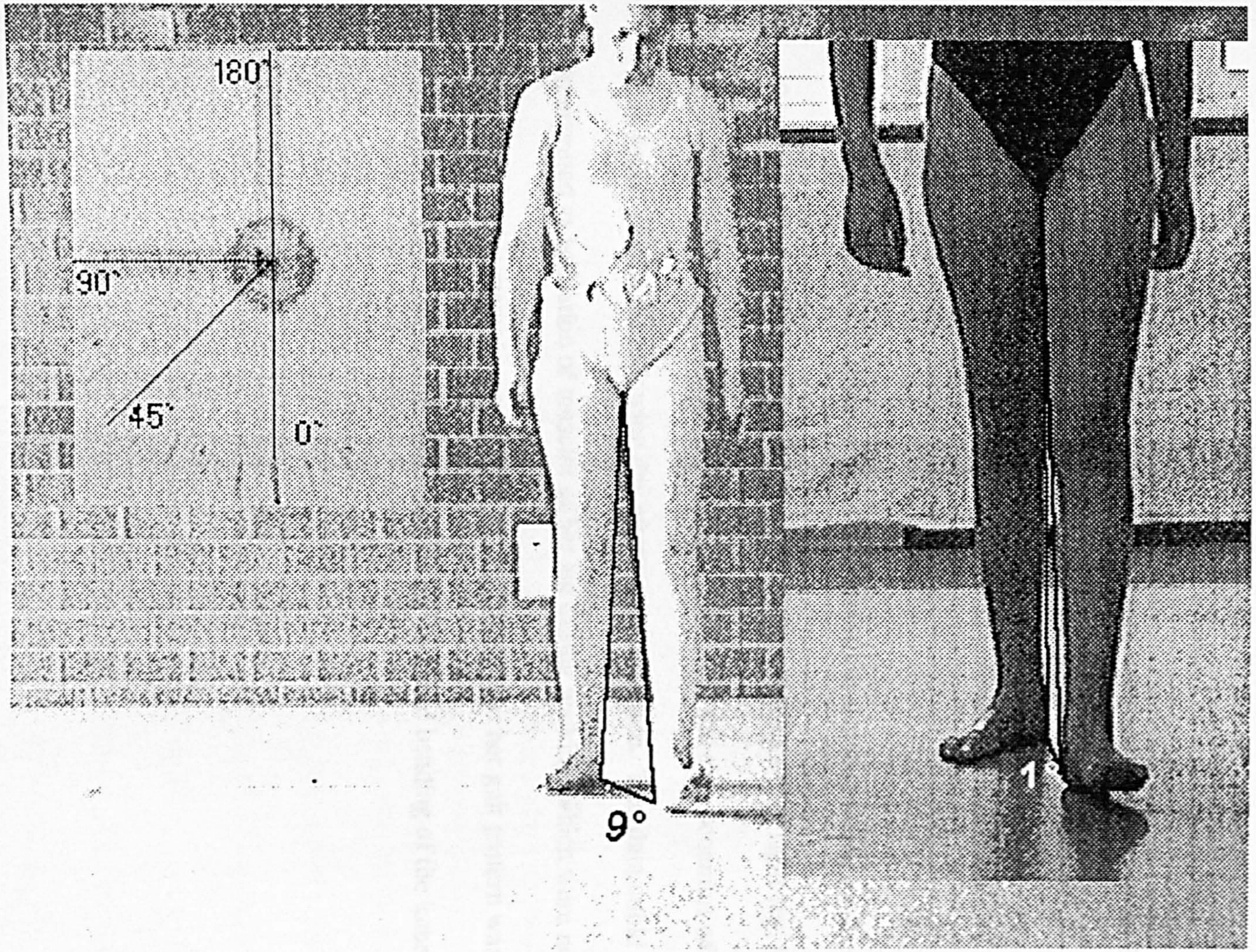


Figure 6- These two pictures show the female participant at terminal stance phase. Her walking base between the first and the fourth session during this phase was reduced by 8º.

As it can be seen on picture 5 there was a change on the way the right leg behaved during the heel off phase of her gait cycle. On the first session her right knee overextended by about 14 degrees whereas by the end of the fourth session the same knee corrected itself to a level similar to that obtained by a normal person, which is situated between 8º and 12º. As far as rotation of her right foot, during the heel off and toe phase section, picture 6 clearly shows that the participant corrected the movement as the walking base during these two stages was corrected from a 9 degrees angle to 1 degree.

An interesting qualitative piece of information supplied by the subject was that after the first session of active mental practice, the muscles of her right leg, in particular the vastus medialis and lateralis of her thigh, as well as the gastrocnemius of her leg, were rather painful the following day after the intervention. This data could be interpreted as activation of muscles of her leg during walking, which were not in action before the active mental practice, and so confirming that her gait pattern was changed which could have been due to correction of her foot and bending of the knee.

Discussion

The computer analysis of the gait cycles done on this case study seem to be an accurate and reliable way for analysing human gait performance. With the use of one single video camera, a video grabber card, the software supplied with this hardware and a computer it is possible to make accurate measurements of motor skills on people and the cost of such system is much smaller than the very costly dedicated gait analysis systems, like CODA and VIACOM.

Also, these dedicated systems tended to come with software which is produced for very specific motor dysfunctions without the possibility of any modifications unless done by the manufacturers. On the other hand, the system used in this project is more flexible because it allows the development of simple software in order to analyse the grabbed frames, opening the possibility of a very flexible gait analysis system.

With regard to the effects of active mental practice on the correction of motor activity of people after having experienced surgery, this case study confirms the findings in the previous chapter where it was found that active mental practice was particularly effective in maintaining consistent recovering knee angle movements and that during the gait performance of the participants, they corrected their previous gait performance as confirmed by visual analysis of the professional physiotherapists. In the present case study, the visual analysis done by the three experts in physiotherapy, as well as the computer analysis, confirmed the previous impressions of the physiotherapist that, in fact, active mental practice can be an effective technique for correcting gait patterns and the this correction occurs right at the first session with reinforcements during the following interventions.

One probable criticism with this type of work is that, with time, people after physical surgery may eventually correct their gait patterns. But as was pointed out in the previous chapter by Wilson et al (1996), patients still show gait problems 4 years after surgical intervention on the knees of the studied patients. The question then is whether people who have gone through active mental practice can still show some previous gait problems after a period of non-intervention or revert to incorrect patterns?

A later study using more sophisticated software, developed by another group of people, examined sequences of frames of the gait of the female participant in this case study 4 months after the active mental practice experiment and indicated that her knee cycle was still maintained within the normal standard measurements (Alvoeiro, Pinto, Pinto, Oliveira, Santos & Semblano, 1996).

The Figure 7 on next page shows the analysis done by means of this new software, on the same pictures as those used via the Photofinish software package.

The present case study and all previous experimental work done in this project, show one problem which needs now to be addressed. The problem is that active mental practice may be affected by dominance of imagery modality of the individual under study. As was described in the two projects on table tennis and in these last two, the participants are oriented to specific parts of their bodies during active mental practice. It seems that this type of imagery orientation procedure is effective in modifying motor activity as reported in studies discussed in the first and second chapters and throughout out the work done up to now. But the question which has not been answered was how effective can this methodology be if the subjects receive imagery orientation scripts which are different from the preferred modality of the participants. As was pointed out at the end of the fourth chapter the language used in the imagery orientation scripts may determine the type and quality of imagery done by the participants during the interventions.

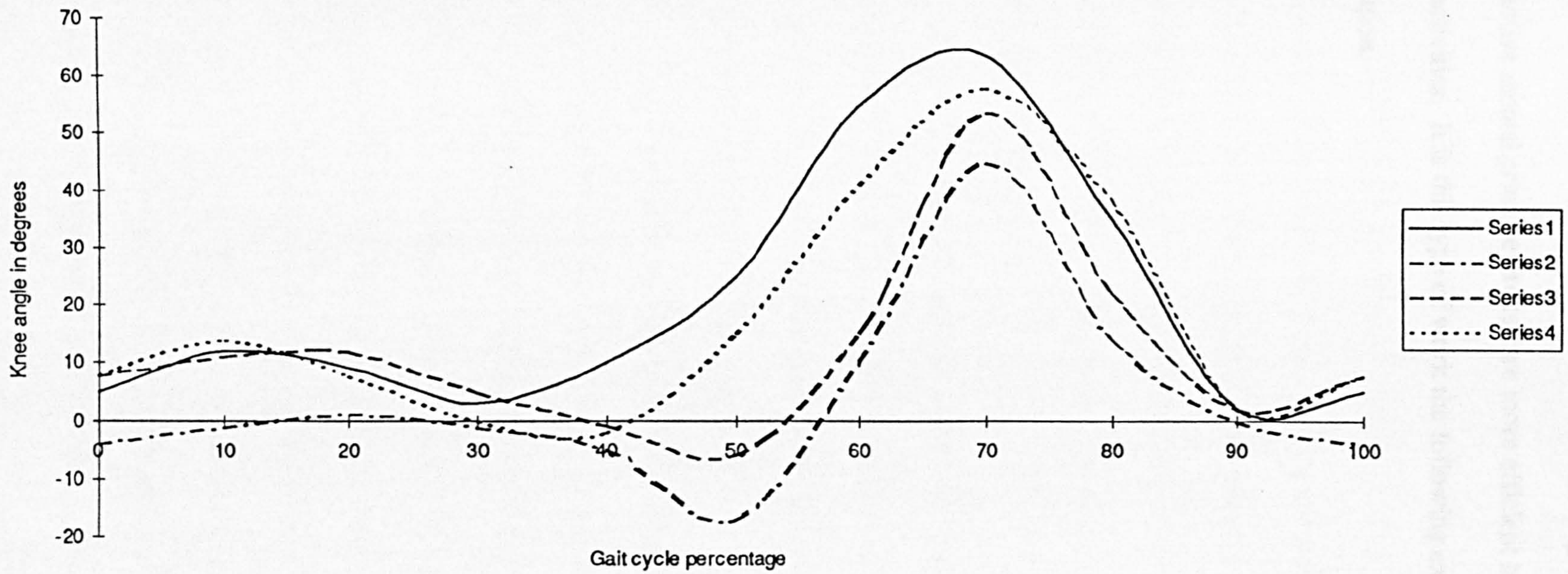


Figure 7- This picture was obtained using the more sophisticated software developed after the completion of the present project in this chapter. The pictures employed during this analysis were the same as those treated via the Photofinish software.

The picture shows the knee gait cycle of the normal subject when compared with the knee gait cycles of the participant during the first, third and fourth session. The curve made by the solid line is the knee cycle of the normal subject, and those for the Series 2 to 4 of the experimental subject.

Therefore, this project needs to investigate this problem in order to make the active mental practice procedure more efficient in the correction of motor skill activities. It is this type of work the following experimental work will concentrate upon.

Chapter 7 - Identification of Imagery Modality Questionnaire - English Version

Throughout this project, interventions of active mental practice in motor skills performance seem to indicate that they can affect the way the subjects in the experimental groups learn or correct their movements. This change was rather surprising in particular on those people who after many years of dysfunctional gait performance were able to correct their movements, which standard physiotherapy interventions had failed to do so, as in the case study of the Portuguese participant in the previous chapter.

But, on the other hand, an aspect that was also detected, in the form of verbal anecdotal comments, was that there could be the possibility of an effect on the way the imagery modality of each individual is formed due to his/her strength of modality, as he/she performs these new behaviours.

Before looking into this problem is there any work which can show that there is a close association between what people do and their strongest imagery modality? A recent article by O'Halloran & Gauvin (1994) seems to show that there may be such association. In this article they investigated how mental imagery could be affected by the way people are oriented by scripts, and whether this could affect motor performance. They used a battery of instruments to measure imagery ability and its relation to motor activity, like the Movement Imagery Questionnaire, The Questionnaire upon Mental Imagery and the Preferred Imagic Cognitive Style Questionnaire (Issacs, 1982) which is one of the very few instruments which claims to be able to measure imagery preferences like the Individual Differences Questionnaire by Paivio (1971), in contrast with the other imagery questionnaires which measure imagery abilities, vividness, or preferential mode of thinking. O'Halloran & Gauvin hypothesised that participants who scored high in the Imagic scale would get more benefit from mental imagery training than those subjects who showed strong scores in the Verbal modality scale. Their results did not support their hypothesis in that Imagic subjects were better when they were oriented with visual and kinaesthetic scripts, but verbal participants stayed the same. However, qualitative data from their Verbal group showed that '*...they had to talk themselves through the imagery...*' for which the authors of this article commented that by doing this procedure '*...they used their preferred mode of thinking, verbal, to accomplish an imagery process.*' Thus, this experiment seems to show that the way people carry out their imagery rehearsal can affect their motor actions and that when the imagery orientation script lacks one of the modalities, those for whom that missed modality is their preferred mode, reorganise the way they perceive the input script in order to accomplish the task.

But can imagery modalities be measured? Are these measures true scores of imagery ability of an individual?

Since the first imagery questionnaires introduced by Galton (1907) researchers have queried what the tests measure. Do they measure the capacity of a person for introspection, or are these testees trying to recall information from their memories, or what they would like the recalled information be like (Betts, 1909)? Are they not biased by personal feelings suggested by the questionnaire itself (Chara, 1992)?

Some of the most widely used questionnaires measuring imagery abilities are the VMIQ (Isaac, Mark, & Russell, 1986), the SQMI (Sheehan, 1967), the SMI (Switras, 1978), and the MIQ (Hall & Pongrac, 1983). These tests describe a situation or a specific movement and ask the testees to rate their imagery accordingly. For instance, the VMIQ asks testees to call to mind the behaviour of '*Sliding on ice*' or '*Riding a* *bike*'. But what would the response be like if the depicted situation aroused negative feelings or the movement has never been experienced before by the subject? For instance Clark (1960) reported that when one of his participants was asked to imagine a basketball foul procedure the ball would not bounce and stayed on the floor. Also Corbin (1967b) commented that some experience with the task was necessary before mental rehearsal interventions.

Another question is whether the testees can make an unequivocal evaluation of what the test is asking. Can this be a reason why imagery tests are open to questions from people like Moran (1993) who indicated that people may experience some difficulty in rating their valuations on the '... *mental experiences which most imagery tests (especially those concerned with vividness) require*'?

One possible way of getting around this problem is to allow the testees to create their own modalities, for example by introducing high imagery words and allowing the subjects to create their own images, rather than being required to imagine a particular imagery modality. This would not go against the requirements introduced by this project of using guided imagery during the active mental practice interventions, because the subjects would be allowed to create their own imagery modalities even though they are still guided to imagine those parts of the body that they are going to use during the motor skill task.

As was suggested above by the study of O'Halloran & Gauvin (op cit), people tend to use their preferred modality whenever they find themselves in situations which require the processing of motor skills. In view of this finding, and taking into consideration Ahsen's Triple-Code Model framework of imagery, which, as was described in Chapter One, states that when people create images they have to use three components - I, to Imagine the activity, M, the Meaning this activity has to the subject, and the S, the Somatic response due to activation of the imagery - in order to formulate any mental rehearsal. These components activate those parts of the brain which people use whenever they imagine motor activity, as was found by Decety and co-workers since the 1990's. Thus, it is reasonable to propose that when people imagine an activity, using the three elements of the Triple-Code Model, by bringing into play their favoured imagery modality, they may be more likely to activate those parts of the brain which brings into their consciousness stronger instances of the sort of motor activity they are going to use in real life. But, how can a person activate these imageries? Could high imagery words presented to individuals possibly trigger their preferred imagery modalities which would enable them to activate those parts of the brain which would enable them to perform their best during real motor actions?

The dual-code hypothesis of Paivio (1971) proposes that people, when visually confronted with high imageability words, activate their semantic systems and evoke images '... *as associative (meaning) reactions*'. This idea suggests that high imagery words can activate images and internal representations of events. This intimation is further substantiated by an explanation offered by Kosslyn (1991) where he says that

> *'We often form images upon hearing the name of objects ... To image an object that is composed of more than one part, we must access information about the structure of the object and use this information to activate the appropriate visual memories and the appropriate spatial relations representations'.*

Thus, taking into consideration the discoveries by Kosslyn which seem to indicate that, as far as the visual modality is concerned, high imagery words can elicit '*...motor-based co-ordinate representations of locations*', does the same apply to other modalities?

There is some research which indicates that people who are taught using their strongest learning modality, visual, auditory or kinaesthetic, learn better and more easily. A study by Persillin & Pierce (1988) tested this idea by measuring the learning and retention of music rhythms in children, by allowing them to use their imagery modalities. After assessing the modalities of the participants via the Swassing-Barbe Modality Index (1979), they found that those children who preferred one modality over any of the others also preferred to use that same modality when learning musical rhythms.

Another area where evidence exists is in modality interference. That is, can the quality of imagery be affected by similar external stimuli? There have been some studies which show that external stimuli can affect imagery ability. For instance the work by Segall & Fusella (1970), found that the auditory and visual signal sensitivity of a person in a detection task was reduced when these people imagined auditory or visual imagery tasks respectively. But this finding could also be explained in terms of processing capacity of human beings who cannot process two modality channels at the same time. The so called bottleneck effect (Solso, 1995). Thus another study by Eddy & Glass (1981), demonstrated that performance in verification of high imagery sentences was interfered with by asking subjects to do a visual task. They hypothesised that if vision and visual imagery used similar cognitive processes then high imagery sentences should be more difficult to comprehend when they were being read than when they were being listened to, because those who read the sentences were using vision and visual imagery which may have made use of the same cortical areas. Eddy & Glass found that high imagery sentences took longer to verify and comprehend than low imagery. Whereas they did not find any difference in the means for verification and comprehension times when both high and low imagery sentences were presented auditory. They concluded that comprehension of high imagery sentences did involve visual cortical representation.

Also an early study by Paivio (1968) and a later investigation by Campos (1989) found that single words, with dual meaning, seemed to be effective at eliciting vividness of imagery whereas stimulation of emotional feelings tended to be low.

Thus all these findings described up to now seem to suggest that there is a good probability that testees, when exposed to high imagery words which can evoke modalities, are likely to objectively associate that keyword with their strongest imagery modality.

This chapter describes a new instrument that uses high imagery words in order to identify the strengths of participants in three imagery modalities; visual, auditory and kinaesthetic.

QUESTIONNAIRE

Method

Subjects

There were eighty one subjects. Forty five males and thirty six females. This group represented 96% of the whole population that received the questionnaire. English was their first language and they had no previous experience of any type of high imagery words analysis.

Materials

The subjects were presented with a list of one hundred and seventy two words collected from a study by Benjafield & Muckenheim (1989). They based their choice of words on three criteria: a- their words were not restricted to nouns; b- the words did not exclude '*uncommon, unfamiliar English words*'; c- their sample '*represents the types of words that occur in the English language, without regard to how frequently they occur*'. They obtained the words from the Oxford English Dictionary (OED) and all its supplements published between 1933 and 1986. One of their major variables was the date of entry of words in the OED. This, they claimed, would

> *'help understand more clearly the way in which the basic, yet diverse, psychological processes involved in the production of imagery and the language on interpersonal behavior are at least partly determined by social and historical forces'.*

Thus, a word was chosen at random from a page and they excluded all those that the OED indicated that were obsolete, archaic, derived from a dialect, were not naturalised as English or did not have a date of entry.

In their '*Imagery Scale Instructions*' they emphasised that any word which in

> '*your estimation arouses a mental image (i.e., a mental picture, or sound, or other sensory experience) very quickly and easily should be given a high imagery rating. Any word that arouses a mental image with difficulty or not at all should be given a low imagery rating. .... it is important that ... you judge only the ease with which you get a mental image of an object or event in response to each specific word chosen.*'

All the one hundred and seventy two words derived for the production of the present instrument had a rate of six as this was the highest rating in the Benjafield & Muckenheim experiment.

Procedure

This test was a paper and pencil type. All the words were typed in a single column. The following instructions were given:

> *'This questionnaire attempts to find out how people imagine written words. For instance, the word DOG. Some people reading this word may imagine a picture of a dog in their minds, they are visualisers (V). Others may imagine barking noises, they are auditory (A). Whereas others may remember the feeling of a dog's fur on their fingers, they are kinaesthetic (K). What is important is what comes to your mind immediately you read each word. Your task, is to read each word and circle V, A, or K.'.*

A further instruction line at the top of the first page with high imagery words read as follows ' *Please choose the modalities (visual (V), auditory (A), kinaesthetic (K)), which you associate the words below with.*' Data were also gathered on the gender of each participant.

Results

A frequency analysis of the number of times each word was assigned to one specific modality showed that of the one hundred and seventy two words eighteen had a frequency of strong single modalities - six visual, six auditory and six kinaesthetic. Also eighteen mixed modality words were selected from the analysis- six visual+auditory, six visual+kinaesthetic and six auditory+kinaesthetic. The words, and the percentages of individuals selecting the modalities were:

Visual	Auditory	Kinaesthetic
Face (93%)	Buzzer (93%)	Hot (94%)
Ship (90%)	Snap (86%)	Cold (88%)
Sky (96%)	Speak (88%)	Heat (91%)
Street (95%)	Drill (80%)	Soft (84%)
Dot (93%)	Barking (95%)	Touch (82%)
Star (99%)	Grinding (82%)	Cramp (88%)

Visual+Auditory	Visual+Kinaesthetic	Auditory+Kinaesthetic
River (54/40 %)	Stand (59/39%)	Laughing (58/35%)
Lock (58/37%)	Throw (46/53%)	Gasping (57/39%)
Chop (51/43%)	Ride (45/50%)	Coughing (56/38%)
Ocean (50/40%)	Run (48/48%)	Scrape (55/33%)
Chipping (40/56%)	Slip (46/44%)	Choking (55/36%)
Burst (36/53%)	Leap (55/42%)	Flush (55/36%)

A further Wald-Wolfowitz Runs test on the gender differences for all the thirty six visual, auditory and kinaesthetic modality words did not show any difference. (Visual, Z adjusted=.356, p=0.721; Auditory, Z adjusted=.831, p=.406; Kinaesthesthetic, Z adjusted=.593, p=.553)

The means levels for the three modalities in relation to gender of the participants are displayed on the table below.

	Mean Males	Mean Females
Visual	14.05556	16.77778
Auditory	12.00000	14.88889
Kinaesthetic	10.02778	13.27778

Conclusion

One of the most important findings in this project was the non-significant difference in gender for all the thirty six words. In the original study, by Benjafield & Muckenheim, women tended to rate words higher in their imagery content than men. On the other hand an early study by Friendly, Franklin, Hoffman & Rubin (1982) report no significant gender difference. The same applied in this experiment. A suggestion for such a result could be that as all the words were high in their formation of imagery the gender effect may disappear. Also, following the suggestion proposed in the introduction of this project in relation to PET analysis of the brain during imagery, high imagery words may activate the same brain array cells in both males and females. In fact, earlier work by Sheehan (1971) in a recognition memory task for abstract and concrete words found that there was no difference between males and females in their task performance nor in performance between any words.

If there is no difference between males and females with these type of imagery words could they show a difference in the consistency of a motor skill performance when people perform according to the modality predicted by the present test? The point is, that if the present instrument can select people according to their mental imagery modalities, then would those who come out with higher rates in a specific imagery modality, for instance visual, perform worst if they were required to perform in a different imagery modality, such as kinaesthetic, during a motor skill task. In contrast those who rates stronger in a kinaesthetic modality, might perform worse if required to perform using a visual imagery intervention. This is of significance as there is not yet any available imagery test which uses high imagery words as its method of inducing and selecting imagery modality in people.

VALIDATION

A major problem with self-report imagery questionnaires is that there is no '*natural*' real-world principle which can be used to validate imagery experiences (Cureton, 1965). Traditionally, when a new test is designed, validity is obtained by comparing the results given by the new test with old ones. This is accepted if the test used is generally considered meaningful and important. As Cronbach (1970) has said, what a tester should ask when is trying to validate a new instrument is whether the '*...test represents the behavior I consider important in its own right...*'. The tester should '*...compare the test tasks with the content and behavior he wishes to know about*'.

Cronbach also suggested that another aspect a tester should ask when validating a new test is whether the test scores can define the performance of the testee. He concludes by saying that '*...The psychologist or educator evaluating a training program must check out the content validity of the proficiency tests for that particular program.*', that is a tester should be very aware of what the test is designed for otherwise he is selecting behaviours which the test is not supposed to select.

Imagery instruments on the whole, by suggesting or describing events or actions may be selecting people according to their past experiences and the feelings they had during those situations. Otherwise, if the testees have not been through those events their scores may be based on some information which may not be relevant to what the test tries to measure.

Thus, a major difficulty with the present instrument was to find a way to validate the scores obtained with this test and the imagery modalities of people in general.

A literature search on imagery tests did not show any instrument which used a similar methodology to the present test. On the other hand, as this project is concentrating on the way people correct motor movements and skills it seems appropriate to validate the present imagery test using a simple motor consistency pointing task. This sort of task should have very little variation due to the fact that it is a skill which people perform everyday and quite regularly throughout their lives. As Magill (1989) has pointed out, learning of a task is characterised by two factors: first, the person gets better at performing the skill, and second, the performance of the movement '... *become increasingly more consistent*'. Thus it seems reasonable to assume that if imagery modality does not affect performance, people would show no variation on their pointing task. On the other hand, subjects with a high kinaesthetic score on the instrument would have less movement variation if they used a kinaesthetic imagery movement orientation, because they are using their preferred modality, than if they use a visual imagery orientation, and also no conflicting modalities as in the bottleneck effect (Solso, 1995). Whereas those with high scores on the visual modality would show less movement variation when using visual imagery movement orientation. This variation, also called '*variable error*' by Magill (1989), was obtained by applying a standard deviation procedure on the scores of the pointing task.

One problem with pointing tasks is that they are far too easy to perform. Thus one way of making pointing tasks more difficult to perform is to allow subjects to perform the movement but looking through lateral displacement goggles. Then the question is whether people would use a preferred type of modality and whether they are consistent at performing the task under these conditions

The first question may be answered by work done by Redding, Rader, & Lucas, (1992) who, using lateral displacement goggles, have found that visual and kinaesthetic sensory-motor co-ordination are independent from each other.

The second question is explained by the findings in the first study in this project which has shown that, orientating active mental practice in a motor skill performance is effective at producing movement consistency.

Thus, the proposed suggestion for investigation is that if subjects when, after accommodation to lateral displacement goggles, use their preferred imagery modality, as suggested by the imagery test, during the performance of an active mental practice, will be more likely to point more consistently at a target, than those who use a different type of imagery modality, as determined by the test. That is, those for whom the test predicts a strong visual modality will be more likely to point more consistently when asked to use the visual modality than if they are requested to do a kinaesthetic type of active mental practice.

On the other hand those whom the test classifies as kinaesthetic will be more consistent when oriented to perform a kinaesthetic imagery modality.

Method

Subjects

There were 32 subjects. 18 females and 14 males. They were all naive to the aims of this experiment. Also they had not experienced this type of active mental practice before.

Materials

The presentation of the 36 words selected by people as being strong single and mixed imagery words during the previous experiment was carried out using a dedicated computer program. This program can be seen in Appendix A.

This program presented the instructions to the subject. Afterwards the 36 words were presented in a random order, one at the time, to the subject. The selected modality for each word given by the subject was collected by the program in another file as well as the time taken by each subject to select the modality for each word. After finishing the task the program prints out the results stored on the collected file. These are the total choices for each modality, and the total time taken to choose each modality. The printed page has also one line which allows the tester to circle the gender of each subject.

There were also a pair of goggles, which when worn by the participants, displaced their vision by 20º as each standing subject pointed, at shoulder height, to a dart board.

Procedure

As the instrument was presented via a computer, after typing the name of the program on the keyboard a screen with instructions was displayed to each subject. These instructions used the word '*dog*' and indicated how a person imagining the feelings of the fur of the '*dog*' between fingers illustrated a kinaesthetic modality, a picture of a dog indicated a visual modality, and an auditory modality if imagining the sound of a dog barking. The task the subjects had to perform was to choose the key on the keyboard which represented the visual modality (key B), auditory (key N) and kinaesthetic (key M) each time a word was presented on the screen.

After the test, each participant stood in front of a dart board and was asked to point at the centre with the arm extended. This determined the distance of each subject from the board during the performance of the task, and also allowed the tester to position the testee in a parallel position with the dart board, in order to get accurate measurements of any deviations from the centre of the dart board when the participants did the pointing task. As soon as displacement goggles were placed on each subject, he/she would start pointing at the centre of the dart board with an approximate rate of one full movement - arm move up, point, arm move down, rest - for three seconds, until the rightward displacement from the centre disappeared. After accommodation, the subject was asked to close his/her eyes and to keep them closed until asked to open them again. The participant kept the goggles on and were not completely blindfolded during the imagery intervention for to two reasons. One was the possibility of any extraneous body and head movement effects on the accommodation of the 20° goggles, and secondly, due to the fact that the displacement from the centre of the dart board was eliminated as soon as they opened their eyes. Thus, if the subjects opened their eyes the tester knew straight away that they had done so.

The imagery intervention pointing task was divided into two sections. Both sections were counter-balanced in a random way. With their eyes closed the subject pointed at a position in space which he/she believed to be the centre of the board. As the movement of the arm progressed, he/she was asked to imagine kinaesthetic type of awareness on the arm . As soon as the subject declared that his/her arm had reached the point section of the out movement on the dart board, a measure was taken of the area between the finger of the pointing hand and the centre of the darts board, before the arm went back to its initial place on the side of the body. This procedure was repeated for five full pointing movements.

After finishing this first section of the task, and still with their eyes closed and with goggles on, the subject was asked to active visual image the same motor pointing task for another five pointing movements. Measurements of the distance between the finger and the centre of the board were taken once more time

As soon as he/she finished this section of the intervention, the goggles were remove with the minimum disturbance to the head and body. Then, the subject was asked to open his/her eyes, and as soon as he/she did this he/she was asked to point at the centre of the board. Once again another measure between the finger and the centre of the board was taken.

The next subject of this experimental group would active imagine the intervention in the same way as the previous subject but this time the first five motor tasks were done using visual modality and kinaesthetically for the other five.

To sum up, the first subject of this group, would have performed active mental practice of five pointing movements using first kinaesthetic and then visual imagery modalities. The second subject would be doing five active mental practice pointing tasks exercises using a visual modality first and kinaesthetic afterwards. The third subject would have performed like the first subject and the fourth like the second and so on.

The control group did the same motor pointing tasks as the above group and for the same amount of time, but instead of performing the same type of mental practice during the performance of the intervention as the experimental group, the first subject of this group was asked to imagine first the numbers as he/she counted backwards from 100 to 1, whereas, and for the second part he/she was asked to imagine walking in some pleasant environment while pointing at the board. However, the following participant of this group was asked to imagine first walking in some pleasant surroundings and then count backwards from 100 to 1. The third subject would perform as the first subject did and the fourth as what was done by the second and so on.

Results

All subjects, when pointing at the board with their eyes closed, shifted their movements to the left of the centre of the board, after rightward displacement accommodation.

In order to find out how much the overall consistency of the leftward movement from the centre of the board a standard deviation analysis was performed on the data for the five measures of the kinaesthetic imagery motor task, and another for the five measures of the visual imagery motor task . The same type of analysis was done on the imagery counting and walking tasks of the control group.

A Pearson product moment correlation analysis on the data from the experiment group showed a significant correlation between the scores from the imagery test and the standard deviations of the imagery motor measures. This means that those people who scored visually high on the instrument showed less movement variation when they visually imagined the pointing movement task ($R=-0.4987$, $n=16$, $p<0.049$). On the other hand this same group showed high movement variation when they imagined the same pointing movement kinaesthetically ($R=0.68$, $n=16$, $p<0.01$). Those subjects for which the questionnaire showed high kinaesthetic test scores had less variation when they imagine the motor task using kinaesthetic imagery ($R=-0.5133$, $n=16$, $p<0.041$). But this same group of people showed an high pointing movement variation if they imagine the task visually ($R=0.75$, $n=16$, $p<0.01$). The table below gives the means of the variable error values for subjects in the experimental group.

Table 1 - Means of Variable Errors for Imagery Modality Questionnaire

	Kinaesthetic		Visual	
Orientation	Kinaesthetic	Visual	Kinaesthetic	Visual
	0.97	2.36	1.74	0.66

One interesting result was from a female subject who produced the same scores for kinaesthetic and visual in the imagery instrument and her variable error during the validation task was also similar for kinaesthetic (1.79) and for visual (1.81) performance.

As far as the control group was concerned they did not show any differences in their pointing measures between any of the control interventions.

Further analysis on the same data showed a negative correlation between subtracted test scores and subtracted standard deviation measures ($R=-0.83$, $n=16$, $p<0.01$) for the experimental group, thus confirming the above findings.

It was also found that those subjects who scored high visually on the test would score low kinaesthetically ($R=-0.86$, $n=16$, $p<0.01$) in the test. This result seems to suggest that the test scores obtained by the subjects in this validation experiment would reliably distinguish between visual and kinaesthetic modality choices.

Discussion

The results obtained by the validation pointing movement experiment showed that those people whom the test predicted to have strong visual imagery modality were more likely to show more movement consistency when they used a visual mental rehearsal training. On the other hand those people whom the test selected as having strong kinaesthetic imagery modality had more movement consistency when they imaged the motor skill kinaesthetically.

Past reports, like Hall, Rodgers & Barr (1990) or Jowdy & Harris (1990), did not find imagery modality to be influential in performance of motor skills. The question that the present results seem to pose is whether the negative findings from those experiments were due to the insensitiveness of the tests used to measure imagery modalities. The present instrument, by allowing people to create their own imagery situations from the high imagery words, seems more sensitive at selecting imagery modalities. As was declared in the Jowdy & Harris study instruments like the Movement Imagery Questionnaire tend to select people who have high imagery ability '... *in either the visual or kinaesthetic categories*'. The present questionnaire seems to be able to select imagery modalities even in those people who do not display high imagery ability. But as the instrument used from this project is very new, further psychometric measures, like test-retest and part-whole reliability, should be undertaken before we can feel fully satisfied of its usefulness and results.

On the other hand, even though the results are very encouraging, the method of using high imagery words in order to select imagery modality in people is not recognised on a broad basis. Thus there is a need to find out how universal the method is in other cultures. As the words used in this experiment are English based, the question then is whether the same words, translated into another language, would produce similar findings to the present experiment. There is also a need to find out whether words that qualify a specific modality in the English language are also chosen in the target language.

The next chapter in this project seeks to answer these two questions by translating the high imagery words into Portuguese and tests them with a Portuguese sample.

Chapter 8 - Identification of Imagery Modality Questionnaire - Portuguese Version

Universality of research findings is a fundamental aspect for any scientific subject matter. If psychologists want to claim that cognitive psychology is an universal science they have to show that their findings can be applied to any culture or society. Until recently, imagery, as was pointed out in the first chapter, has been named as an area of cognitive psychology which lacked a firm scientific basis. This was due in part to the fact that people could not find satisfactory answers to questions such as how can psychologists researching in imagery know that their participants were actually doing mental imagery. With the advent of techniques like the electroencephalograph (EEG), the magnetic resonance imaging (MRI) and the positron emission tomography (PET) imagery research can at last show that there is a close relationship in brain activity between real and imagined behaviours.

On the other hand, selection of humans according to their imagery ability is still very controversial. Most instruments tend to use the technique adopted in the first imagery test introduced by Galton (1907) which asks people to imagine or recall situations. This technique has only recently been questioned, as pointed in the previous chapter, on the grounds that when people are asked to imagine events or situations they need to have at least some experience of them. Instruments which use statements such as '*Sliding on ice*' (Isaac, Marks & Russell, 1986) are culturally biased and would be inappropriate for use with people who had no conception of ice or sliding on ice. Such a contention is reinforced when considering the evidence that the MRI and PET investigations which tend to show that when people are doing imagery they activate those parts of the brain which they actually use during real performance. Therefore it seems reasonable to propose that individuals may be deficient at rating imagery vividness judgements of behaviours that have never previously experienced. This idea has recently been also supported by Kosslyn in a personal e-mail communication to the author of this project (Kosslyn, May 23, 1996).

The question then is to ask whether it is possible to develop an imagery questionnaire which can assess imagery modalities of individuals irrespective of their background or country.

The instrument described in the previous chapter is an attempt to address this question. Thus, will the high imagery English keywords test, when translated into another language, produce similar results to those obtained in the previous chapter?

A key issue in this context is whether high imagery words when applied to any culture can activate cognitive activities, such as memories, in those people which would allow them to generate environments or events which they can then be used in order to identify their imagery modalities.

The work by Vygotsky (1962) tried to explain universal features common to all languages. This was done by analysing the development of language in children, from birth up to the moment when the children can communicate their thoughts in social environments.

Vygotsky declared that from birth up to about two years old children vocalise in order to summon attention from significant adults. At about two years old children start explaining their inner thoughts. This is the point where '*...thought becomes verbal and speech rational*' (1962).

Over the next five years Vygotsky proposed that children learn that there are two types of language: internal speech, which is used for monitoring and to direct internal thoughts, and external speech which is used to communicate to others their thinking processes. They express both without recognising that some of their internal speech should not become external. It is only after the age of seven that children start to become aware that speech should be restricted to communicate social interactions.

The inner speech that Vygotsky described is language which is mainly used to monitor inner thoughts and logical thinking. Paivio (1971) goes further by suggesting that verbal symbolic processes, which are very much equivalent to inner speech, overlap with imagery processes. This explanation suggests that there may be some words which even though they come from different languages, when presented to bilingual people should express similar understandings and that these could have been developed according to the way these people have experienced or internalised their imagery experiences or events. This suggestion has been confirmed in a study done by Rosenberg and Simon (1977) where bilingual subjects were presented with words in French and English. They found that they showed '*...very similar, if not identical, semantic systems ...*' for both languages. They concluded that semantic understanding of sentences in languages coming from different cultures have a single semantic structure.

Perhaps a more relevant study to why words can activate imagery modalities in people is the one by Bugelski (1977). This article not only criticises the work published at that time by people like Pylyshyn (1973) but it also describes a study by Bugelski with children from Spanish and English cultures. Bugelski criticises the work of Pylyshyn on imagery by indicating that he proposes that imagery is a defective area in cognitive activity due to the fact that ' ... *imagery has to be descriptive rather than pictorial* ...', and that most writers Pylyshyn mentions were describing imagery as a '...*reactivation of a previously experienced sensory experience.*' But, as Bugelski explains, Pylyshyn was never able to explain what this '...*reactivation*...' was about. On the other hand by citing this aspect Bugelski may have been the first researcher linking imagery with individual personal experiences.

In relation to imagery modality, Bugelski points out that Pylyshyn asks whether imagery is modality specific . To answer this question Bugelski suggests that ' ... *if images are revivals of prior sensory activity in the brain, then the modality will depend on what sensory activity is revived.*' This, again, indicates that as early as 1977, people like Bugelski were already proposing that imagery was coded in the brain according to specific sensory stimuli and that, if a person wanted to recall a specific mental imagery, it was more likely to be done via the modality that person used during storage. The recent work done using MRI and PET technology tends to confirm the above suggestion of Bugelski.

As far as the use of words to exhort imagery is concerned, Bugelski states that

> '... *Words do not possess meaning - they arouse it, and the best evidence we have suggests that what is aroused is involuntary imagery. ... The basic question is what happens inside the auditor when he hears the word "dog". The spoken word is a stimulus, and in the normal English-speaking auditor, it will produce an internal response.*'

But what would happen if individuals started speaking in one language and then switched to another? To respond to this question Bugelski presented an experiment with bilingual participants. They had first spoken Spanish during childhood but then changed into English at an adult age. It was found that English words were more related to thoughts developed at a mature age, whereas the Spanish words recalled thoughts from a younger stage of life. Bugelski concludes that words

> '... *can serve as conditioning agents and become related to responses that are made when the words are used. ... If the events or objects are experienced in childhood, the words now heard will arouse corresponding childhood imagery. If the language used in childhood differs from that used in adulthood, the original language will retain its associated imagery. When the adult is tested with childhood language, he will then think not in childish terms but in imagery relating to childhood experiences.*'

It is this conclusion that is the driving force behind the present imagery modality instrument. This suggests also that imagery words can become the primary agents to recall the modality used during storage of the stimuli irrespective of the type of language used. Thus, translation of single high imagery words from one language to another would more likely to access the imagery modality of any person who would prompt their own experiences during the execution of the imagery test.

QUESTIONNAIRE

Method

Subjects

For this part of the project there were 85 subjects, forty males and forty five females. Their age ranged from nineteen up to forty seven years old, their main language was Portuguese and they had no previous experience of imagery testing or analysis.

Materials

This project made use of the one hundred and sixty eight words collected from the report published by Benjafield & Muckenheim (1989) project and which were given to the English speakers in the previous chapter. The words were translated into Portuguese, and four words of the original list could not be translated because their translation corresponded to one Portuguese word, and some could only be translated into two separate words. Their translation was checked by a second Portuguese speaking person. The words were then translated back into English to confirm their original translation.

The list of words was presented to subjects one at a time using the computer program developed in the previous project. A small alteration to this program enabled the results of each subject to be recorded on the hard disk rather than being printed out on paper. The instructions were also translated into Portuguese and presented to the subjects.(See the Appendix B)

Procedure

Each subject sat in front of the computer and was asked to read the instructions displayed on the monitor, as explained in the previous chapter. After being asked by the tester if there were any questions, the participant placed one finger on each of the B, N, and M keys on the keyboard and waited for a word to appear on the monitor. If the word stimulated a visual image the key B was pressed. If there was an auditory image the key N was pressed. Key M was pressed if the word activated a kinaesthetic imagery

After the presentation of all the words, the selection for each modality and the mean time taken by each subject to press the B, N, and M keys were displayed.

Results

A frequency analysis was performed on the number of times each word was selected for each modality. As in the previous English test thirty six words were selected as being the most representative of the single and mixed modalities. Thus there were six visual, auditory and kinaesthetic imagery modalities, eighteen on total, and six visual-auditory, visual-kinaesthetic and auditory-kinaesthetic mixed imagery modalities, making the other eighteen words.

Of all thirty six words, eight were qualified with the same modalities both in English and Portuguese. These were: *soft, buzzer, river, hot, scrape, cold, barking, and speak.* Seven of those words were qualified as being auditory or kinaesthetic modalities and only one, river, as a mixture of auditory-visual modality.

As in the previous experiment there was no difference in the type of imagery modality attribution to the words between males and females.

Conclusion

The words chosen by Portuguese people seem to show that cultural and local experiences can play a very important part in the way imagery modality is organised. Of the thirty six words only eight were associated with the same imagery modality as in the English sample. They all relate to auditory, kinaesthetic or a mixture of auditory and kinaesthetic imageries. The words which activated the visual modality in the English sample were the ones which produced the least communalities and those that were common were words which tended to be associated with auditory imagery modality. This result seems to indicate that, as was mentioned by Bugelski, words qualify personal experiences and that when they are presented to people they excite stored experiences. It also indicates that cultural differences may be more pronounced in the visual imagery modality than in the others. Auditory and kinaesthetic modalities seem to be characterised in a closer way to the English and Portuguese cultures. One explanation for such result could be that auditory and kinaesthetic imagery modalities words are more basic in their origin. For instance, the words barking, speak, buzzer, all single auditory imagery modality, or hot and soft, all single kinaesthetic imagery modality, are words that an individual may tend to understand effortlessly because they are easier to associate with stimulation a person is more used to from a very early age. For example, work by Condon & Sander (1974), has shown that new-born babies are very sensitive to rhythms of speech. Also the work by Meltzoff (1982) showed that babies tend to imitate the movements of mouth, tongue and hand movements of their parents when they speak to them. On the other hand visual imagery modality words, like square, or dial, are words which an individual learns later in life. They also belong to visual environments which can be composed of more than one object. Therefore they may be related to a part of a whole rather than the whole itself.

A probable explanation of why babies seem to be more sensitive to auditory and kinaesthetic stimuli is that their vision up to the age of one year is not fully developed. Earlier work by Abramov, Gordon, Hendrickson, Hainline, Dobson & LaBossiere (1982) has shown that eye receptors in and around the fovea in infants are immature. This provides a lack of visual acuity, as was found by Sireteanu, Fronius and Constantinescu (1994), which may make babies rely on other sensory receptors. Thus, as the auditory and kinaesthetic sensory stimuli develop stronger brain cells arrays the association between these modalities and imagery formation may become stronger. It seems reasonable to speculate that vocal sounds heard by new-born in association with touch become stored at an earlier age and they may be more rapidly and easily learnt. On the other hand visual stimuli, as they develop brain cells arrays at an older age, can be more influenced by significant others like family, friends of the family or caretakers, as well as environmental stimuli and the information stored due to early auditory and kinaesthetic stimuli. This may imply that cultural effects in the development of visual imagery can become more influential than in the development of auditory or kinaesthetic imagery. This implies that auditory and kinaesthetic experiences are, in a sense, probably more '*basic*' in the brain than visual which can be affected by an assortment of influential external stimuli. As pointed out by Intons-Peterson (1996)

> *'...images generated by subjects include not only information specifically provided to them but also real-world knowledge presumably elicited by associations already in long-term memory'.*

VALIDATION

The present Portuguese instrument was validated using the same procedure as that used in the English language version. Therefore a criterion validation procedure was used in order to find out if the Portuguese imagery questionnaire was able to differentiate between subjects scoring high in kinaesthetic or visual modalities and their consistency in a pointing movement task after being accommodated by lateral displacement goggles.

As in the previous chapter it was hypothesised that those subjects who produced a high kinaesthetic modality score from the questionnaire would be more consistent in the pointing task if they used kinaesthetic imagery, that is less pointing movement variation, but less consistent if they used a visual imagery modality. On the other hand those people for whom the instrument gave a high score in the visual modality would be less consistent if they pointed at the target using a kinaesthetic imagery modality and more consistent if they used a visual imagery modality.

Method

Subjects

There were twenty subjects, 10 males and 10 females. They were all naive to the objectives of the present study and had no previous experience of imagery interventions.

Materials

The 36 words selected from the questionnaire were presented via a computer, using a similar program to that of the English version. The only difference was in relation to the storage and display of the results which, in this Portuguese version, were accomplished via storing the results on the hard disk of the computer. The instructions were also translated into Portuguese and presented to the subject at the start of each session.

Like in the English version, there was also a pair of 20º displacement goggles and a dart board for the pointing task.

Procedure

The procedure followed in this experiment was the same as during the English version. Thus, as soon as the instructional page was displayed on the screen each subject was asked to read it and ask any questions they may have before going into the word display and imagery formation section.

After completing the questionnaire the number of times the kinaesthetic, visual and auditory modalities had been selected was displayed on the monitor.

At this point each subject was randomly allocated to two groups. A group of ten subjects were put through a pointing task similar to the English project in the previous chapter, using active imagery modality orientation, visual or kinaesthetic, which were the modalities specified by the questionnaire as the strongest modalities for these participants. Thus, if the results showed that the subject had a high rate value for visual modality the training would use visual active imagery training orientation. A similar procedure was used for kinaesthetic imagery if the questionnaire indicated that the subject had a high count kinaesthetic word choices. On the other hand, the second group of ten subjects was trained using active imagery modalities different from those specified by the questionnaire as their strongest modalities. Thus, those participants whom the instrument revealed as being strong in visual imagery would be doing active kinaesthetic imagery during their training, whereas those who were strong in kinaesthetic modality would be doing active visual imagery during their training of the motor pointing task.

Each subject then stood in front of a dart board and pointed at the centre of it a few times in order to understand the nature of the task and at the same time determined a close but not touching distance between the centre of the board and the middle finger of the subject's strongest hand. As soon as the distance was determined the subjects put on the 20º goggles and were asked to repeatedly point and correct their hand-eye deviation from the centre of the board until they stopped making any deviations. That is, until they were accommodated to the distortion of the motor task pointing task due to the aberration of the glasses.

As explained in the previous chapter during the Validation section of the English Questionnaire, the subjects were just asked to closed their eyes and to keep them closed until being told to open them. As soon as they closed their eyes they were asked to point at the board in the same way as they did during the training task and at the same time to imagine the movement according to the modalities described two paragraphs above. As soon as they performed each active imagery pointing task towards the centre of the board a measure of any displacement between their middle finger and the centre of the board was taken and recorded.

A modification from the English version experiment was that in the present Portuguese version there was no 'no imagery' group intervention due to the clear no difference results obtained in the earlier experiment.

Also in this version some of the subjects described their overall impressions after doing the imagery pointing intervention and this qualitative data was recorded and taking into consideration during the analysis of the results.

Results

The standard deviations of the ten pointing movements for each of the twenty subjects that were performed in the task were analysed using a Pearson product moment correlation coefficient like in the English version. It was found that those participants who, during the pointing task used an imagery modality intervention as indicated by the imagery modality instrument as their primary modality were more consistent in their pointing task than those using an imagery modality that was different from the one indicated by the test. The r=-7925 was significant at p<0.001 for 18 df.

The mean variation of the standard deviations for those subjects who matched an active imagery modality training in the pointing task as indicated in the test was much smaller (4.71) than those who used an active imagery modality different from the one determined by the test (22.113). Those who used an active imagery modality intervention as indicated by the test varied between 2.35 and 6.25, with five subjects producing standard deviations within a value of 5, whereas those that did not use an imagery modality as found by the test varied between 14.18 and 46.9, with three subjects having standard deviations within the value of 20.

In view of the above results being similar to those in the English version, it was decided to do a t-test, on the present data, in order to find out if there was any separation of the results between the two independent groups of subjects who used an active imagery modality as determined by the imagery instrument and those who did not. The obtained t-value was 5.51 for 18 degrees of freedom which makes this result to be significant at $p<0.00003$ level.

As far as the qualitative data were concerned the most interesting reports were from those subjects who used an active kinaesthetic imagery modality as indicated by the instrument as their primary modality. They declared that they were aware of the position of their bodies in relation to the way their arm was pointing at the board. They would correct their bodies if they felt that, during the imagery intervention task, their arm and their shoulder were not at a 90 degree angle in relation to the centre of the board. Similar disclosures were pronounced by those subjects who used active visual imagery modality as indicated by the instrument as their strongest modality. These said that during their active visual imagery training period with their eyes closed they had clear imagery similar to that when they were pointing at the centre of the board during the demonstration phase and with their eyes open. In fact a participant from this group said that she had always used visual imagery even when reading any texts.

On the other hand those who used an imagery modality different from the one established by the test reported that they had found it very difficult to do the pointing task.

An interesting finding among the individual data was from two subjects who were rated as being very strong in the auditory modality by the questionnaire, and their second and third strongest were kinaesthetic and visual for one participant and visual and kinaesthetic for the second. During the active imagery pointing task their standard deviations showed a mean of 5.47 when the first subject was asked to do an active kinaesthetic imagery modality pointing activity whereas the second participant got a mean standard deviation of 15.99 when asked to do a visual imagery modality which was different from the one he was second strongest. These results may seem to indicate that there could be a stratum of imagery modality preference during active motor imagery tasks starting with the strongest modality followed by the second strongest if the first is not activated.

Discussion

The results obtained from the present Portuguese version of this test substantiate those already found in the English version. That is, those people who in a motor skill task use a mental rehearsal modality procedure, as indicated as their dominant modality, will exhibit a more consistent movement than if they use a different imagery modality. This is due to the fact that high imagery words, like the ones chosen for the present instrument, can stimulate the imagery modality individuals are more likely to associate these words with. Thus, taking into consideration the findings from the English and Portuguese instruments, it seems reasonable to suggest that when people are asked to perform a novel activity together with active imagery intervention in order to learn this activity, they would learn and perform faster if they use the modality they are more likely to use when storing new activities. That is '*visual*' imagers should use an active visual modality whereas '*kinaesthetic*' imagers should use active kinaesthetic modality and in view of the finding regarding the two subjects in this experiment who were rated high in auditory imagery, '*auditory*' imagers should use active auditory imagery modality. But can this claim be explained in accordance with current imagery theories?

Paivio (1971) seems to be the most likely candidate for the above explanation. In fact he said that when words are presented to people their

> *'... reactions, whether covert or overt, non-verbal or verbal, are associative reactions that depend for their occurrence not only on the*

particular stimulus to which one reacts but also upon one's past experience ... '.

Thus, from this citation it seems that Paivio does indeed claim that words can activate imagery reactions which are stored in individuals and that these would be recalled everytime those specific words are presented to them. But, as Kosslyn (1980) pointed out, imagery and verbal representation are distinct from each other. He says that

> *' ... Paivio's claim that only two codes, Image and Verbal, exist for representating information in memory ... A tenet of this approach, ..., is that the long-term memory representations of images are qualitative distinct from the representations underlying production and comprehension of language. It is left open whether the image, as occur in active memory, is generated by some other representation in long-term memory; this presumably would be acceptable to Paivio as long as the long-term memory representations are distinct from those underlying verbal behavior.'*

On the other hand, the present instrument seems to indicate that verbal behaviour is not separated from imagery. In fact they seem to complement each other. Thus, contrary to Paivio dual-code theory, the results from this questionnaire may indicate that people may not just imagine an object or scene represented by words and then store the visual scene in memory. What we may be doing is to experience an object or scene via a sensory modality, and as we do this we attach a word to it and then both may be stored in memory. Later on, as soon as the word is presented to us, like in the present test, the sensory modality of the object/scene is brought back to our consciousness.

In relation to the functional-equivalent hypothesis, proposed by Shepard and more recently by the work of Kosslyn, it may be said that there are very few aspects that can be relevant to the findings from this instrument.

This hypothesis proposes that imagery and its perception are quite similar, and also that time is related to the difficulty of the imagery task. This means that the more difficult the task the longer the imagery. The work of Shepard proposed that there was a relationship between the degree of turn a person rotated the object and the time people would take to do that rotation. Thus the more degrees of rotation a person did the more time that person would take in doing it.

Kosslyn went one step further from Shepard and progressed from rotation of objects into the size of the objects and scanning. In one of his experiments Kosslyn (1975) asked people to imagine, using a visual modality procedure, an animal, like a rabbit, next to another much bigger, like an elephant, or much smaller, like a fly. Next he asked these subjects to look for a property of an animal, like ears, in these two conditions. Kosslyn found that the participants in this experiment took longer to evaluate the rabbit and elephant ears properties than the rabbit and fly. This, he explained, was due to the fact that the subjects took longer to scan the ears of the elephant and rabbit than the rabbit and fly. To counterbalance the results of this experiment, Kosslyn then compared the time people would take to scan the animals when they were compared with a very large fly and with a tiny elephant. He found that people would take more time to scan animals when they were doing it with a large fly than with a tiny elephant. So how can these findings related to those found with the test?

First, it has to be recognised that the work of Shepard and Kosslyn used only the visual modality. Thus, how do they know that their results are not due to modality differences rather than the time people took to scan or rotate the objects?

Secondly, they looked at the time people would take to rotate an object or scan a specific part of images of large and medium size objects and then between medium and tiny sizes. But how often do people do this sort of behaviour? Also, how do they know that when people are asked to do this type of imagery they would not use other modalities? In fact, there is some evidence which shows that people, when asked to do this type of imagery, may cross-modal their imagery. For instance, work by Katz (1989) found that kinaesthetic images are usually mixed with visual images when people are asked to imagine the smoothness of a panel of glass. This conclusion goes along with the point made in the introduction in the previous chapter were people in imagery tests are asked to imagine a situation rather than allowing them to create it themselves. Further, a recent article by Klatzky, Lederman and Matula (1991) tested the idea of whether people who are asked to imagine properties of texture, hardness, apparent temperature and weight would show a greater kinaesthetic modality response than if they were asked to consider visual modality properties like shape and size. They found that these participants would make greater substance-related imagery when asked to imagine objects kinaesthetically than structure-related imagery.

Thus, it seems that the two most established theories fail to support the present findings. On the other hand, there is a third imagery model which seems to come very close to what has been found in the last and present experiments. The Triple-Code Model from Ahsen has been mentioned throughout this project and it seems to be the only one which can substantiate the most of the findings from all the experiments done throughout this project. So what is about the Triple Code model that is so relevant to what the present work has found?

To recapitulate, the triple code model proposes that there are three essential parts to every imagery. One, the Image (I) itself which Ahsen describes as

> *' a centrally aroused sensation. It possesses all the attributes of a sensation but is internal at the same time. It represents the outside world and its objects with a degree of sensory realism which enable us to interact with the images as if we were interacting with a real world.'*

The second aspect is sensation or the '*somatic response*' (S), for which he says that everytime a person creates or recalls an image this is accompanied with a '... *neurophysiological change which involves skeletal, proprioceptive, sensory experience* ...'. Lastly, the '*meaning*' (M) of the imagery to the person is making. That is

> *' Every image imparts a definite significance or meaning. Through*

meaning the organism interprets its relationship with the visual or with the world.'

It is this last aspect which separates the explanation of Ahsen of what is imagery from what other people have said up to now. This '*Meaning*' means that every individual brings his or her unique experiences to the imagined situation. Therefore, when each participant in these two experiments is presented with a word there would be an activation of these three aspects because all three interact with each other. Thus a combination of ISM means that recall of an imagery is followed by a somatic and then a meaning response. An IMS represents imagery that is initiated by an image followed by a meaning and then a somatic response. The SIM represents a somatic response followed by an imagery and then the meaning. An SMI is the recall of a somatic response followed by meaning and then imagery. Finally the last two, MIS and MSI, are particularly relevant to this instrument. These two last combinations mean that the Meaning component may be elicited from an individual, which in the present test represents the list of words presented to each participant, via a visual modality for some people and a kinaesthetic modality for others. As Ahsen says in relation to his Meaning it '... *is treated as an experiential mode involving understanding which may or may not express itself in a verbal form but which has a direct access to language*'. Also

> *'... when a word and meaning are seen together, we have two processes which both diverge and converge and contain their own separate language and imagery links appearing simultaneously along convergence and divergence axes. This suggests that there is a covert*

imagery process in language which affects imagery experience at the overt level.'

This last quotation quite clearly supports the basic foundation of the present instrument in that everytime a word is presented to individuals, they would recall the experience with which those individuals have associated that word. In doing so, the people will choose the modality most frequently used to store information. Then, when that information is activated by an high imagery word, like those from the present questionnaire, the way the testee creates the imagery situation, would be in accordance with the most used modality of that individual.

Chapter 9 - General Conclusion

The last six chapters have described experimental work which has attempted to find out what sort of effects active mental practice can have on the performance of motor skills. This last chapter is going to concentrate on this work, taking into consideration the Triple Code Model as the theoretical basis for the findings and any possible changes to the Model in line with what was found from these experiments and in any recent literature.

The first two experiments, carried out within a sport psychology context, indicated that active mental practice, that is, performance of the table tennis motor skills together with mental imagery of the act itself having the participants oriented towards those parts of the body they were using during the performance of the task, seem to be able to have an effect on the way the participants perform the motor activity task. The effect is manifested itself by providing a greater accuracy and placement of the ball on the table and also on a possible initial development of mental schemas due to the execution of the sequences of motor movements during active mental practice. These two experiments showed also that the Triple Code Model supports the results obtained during the performance of the task. The three basic facets of the Model, the I for Imagery, the S for Somatic and the M for Meaning, are put into action during active mental practice. That is, when participants active imagine motor tasks the I component goes into action. At the same time the experimenter, by orienting the imagery of the participants to those parts of their bodies as if they were performing the movements, trigger somatic responses, and this is the S component. The M element comes also into action because the subjects know what they should be doing during the performance of the table tennis skills. Thus, on the whole, these two experiments seem to support the Triple Code Model and explains how the participants improved after performing active mental imagery.

On the other hand, as explained during the Introduction, recent work on imagery formation and the analysis of these cognitive activities using PET scanners, seems to indicate that when people imagine human activity, such as motor acts, they activate those parts of the brain which are used during actual movement. As Decety (1996) claimed recently,

> *'... motor images share the same neural mechanisms as those that are also responsible for preparation and programming of actual movement'*

which leads Decety to define motor imagery as

> *'... a dynamic stage during which a subject mentally simulates a given action ... [this] implies that the subject feels himself performing a given action'.*

When these two quotations are read in the way they have been presented above, they seem to indicate that when people imagine an action the act itself activates the three ISM components of the Triple Code Model, being the *'simulation'* the I, the *'... feels himself ...'* the S, and even though the M factor is not clearly pointed out there is an implication in the statement '... *given action* ...', because the subjects have to have some understanding on how to perform the act. This suggests also that they have to activate those cortical areas which people use during their actual performance. This view leads to a question of whether active mental practice can have an effect on motor skills which an individual has been performing for several years. The reason for such question is because if imagery activates motor areas in the brain, it implies that established brain cell arrays in motor neural sites go into action whenever a person performs that skill. If the act is performed many times over, the inter-cell connections get stronger and stronger and thus would be very resistant to any change in the way a person has been used to perform the movement. This, in fact, has also been pointed out by Decety (1996) who said that

> '... *simulation of one's own actions, share common neural mechanisms with other covert aspects of motor performance, such as planning and programming.*

But could active mental practice change the '... *planning and programming...*' of individuals? Thus, in order to answer this question, two further experiments were performed which used subjects who had surgical transplant of their knees due to their deficient bone formation. As these deformations develop through a very long period of time, they cause gait patterns which are very characteristic of people with these type of knee disfigurements and different from the norm. The problem is that, as pointed out in Chapters 5 and 6, rehabilitation from the surgery on the knees occurs without any problems, but correction of the gait pattern is very difficult and sometimes does not happen at all. The question then was whether active mental practice could have any sort of effect during the rehabilitation phase and also on the correction of performance of the gait execution. The results from the first experiment indicated that those subjects who used active mental practice during the rehabilitation phase seemed to progress in a more consistent manner than those who just followed the traditional rehabilitation procedure as practised by physiotherapists. An explanation for these findings is that when the patients were doing active mental practice the I, S, and M components may have forced them to become aware of the performance of the movement itself rather than allowing these people to become aware of the pain feedback from their bodies. A similar and rather amusing description was given by the swimmer Mark Spitz who was asked ' ... *how he could keep going lap after lap in practice despite being in the verge of exhaustion.'* and thus rather in pain. The swimmer said that

> ' ... *he imagined a different girl at each end of the pool, waiting for him with open arms ... and if the times decreased, it simply reflected the attractiveness of the girl rather than his fatigue'* (Nideffer, 1983).

This quote is a clear example on how this athlete changed traditional interpretation of exhausting, the M component, from his somatic (S) responses due to his imagery (I).

The subjects from the first experiment on knee rehabilitation experiment received also some interventions of active mental practice, in order to find out if these could change their gait. Even though the physiotherapist who supervised the performance of the subjects did agree that they all tended to correct their gait, the analysis was done using visual procedures. Such a technique is not very reliable, as it is dependent upon the amount of experience the expert has in analysing gait activity. Thus, it seemed that unless there was some more reliable technique to analyse gait performance, the qualitative data obtained from the physiotherapist during the first experiment could not be completely substantiated. This requirement lead to a search for an alternative way in analysing gait and one of them is by using analysis of video recording during gait movements. The main problem with such type of procedure is that the equipment for doing such analysis is very expensive and thus beyond the majority of health centres like small local hospitals. A simpler solution was to use available computational and less expensive technology and find out if this equipment was able to provide numerical measures during gait performance.

The equipment described in Chapter 6 seemed to show measurement accuracy similar to those from professional dedicated gait analysis systems and for a fraction of the price. This equipment was then used in a case study of a Portuguese subject who had developed a dysfunctional gait pattern due to faulty foot development. Even though the participant had received proper surgical intervention and physiotherapy rehabilitation, her gait was performed in the same manner as when she had the foot problem. This was a rather interesting case not just from the point of view of whether active mental practice was able to change her gait activity, but also because traditional gait interventions were unable to change the gait of this subject as predicted by the above explanation of the brain cells arrays and also by Decety. The results from the gait analysis equipment clearly shows that active mental practice was able to change the gait pattern of this subject and so substantiating the visual analysis conclusions of the physiotherapist in relation to the active mental practice interventions done on the gaits in the previous experiment.

Thus, on the whole the Triple Code Model of Ahsen used within an active mental practice procedure seemed, up to this fourth experiment, to be very effective at explaining why mental practice can change the performance of a motor skill Also that this type of intervention may have an effect even during those situations where people have been doing motor activities for quite some time.

However, when the three components are analysed more carefully it seems that two of these could also be influenced by the way the subjects process them. Imagery can be constructed using different sensory modalities and the same could be said of the meanings subjects make when they were performing their mental practices. On the whole, the three most used modalities in the literature of mental practice are auditory, kinaesthetic and visual. However, when Ahsen wrote about the Triple Code Model, he did not point out what sort of imagery his interpretation of his *'imagery'* was like nor his definition of his *'meaning'* factor. Of course such a line of reasoning brings another question which asks whether these imagery modalities could affect the performance of motor activity during active mental practice. Thus, it was necessary to develop an instrument in order to find out if imagery modalities used within an active mental practice context could affect the way people perform motor skills. Looking at various imagery questionnaires developed until then most of them tended to use descriptions of situations in order to have testees quantify these in some way so that a high rate attributed to one modality meant that the participant was also stronger on it. But as pointed out in Chapter 7, the work by Chara, also confirmed recently by Kosslyn, indicated that the ratings given to such descriptions might not correspond to a true value due to the fact that the people doing the test may not have had a personal understanding and experience of the given description. If this is the case, the chosen modality would be more like what people think it should be rather than a true embodiment of the three components of the Triple Code Model. Therefore, there was a need for an alternative type of test which would allow people to create their own environments, so that the role of this instrument would just ask participants to indicate what sort of modalities they were using. Also, as described in Chapter 8, at this time a series of speakers at the 8th World Congress of Sport Psychology pointed out that most tests used in psychology lacked universalization and cross-cultural validation. Thus, it was decided that the developed test should not only approach the measurement of imagery modalities from a different point of view but also that the methodology used in the creation of this instrument should have cross-cultural validation. The approach taken to measure imagery modalities was to display high imagery words and allow people to indicate what type of modalities they were experiencing when these words were presented to them. The idea of presenting high imagery words as triggers to generated imagery situations derived from the Dual-Code theoretical model by Paivio as explained in Chapter 7, but after performing the experiments it may be said that the Meaning component of the Triple Code Model may, to a certain extent, explain why high imagery words bring into consciousness imagery modalities which are particularly applicable to a specific person. This is because if a word meant something to a person it is logical to assume that it would also activate the other two components, the imagery and somatic, which would enable this person to indicate whether the imagery was visual, kinaesthetic or auditory.

The first test, which was developed in English language, showed that the imagery modality used during the active mental practice did have an effect in the performance of the movement during the intervention so that the modality which the test indicated as the strongest one resulted in less movement variation than if people did the same movement using any of the other two modalities. This was a clear and direct indication that the modality people used to imagine their movements could affect the way they performed the activity. But would the same results be applicable to another society which was different not only in language but also in use and customs? After translating the words into Portuguese and presentation to Portuguese participants it was found that, for the kinaesthetic and auditory modalities, the chosen words were similar as those in the English language questionnaire. But those words which were selected to formulate the visual imagery modality section were on the whole different from the ones picked by the English participants. The explanation given for this finding was that visual words could be more dependent upon environmental effects than kinaesthetic or auditory and so less elementary. Even though this explanation may seem to be rather improbable there is some recent work by Menard, Kosslyn, Thompson, Alpert & Rauch (1996) which may give some indirect support for the given explanation. They performed an experiment where they wanted to find out which areas of the brain, via PET analysis, were most active when people were asked to read familiar words and identify familiar pictures to themselves. They found that the left angular gyrus and the Broca's area were most active when people read the words, whereas the middle temporal gyrus and the parencental area (the precentral motor gyrus and the postcentral sensory gyrus) were more active when people saw the familiar pictures. But almost at the end of their paper they report that their qualitative data extracted from verbal reports from the subjects showed that

> *'... almost all the subjects reported a tendency to say the words to themselves as it appeared on the screen, and to a lesser extent, to name each picture. (None of the subjects, however, reported visualising the named objects)'.*

In light of what was suggested above in relation to why auditory and kinaesthetic modalities may be more basic, this quotation may also indicate that people may be more prone to use these two modalities during activation of accustomed situations than visual modality, which may be what the high imagery words were doing when they were selected for this questionnaire. Furthermore, another article by Kartsounis & Shallice (1996) reported a case study of a person who suffered from anoxia after a myocardial infarction, which affected his memory for identification of familiar visual stimuli but not for auditory ones. They suggested that

> *'... visual recognition tasks are cognitively more demanding than the verbal identification ones and that the observed differences in the performance of our patient simply reflect task difficulty.*

They also reported that the visual identification problems of this subject did not extend to other objects '... *such as flower and dog species'.*

Another article which can provide some evidence on the disengagement of the visual modality from interaction with other areas of the brain in contrast with the auditory and kinaesthetic modalities was a case study done by Shuren, Maher & Heilman (1996). They report a case study of a woman who had an intracerebral haemorrhage on the occipital lobe, inferior temporal lobe and temporoparietal-occipital junction. The performance of this woman at imagining words was more hampered when asked to write their spelling or even when she was asked to recognised the words when they were orally spelled to her. They concluded that ' ... *visual imagery of a word is not necessary to spell that word or to recognise the word when spelled orally'*.

This explanation is very much against a proposal from Friedman & Alexander (1989) who have suggested that people needed to visually imagine words in order to store them in the orthographic output lexicon otherwise they would experience lexical agraphia.

Also, a recent article published by Fallgatter, Mueller & Strik (1997) investigated brain activity of mental imagery in the visual, auditory and tactile modalities. They compiled word lists which were able to elicit powerful imagery in these three modalities, akin to the questionnaire developed in Chapter 7 and 8. They presented the words to nine individuals via a computer screen at a rate of a word for every 3 seconds. The P300 component of the evoked response for the visual sensory modality was most active on the posterior centroid, for the tactile imagery words the most active part of the brain was on the left posterior centroid area of the brain, whereas the acoustic words produced stronger P300 activity on the midline posterior position of the brain. They concluded bay saying that

> *' ... These differences in centroid locations during mental imagery in different sensory modalities can be explained by the underlying*

activity of different neural generator ensembles, possible involving modality specific primary cortical areas.'

In total, all this recent experimental work seems to give some support to the notion that, taking into consideration the Triple Code Model and that identification of stimulus is an interaction of various brain areas, the verbal and kinaesthetic stimuli identification may activate more cortical areas than visual stimuli and this may produce stronger responses to outside familiar stimuli such as high imagery words. Thus, if imagery modalities can, in some way, bring into consciousness stored familiar experiences, following the M, I, S, components of the Triple Code Model, that is the Meaning the person has of a word can produce a specific type of Imagery which has a Somatic response, it seems reasonable to propose that auditory and kinaesthetic modalities are more basic and thus less prone to cultural variations than is the case with visual modality.

So what can be said about the Triple Code Model of Ahsen and the findings from the experimental work done in this project? Is the Model capable of supporting all the evidence? On the whole it can be said that it can, but that it just stops short in explaining the findings from the imagery questionnaire. Thus, based on these results it is proposed that this Model could be refined so that even though the three components of the Model are still the principal variations of any mental practice activity, the Imagery aspect should be defined differently. The Meaning and the Somatic definitions provided by Ahsen should be left unaltered in that people have to understand (M) of what is required of them when presented with unknown activity, and that this produces a proprioceptive experience (S) within the organism. But, the definition of the Imagery component should be expanded in that the Imagery used is dependent upon the type of modality the individuals employ during activation of those brain areas which go into operation when activated by the external demand. These cortical areas then come into action when imagining the activity later on, which also activates the Meaning and the Somatic factors experienced during the initial exposure to the unknown stimuli.

Almost at the end of Chapter 1 there is a list of what the present project was going to use as basic guidelines. These pointed out not only the theoretical framework used in this project but also the type of methodology. One of them, number three, indicated that the participants were going to do active mental practice for a period of three minutes. Even though this period of time was supported by the work explained in Chapter 1, a recent article by Etnier & Landers (1996) has reinforced the three minutes position as the ideal time for mental practice, because they also found that mental practice activity of basketball shooting task for periods of 1 and 3 minutes improved the actual performance of task in comparison with longer times like 5 and 7 minutes. In fact, a closer look at their results section indicated that the 3 minutes intervention was the one which produced the best results of all the other times, with a mean of 2.51 improvement of good baskets over base line, whereas the mean of improvement for the one minute of mental practice was of 2.27 over base line.

A further point is in relation to the formation of brain cells arrays which form singular 'understandings' of external stimulus, as explained in Chapter 1. A recent article by Crick & Koch (1997), support this idea of brain cell array formation, which they called ' ... *active representation* ... ' but they concentrate mainly on the visual system. In here, the speculative suggestion is that these arrays develop specific close connectedness with specific sensory inputs. These arrays connect among themselves and in specific local areas when the sensory input is appropriate to one sense. On the other hand they may inter-connect to other brain cells arrays when a mixture of sensory modalities is perceived by the organism, such as crackling of fingers, which can be a mixture of auditory (the small sharp popping noise of the finger joint) and kinaesthetic (the grasping, movement and compressing of two hands and fingers) stimuli. The question which still remains elusive is in regard to how the brain forms a conscious representation of external stimulus. Following the above explanation one further tentative explanation could be that around these small brain cells arrays there are big arrays which allow the organism to 'understand' cognitive properties such as concepts, or schemas of behaviour, and in the present case human motor skills. Active mental imagery may allow activation of these as well as the small brain cells arrays. By doing so they may reinforce, or redirect the formation of, the connections between the small and the large nervous cells clusters.

In summary, the research work done during this project, shows that active mental practice based on the Triple Code Model where the Imagery component takes into consideration the strongest imagery modality of the participant, and where the intervention is done for the duration of a period of three minutes, can affect the pattern of motor skill people perform. Further, this performance will be more akin to what the participants rehearse during the mental practice procedure rather than what they were doing in the past.

SUGGESTIONS FOR FURTHER WORK

The Triple Code Model at the moment is perhaps the only framework which can provide the most complete explanation on why the use of mental practice can affect motor skills performance. By just changing the mental practice into active mental practice and by identifying imagery modalities people use during their imageries this Model may, at the moment, not require any further refinements. If this suggestion is maintained throughout any further work which tries to test this Model the question then is what can be done in order to progress within this area?

One possibility is to increase the amount of qualitative research in this area. Even though there was some qualitative data in this project, like in chapter three, four, five and six, the amount obtained was more in order to substantiate quantitative results rather than just qualitative data. This was because the objective of this work was to find outcomes of experiments rather than the processes people experience through the interventions, which is what qualitative research tries to concentrate upon. But as Richardson (1996) has recently pointed out qualitative work ' ... *has its own language*', and that it ' ...*is not easy research*'. It is rather interesting that one of the most recent research methodological books on human movement is titled 'Qualitative Analysis of Human Movement' by Knudson & Morrison (1997). This type of literature would be very useful to those who still have very little training and knowledge on how to do this type of research and would enable established investigators to use alternative methodologies within the study of human motor skills and mental practice.

Another sphere is in the world of virtual environments where people could be tested for their reactions or behaviours before they are placed in new real life situations. The great advantage of such procedures is that these people can change their reactions or performances by using active mental practice in accordance with what the real situation may be going to be like.

The development of virtual environments may also allow the testing of simulated mental activity. This is the case of the latest work by Decety and Jeannerod (1996) who wanted to find out if people when put through virtual gates of different widths and distances would produce similar response times as when they were doing these tasks mentally. They found that this was the case and they concluded saying that

> *'... the time needed to imagine oneself walking towards a given gate is affected both, by its distance and its width'.*

But perhaps the most radical proposal will be the use of the findings obtained from analysis of brain areas with PET scanning and fMRI during mental imagery in a new type of physiotherapy rehabilitation. As more and more evidence seems to indicate that there is a close association between brain area activity and the formation of imageries of motor movements, medical practitioners could use these analyses in order to identify cortical areas of the brain, so that in the future, those people who lack activity of or do not possess all their limbs have these artificially implanted to the body and control them by interfacing those identified motor areas of the brain, via mental practice, to silicon chips. In fact, this is similar to work of people like Peter Fromhertz at the Max Planck Institute in Germany. His latest work (Fromhertz, 1996) has shown that nerve cells not only can be attached to silicon microstructures but that these have been able to detect action potentials from the attached neuron. If such proposal is going ever to be achieved it is solely due to work done in a area of cognitive psychology, such as imagery and its more recent development mental practice, which has for quite some time, as pointed out in Chapter 1, being thought of as not worth researching or studying.

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APPENDIX A

PROGRAM ImageryTest

{This program identifies people's mental imagery, (visual, auditory or kinaesthetic) and each person's time response. English Version by Jorge Alvoeiro.}

```
Uses CRT, DOS, PRINTER;


VAR
  btotal, ntotal, mtotal    :Single;
  vtotal, atotal, ktotal    :Single;
  Ans                       :Char;
  ReturnCode                :Byte;
  Printable                 :Boolean;
  TYPELIST,Olist            :Text;
  bword, nword, mword       :Single;
  Oneline                   :String[50];


{$I D:\TP\INC\YESNO.INC}
{$I D:\TP\INC\TIMER.INC}
{$I D:\TP\INC\READKEYC.INC}
{$I D:\TP\INC\BEEP.INC}


procedure Sound;

    VAR
      NumberToDo, Pitch, Duration    :integer;

   begin
      NumberToDo:=5;
      Pitch:=50;
      Duration:=500;
      Beep(NumberToDo, Pitch, Duration);
      Beep(0,0,0);
      Halt;
   end;

procedure ShowWord;

  VAR
```

```
    ch                          :char;
    t1, t2                      :longint;
    aword                         :single;
    List, Line                    :shortint;
    Word                          :string[8];
    pcode                         :string[2];
    WList,WORDLIST                      :text;
    WCodes,CODES                        :text;

  begin
    ClrScr;
    Assign(WCodes, 'CODES');
    Reset(WCodes);
    Assign(WList, 'WORDLIST');
     Reset(WList);
    while not Eof(WList) do
   begin
    timer_mod_2; {This initializes the timer}
    Readln(WList, Word);
    GotoXY(35,10);
    write(Word);
    GotoXY(3,15);
 write('Escolha -B- para imagens, -N- para sons, -M- para sensa',#135,#149,'es da pele
ou m',#163,'sculos');
    GotoXY(35,17);
        t1:=timex; {This starts the clock}
    ReadKeyCode(ReturnCode,Printable);
        t2:=timex; {This stops the clock}
    if Printable then
      begin
      if (CHR(ReturnCode))='V' then
      begin
      btotal:=btotal+1;
      timer_mod_3;
      aword:=(t2-t1)/19.6435;  {(t2-t1)/18.6435 original correction value}
      bword:=bword+aword;
      end
        else
       if (CHR(ReturnCode))='A' then
        begin
        ntotal:=ntotal+1;
        timer_mod_3;
      aword:=(t2-t1)/19.6435;  {(t2-t1)/18.6435 original correction value}
      nword:=nword+aword;
      end
       else
        begin
        mtotal:=mtotal+1;
        timer_mod_3;
      aword:=(t2-t1)/19.6435;  {(t2-t1)/18.6435 original correction value}
```

```
      mword:=mword+aword;
      end;
 write(OList, (CHR(ReturnCode)),' ')
      end
      else
       begin
        ClrScr;
        GotoXY(12,15);
 writeln(' YOU HAVE PRESSED THE WRONG KEY. PLEASE CALL THE TEST
ADMINISTRATOR');
        Close(WList);
        Close(OList);
        Halt;
       end;
    readln(WCodes, pcode);
 write(OList, pcode);
 writeln(OList,'    time was: ',aword:8:1);
    ClrScr;
   end;
   Close(WCodes);
   Close(Wlist);
   Close(OList);
    end;
 begin

  ClrScr;
  Assign(OList, 'TYPELIST');
  Rewrite(OList);
  btotal:=0;
  ntotal:=0;
  mtotal:=0;
  bword:=0;
  nword:=0;
  mword:=0;
 writeln('             THREE MODALITY IMAGERY TEST ');
 writeln;
 writeln(' This questionnaire attempts to find out how people imagine');
 writeln('written words. For instances the word DOG. Some people, when ');
 writeln('reading this word, imagine a picture of a dog in their minds.');
 writeln('They are  using a visual modality. Others, imagine barking');
 writeln('noises. They are using an auditory modality. Whereas others,');
 writeln('experience the feelings of a dog''s fur between their fingers.');
 writeln('They are using a kinaesthetic modality.');
 writeln('What is important is what you imagine - pictures, noises or ');
 writeln('feelings - as soon as you read the word on the screen.');
 writeln;
 writeln(' Your task is to read the word and as soon as you get the sensation');
 writeln('press the -b- for pictures, -n- for sounds or -m- for skin or');
 writeln('muscle feelings. ');
 writeln;
```

```
writeln(' To start the test press the Y key and put your fingers IMMEDIATELY');
writeln('over the b, n and m keys. Else press N to call the test administrator.');
writeln;
writeln(' If you are ready to start just press Y now. There will be a short ');
writeln('delay for you to place your fingers over the keys.');



   Ans:=YesNo;
   if (Ans='N') then
           Sound;
           writeln;
writeln(' Please WAIT until a word appears in the middle of the screen.');
           Delay(9000);
           ShowWord;
           ClrScr;
           GotoXY(1,5);
writeln('YOUR TOTAL FOR VISUAL WAS: ',btotal:4:1);
writeln('        FOR AUDITORY WAS: ',ntotal:4:1);
writeln('     AND FOR KINAESTHETIC WAS: ',mtotal:4:1);
           Delay(5000);
           GotoXY(1,10);
           vtotal:=bword/btotal;
           atotal:=nword/ntotal;
           ktotal:=mword/mtotal;
writeln('YOUR TOOK A MEAN VALUE OF ',vtotal:8:1, ' mSec. FOR VISUAL');
writeln('        A MEAN VALUE OF ',atotal:8:1, ' mSec. FOR AUDITORY');
writeln('    AND A MEAN VALUE OF ',ktotal:8:1, ' mSec. FOR
KINAESTHETIC');
           delay(10000);
           GotoXY(1,15);
write('THANK YOU FOR DOING THIS TEST. A PRINTOUT OF THE RESULTS
WILL COME OUT SOON');
   Delay(6000);
writeln(Lst);
 Assign(OList, 'TYPELIST'); {this area for printing }
 Reset(OList);            {the response file}
 while not Eof(OList) do     {|}
           begin            {|}
           readln(OList, Oneline);   {|}
writeln(Lst, Oneline);   {|}
           end;             {|}
           Close(OList);
writeln(Lst);
writeln(Lst, 'T-VISUAL ',btotal:4:1);
writeln(Lst, 'T-AUDITORY ', ntotal:4:1);
writeln(Lst, 'T-KINAESTHETIC ',mtotal:4:1);
writeln(Lst);
writeln(Lst, 'M-VISUAL ',vtotal:8:1);
writeln(Lst, 'M-AUDITORY ',atotal:8:1);
```

```
 writeln(Lst, 'M-KINAESTHETIC ',ktotal:8:1);
 writeln(Lst);
 writeln(Lst, '      GENDER:   Male    Female');
 writeln(Lst, '      AGE:');
 writeln(Lst);
 writeln(Lst, 'Copyright Jorge H.C. daS. Alvoeiro');
end.


FUNCTION YesNo:Char;
 {This function comes from 'Turbo Pascal Toolbox' book pag.278}
     Var
       Ch      :Char;

     Begin
        Repeat;
             Ch:=ReadKey;
             Ch:=UpCase(Ch);
        Until (Ch IN['Y','N']);
        Write(Ch);
        YesNo:=Ch;
     End;


{Program to time events using the PC clock/ Behaviour Research Methods
Instruments & Computers, 1990, 22(3), 332-334.}
Const
   TIMER_O       =$40;
   TIMER_CTRL     =$43;
   SET_TIMER     =$34;
   RESET_TIMER    =$36;
   BIOS_SEG      =$40;
   TIMER_LOW     =$6C;
   TIMER_HIGH    =$6E;
   TIMER_LATCH    =$00;


Procedure timer_mod_2;
Var t:byte;
begin
   t:=mem[BIOS_SEG:TIMER_LOW];
   repeat until t <> mem[BIOS_SEG:TIMER_LOW];
   port[TIMER_CTRL]:=SET_TIMER; {sets timer-chip in Mode 2}
   port[TIMER_O]:=0;
   port[TIMER_O]:=0;
end;

Procedure timer_mod_3;
Var t:byte;
begin
```

```
    t:=mem[BIOS_SEG:TIMER_LOW];
    repeat until t <> mem[BIOS_SEG:TIMER_LOW];
    port[TIMER_CTRL]:=RESET_TIMER; {sets timer_chip to Mode 3}
    port[TIMER_O]:=0;
    port[TIMER_O]:=0;
 end;

 Function Timex:longint;
 Var nticks1, nticks2:longint;
    lo, hi, ntocks:word;
 begin
  inline($FA);
  port[TIMER_CTRL]:=TIMER_LATCH;
  lo:=port[TIMER_O];
  hi:=port[TIMER_O];
  nticks1:=meml[BIOS_SEG:TIMER_LOW];
  inline($FB);
  ntocks:=(hi shl 2) or (lo shr 6);
  inline($FA);
  nticks2:=meml[BIOS_SEG:TIMER_LOW];
  inline($FB);
  ntocks:=NOT(ntocks) and 1023;
  if (hi<>0) then timex:=(nticks2 shl 10) or ntocks
         else timex:=(nticks1 shl 10) or ntocks;
 end;



PROCEDURE ReadKeyCode(VAR Code:Byte; VAR Ans:Boolean);

{This procedure comes from 'Turbo Pascal toolbox' book pag.91}


VAR
     Ch            :Char;

BEGIN
    Ch:=ReadKey;
    Ans:=(Ch IN['b', 'n', 'm', 'B', 'N', 'M']);
     if (Ch='b') OR (CH='B') then Ch:='V' else
          if (Ch='n') OR (CH='N') then Ch:='A' else
          if (Ch='m') OR (CH='M') then Ch:='K';
      {IF NOT Ans THEN      This section until Code is to get shift keys}
      {IF ((Ch=#0) AND (KeyPressed)) THEN}
        {Ch:=ReadKey;}
       {if Ch=',' then Ch:='V' else}
          {if Ch='.' then Ch:='A' else}
          {if Ch='/' then Ch:='K';}
      Code:=ORD(Ch);
END;
```

```
procedure Beep(NumberToDo, Pitch, Duration:integer);
const
   DelayLength  =200;
   DefaultNumb  =3;
   DefaultPitch =440;
   DefaultDur   =250;

var
  J :integer;

begin
   if NumberToDo < 1 then
     NumberToDo:=DefaultNumb;
   if Pitch < 1 then
     Pitch:=DefaultPitch;
   if Duration < 1 then
     Duration:=DefaultDur;
   if NumberToDo > 0 then
     for J:=1 to NumberToDo do
        begin
           Sound(440);
           Delay(Duration);
           NoSound;
           Delay(DelayLength)
        end;
end;
```

APPENDIX B

PROGRAM ImageryTest

{This program identifies people's imagery (visual, auditory or kinaesthetic), and each person's time response. Portuguese Version by Jorge Alvoeiro.}

```
Uses CRT, DOS, PRINTER;

 VAR
   btotal, ntotal, mtotal    :Single;
   vtotal, atotal, ktotal    :Single;
   Ans                       :Char;
   ReturnCode                :Byte;
   Printable                 :Boolean;
   TYPELIST,Olist            :Text;
   OFILE                     :Text;
   Cfile                     :String[5];
   N                         :String[2];
   bword, nword, mword       :Single;
   Oneline                   :String[50];


{$I C:\TP\INC\YESNO.INC}
{$I C:\TP\INC\TIMER.INC}
{$I C:\TP\INC\READKEYC.INC}
{$I C:\TP\INC\BEEP.INC}


procedure Sound;

     VAR
       NumberToDo, Pitch, Duration    :integer;

    begin
       NumberToDo:=5;
       Pitch:=50;
       Duration:=500;
       Beep(NumberToDo, Pitch, Duration);
       Beep(0,0,0);
       Halt;
    end;

procedure ShowWord;
```

```
VAR
  ch                    :char;
  t1, t2                :longint;
  aword                 :single;
  List, Line            :shortint;
  Word                  :string[14];
  pcode                 :string[2];
  WList,WORDLIST                :text;
  WCodes,CODES                  :text;

begin
  ClrScr;
  Assign(WCodes, 'CODES');
  Reset(WCodes);
  Assign(WList, 'WORDLIST');
   Reset(WList);
  while not Eof(WList) do
  begin
  timer_mod_2; {This initializes the timer}
  Readln(WList, Word);
  GotoXY(35,10);
  write(Word);
  GotoXY(3,15);
 Write('Escolha -B- para imagens, -N- para sons, -M- para sensa',#135,#145,'es na
pele/m',#163,'sculos');
  GotoXY(35,17);
      t1:=timex; {This starts the clock}
  ReadKeyCode(ReturnCode,Printable);
      t2:=timex; {This stops the clock}
  if Printable then
   begin
    if (CHR(ReturnCode))='V' then
    begin
    btotal:=btotal+1;
    timer_mod_3;
    aword:=(t2-t1)/19.6435;  {(t2-t1)/18.6435 original correction value}
    bword:=bword+aword;
    end
      else
     if (CHR(ReturnCode))='A' then
      begin
     ntotal:=ntotal+1;
     timer_mod_3;
    aword:=(t2-t1)/19.6435;  {(t2-t1)/18.6435 original correction value}
    nword:=nword+aword;
    end
     else
      begin
      mtotal:=mtotal+1;
      timer_mod_3;
```

```
        aword:=(t2-t1)/19.6435; {(t2-t1)/18.6435 original correction value}
        mword:=mword+aword;
        end;
        write(OList, (CHR(ReturnCode)),' ')
        end
        else
         begin
          ClrScr;
          GotoXY(12,15);
writeln('Voc',#136,' carregou na tecla errada.');
writeln('Pe',#135,'a ajuda por favor.');
          Close(WList);
          Close(OList);
          Halt;
         end;
    readln(WCodes, pcode);
    write(OList, pcode);
writeln(OList,'    tempo foi: ',aword:8:1);
    ClrScr;
  end;
  Close(WCodes);
  Close(Wlist);
  Close(OList);
   end;
begin

  ClrScr;
  Assign(OList, 'TYPELIST');
  Rewrite(OList);
  btotal:=0;
  ntotal:=0;
  mtotal:=0;
  bword:=0;
  nword:=0;
  mword:=0;
writeln;
writeln('        Instrumento para Avalia',#135,#134,'o de 3 tipos de
Imagina',#135,#134,'o');
writeln;
writeln(' Este instrumento tem como finalidade encontrar a maneira como as
pessoas');
writeln(' imaginam palavras escritas. Por exemplo a palavra c',#134,'o. Algumas
pessoas');
writeln(' quando l',#136,'m esta palavra imaginam uma imagem de um c',#134,'o. Elas
est',#134,'o');
writeln(' a usar um tipo de modalidade visual. Outras, imaginar',#134,'o o ladrar do
c',#134,'o');
writeln(' Elas est',#134,'o a utilizar um tipo de modalidade auditiva. Enquanto que
outras');
writeln(' tem a sensa',#135,#134,'o de ter o p',#136,'lo do c',#134,'o entre os dedos.
```

```
Elas est',#134,'o a');
  writeln(' utilizar o tipo de modalidade quinest',#130,'sica.');
  writeln('  O que ',#130,' importante ',#130,' que imagine - imagens , sons, ou
sensa',#135,#145,'es - ');
  writeln(' assim que l',#136,' a palavra no ecr',#134,'.');
  writeln;
  writeln('  A sua tarefa ',#130,' ler a palavra e logo que tenha a impress',#134,'o
carregue');
  writeln(' na tecla B para imagens, N para sons e M para sensa',#135,#145,'es da pele
ou');
  writeln(' de m',#163,'sculos.');
  writeln;
  writeln('  Para come',#135,'ar o teste carregue na tecla Y e ponha os seus dedos ');
  writeln(' imediatamente em cima das teclas B, N e M sem as carregar.');
  writeln;
  writeln('  Se est',#160,' pronto para come',#135,'ar carrege no Y agora. O pequeno');
  writeln(' intervalo ',#130,' para p',#147,'r os seus dedos nas teclas.');




     Ans:=YesNo;
     if (Ans='N') then
              Sound;
writeln;
writeln('Espere at',#130,' quando uma palavra aparecer no video.');
              Delay(9000);
              ShowWord;
              ClrScr;
              GotoXY(1,5);
writeln('O SEU TOTAL PARA VISUAL FOI: ',btotal:4:1);
writeln('        PARA AUDITIVO FOI: ',ntotal:4:1);
writeln('    E PARA QUINAST',#144,'SICA FOI: ',mtotal:4:1);
              Delay(5000);
              GotoXY(1,10);
              vtotal:=bword/btotal;
              atotal:=nword/ntotal;
              ktotal:=mword/mtotal;
writeln(' LEVOU UMA M',#144,'DIA DE ',vtotal:8:1, ' mSeg. PARA VISUAL');
writeln('             E ',atotal:8:1, ' mSec. PARA AUDITIVO');
writeln('             E ',ktotal:8:1, ' mSec. PARA QUINAST'#144,'SICA');
              delay(10000);
              GotoXY(1,15);
writeln('Muito obrigado por ter feito esta an',#160,'lise.');
     Delay(1000);
writeln('Chame o operador por favor');
     write('>=');
     read (N);
     Assign(OFILE, 'TYPELIST');
     Rename(OFILE, 'Cfile'+(N));
```

```
end.


FUNCTION YesNo:Char;
 {This function comes from 'Turbo Pascal Toolbox' book pag.278}
      Var
        Ch        :Char;

      Begin
         Repeat;
              Ch:=ReadKey;
              Ch:=UpCase(Ch);
         Until (Ch IN['Y','N']);
         Write(Ch);
         YesNo:=Ch;
      End;


{Program to time events using the PC clock/ Behaviour Research Methods
Instruments & Computers, 1990, 22(3), 332-334.}
Const
   TIMER_O        =$40;
   TIMER_CTRL      =$43;
   SET_TIMER       =$34;
   RESET_TIMER      =$36;
   BIOS_SEG        =$40;
   TIMER_LOW       =$6C;
   TIMER_HIGH      =$6E;
   TIMER_LATCH      =$00;


Procedure timer_mod_2;
Var t:byte;
begin
   t:=mem[BIOS_SEG:TIMER_LOW];
   repeat until t <> mem[BIOS_SEG:TIMER_LOW];
   port[TIMER_CTRL]:=SET_TIMER; {sets timer-chip in Mode 2}
   port[TIMER_O]:=0;
   port[TIMER_O]:=0;
end;

Procedure timer_mod_3;
Var t:byte;
begin
   t:=mem[BIOS_SEG:TIMER_LOW];
   repeat until t <> mem[BIOS_SEG:TIMER_LOW];
   port[TIMER_CTRL]:=RESET_TIMER; {sets timer_chip to Mode 3}
   port[TIMER_O]:=0;
   port[TIMER_O]:=0;
```

```
end;

Function Timex:longint;
Var nticks1, nticks2:longint;
   lo, hi, ntocks:word;
begin
  inline($FA);
  port[TIMER_CTRL]:=TIMER_LATCH;
  lo:=port[TIMER_O];
  hi:=port[TIMER_O];
  nticks1:=meml[BIOS_SEG:TIMER_LOW];
  inline($FB);
  ntocks:=(hi shl 2) or (lo shr 6);
  inline($FA);
  nticks2:=meml[BIOS_SEG:TIMER_LOW];
  inline($FB);
  ntocks:=NOT(ntocks) and 1023;
  if (hi<>0) then timex:=(nticks2 shl 10) or ntocks
         else timex:=(nticks1 shl 10) or ntocks;
end;


PROCEDURE ReadKeyCode(VAR Code:Byte; VAR Ans:Boolean);

{This procedure comes from 'Turbo Pascal toolbox' pag.91}


VAR
      Ch              :Char;

BEGIN
    Ch:=ReadKey;
    Ans:=(Ch IN['b', 'n', 'm', 'B', 'N', 'M']);
     if (Ch='b') OR (CH='B') then Ch:='V' else
          if (Ch='n') OR (CH='N') then Ch:='A' else
          if (Ch='m') OR (CH='M') then Ch:='K';
      {IF NOT Ans THEN       This section until Code is to get shift keys}
      {IF ((Ch=#0) AND (KeyPressed)) THEN}
        {Ch:=ReadKey;}
       {if Ch=',' then Ch:='V' else}
          {if Ch='.' then Ch:='A' else}
          {if Ch='/' then Ch:='K';}
      Code:=ORD(Ch);
END;


procedure Beep(NumberToDo, Pitch, Duration:integer);
const
```

```
    DelayLength  =200;
    DefaultNumb  =3;
    DefaultPitch =440;
    DefaultDur   =250;

var
  J :integer;

begin
    if NumberToDo < 1 then
      NumberToDo:=DefaultNumb;
    if Pitch < 1 then
      Pitch:=DefaultPitch;
    if Duration < 1 then
      Duration:=DefaultDur;
    if NumberToDo > 0 then
      for J:=1 to NumberToDo do
         begin
             Sound(440);
             Delay(Duration);
             NoSound;
             Delay(DelayLength)
         end;
end;
```

APPENDIX C

This is the original list of words for the English questionnaire. The Portuguese words were a translation of this list.

Please choose the modalities (visual <V>, auditory <A>, kinesthetic <K>), which you associate the words below with.

SEX M F

ASH	V	A	K
BACK	V	A	K
BARKING	V	A	K
BILL	V	A	K
BITE	V	A	K
BLOAT	V	A	K
BLOW	V	A	K
BOSS	V	A	K
BOW	V	A	K
BOXER	V	A	K
BREAK	V	A	K
BULLY	V	A	K
BURST	V	A	K
BUZZER	V	A	K

CAT	V	A	K
CATTLE	V	A	K
CHICK	V	A	K
CHIPPING	V	A	K
CHOKING	V	A	K
CHOP	V	A	K
CLOTTING	V	A	K
COLD	V	A	K
COUGHING	V	A	K
COUNTRY	V	A	K
COUPON	V	A	K
COURT	V	A	K
CRAMP	V	A	K
CRUMBLE	V	A	K
CUBE	V	A	K
DEEP	V	A	K
DIAL	V	A	K
DIRECTORY	V	A	K
DOT	V	A	K
DOWN	V	A	K
DRAG	V	A	K
DRAW	V	A	K
DRILL	V	A	K
DRUG	V	A	K
ESCAPING	V	A	K

FACE	V	A	K
FEED	V	A	K
FIELD	V	A	K
FISHERY	V	A	K
FLOOR	V	A	K
FLUSH	V	A	K
FOIL	V	A	K
FOOT	V	A	K
FREIGHT	V	A	K
FRESHWATER	V	A	K
FURNISHED	V	A	K
GASPING	V	A	K
GLIDE	V	A	K
GO	V	A	K
GOLD	V	A	K
GRASS	V	A	K
GREETING	V	A	K
GRINDING	V	A	K
GROTESQUE	V	A	K
HARD	V	A	K
HEAT	V	A	K
HOOKED	V	A	K
HOP	V	A	K
HOT	V	A	K
HOUSE	V	A	K

HULK	V	A	K
HUNTING	V	A	K
ICE	V	A	K
JOINT	V	A	K
LABOURER	V	A	K
LAUGHING	V	A	K
LAYER	V	A	K
LEAP	V	A	K
LEECH	V	A	K
LIGHT	V	A	K
LOCK	V	A	K
LOITERER	V	A	K
LOVER	V	A	K
MAGICAL	V	A	K
MILL	V	A	K
MINERAL	V	A	K
MOUSE	V	A	K
MUCUS	V	A	K
MUMMY	V	A	K
OCEAN	V	A	K
OILING	V	A	K
OPEN	V	A	K
PADDLE	V	A	K
PASS	V	A	K
PEBBLE	V	A	K

PICK	V	A	K
PIE	V	A	K
PIN	V	A	K
PLANE	V	A	K
PLATOON	V	A	K
POINT	V	A	K
POOL	V	A	K
PRAYING	V	A	K
PRINTED	V	A	K
PUNCH	V	A	K
PUTTER	V	A	K
RACE	V	A	K
RECEIVER	V	A	K
RIDE	V	A	K
RIVER	V	A	K
ROUND	V	A	K
RUN	V	A	K
RUST	V	A	K
SCALE	V	A	K
SCRAPE	V	A	K
SEALSKIN	V	A	K
SELF	V	A	K
SHAVE	V	A	K
SHEEP	V	A	K
SHIP	V	A	K

SHOE	V	A	K
SKY	V	A	K
SLATE	V	A	K
SLAUGHTER	V	A	K
SLIP	V	A	K
SMOKE	V	A	K
SMOOTH	V	A	K
SNAP	V	A	K
SNOW	V	A	K
SOFT	V	A	K
SON	V	A	K
SPEAK	V	A	K
SPIN	V	A	K
SPIRIT	V	A	K
SPREAD	V	A	K
SQUARE	V	A	K
SQUAT	V	A	K
STAGE	V	A	K
STALL	V	A	K
STAND	V	A	K
STAR	V	A	K
STICK	V	A	K
STORM	V	A	K
STRAIGHT	V	A	K
STRANGLE	V	A	K

STREET	V	A	K
STRIP	V	A	K
STRONG	V	A	K
STUFF	V	A	K
SUIT	V	A	K
SUMMER	V	A	K
TACKLE	V	A	K
THROW	V	A	K
THROWN	V	A	K
TIE	V	A	K
TOMB	V	A	K
TOOTH	V	A	K
TOUCH	V	A	K
TRAMP	V	A	K
TRAP	V	A	K
TRIP	V	A	K
TRUCK	V	A	K
TRUNK	V	A	K
TURF	V	A	K
TWIST	V	A	K
UNDER	V	A	K
UP	V	A	K
WALNUT	V	A	K
WATER	V	A	K
WEALTH	V	A	K

WEB	V	A	K
WELL	V	A	K
WHEAT	V	A	K
WINTER	V	A	K
WOLF	V	A	K
WOOD	V	A	K
WORK	V	A	K
WORM	V	A	K