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IMPROVED MENTAL REPRESENTATION OF SPACE IN BEGINNER ORIENTEERS[1]

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Summary.—The purpose of the present study was to monitor any improvement in orienteering skills attributable to acquiring a better mental representation of space. Two groups were examined: the experimental group, who attended 6 mo. of orienteering lessons, versus the control group, who did jogging training instead. Each group, consisting of 20 children, was tested on the Corsi Block-tapping Test, run Forward and Backward, and the Star-Butterfly Test. Pre- and post-tests were administered. In the experimental group, scores increased in mean complexity from pre- to post-test on the Forward and the Backward Corsi tests, while on the Star-Butterfly Test both time and mistakes had decreased after the training. In the control group, mean complexity and Star-Butterfly Test scores were unchanged from pre- to post-test. These results showed that after continual training in orienteering techniques, the orienteering group was able to remember and repeat sequences of events with greater precision than before the training, while these skills were unchanged in the control group after training in jogging.

Orientation ability has a profound influence on activities and plays an important role in guaranteeing both survival and reproduction (Thom-

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as, 2006). For all human functions, the ability to plan and carry out activities covering wide spaces is essential. Spatial skills play a key role in many types of reasoning and communication and are important in domains such as mathematics, natural sciences, and engineering (Head & Isom, 2010). This mapping and planning ability is developed in the first years of life and will affect the organization of the future of the individual (Hazen & Durett, 1982). Orienteering empowers the mental processes that are activated when a person "gets lost," in other words, when he realizes that there is a discordance between the "model present on a map" and "what we see in front of us" (Crampton, 1988). The first step toward finding a solution is to become aware of the error. At that point, mental processes will be activated which allow the person to formulate a strategy to try to solve the problem; this activity will call into play cognitive abilities, memories of previous experiences, and personal motivations (Spiers & Maguire, 2008). Individual differences are very important in explaining how different people succeed in orienting themselves in space. Gender, previous experience, mathematical ability, and map-using skills were all found to be significant predictors of wayfinding performance (Malinowski & Gillespie, 2001). Discovering how to increase one's spatial functioning is, therefore, an important goal. Fortunately, the performance of spatial tasks can be improved through practice and training (Baenninger & Newcombe, 1989); this has wide implications for education. Some researchers (Bethell-Fox & Shepard, 1988) have claimed that practice leads people to make fundamental changes in how they process spatial stimuli, which may then allow them to adapt to novel stimuli and new tasks. Previous studies showed that motor activity training should be able to develop and to improve spatial skills when it is based on an initial visual encoding of the stimuli, rotating one object (typically into congruence with another), comparing objects to decide whether they are the same or different and, finally, responding (Cooper & Shepard, 1973). To be able to practice most sports successfully, it is vitally important to develop these spatial skills (Mann, Williams, Ward, & Janelle, 2007). Paas, Adam, Janssen, Vrencken, and Bovens (1994) verified that a sports training program improves physical fitness, but is not necessarily accompanied by improved perceptual skills.

The aim of this study was to assess whether there was any improvement in the experimental group who underwent orienteering training, to verify in children the effects of this sport, which has already been shown to improve spatial cognitive abilities in adult athletes (Guzmán, Pablos, & Pablos, 2008). The experimental group was compared with an age- and sex-matched control group who did not do orienteering but jogging, which is reported in literature to demand a prevalently physical rather than psychological effort (Siddiqui, Nessa, & Hossain, 2010). Pre- and post-tests were to verify whether there was a cognitive improvement in the experimental group of children after a beginner's course in orienteering, and to compare the results obtained before and after training in both the experimental and control groups.

Method

Sample

A randomized longitudinal clinical study was conducted at an elementary school in Apulia, Italy, during the period from October 2009 to March 2010. The parents or guardians of all participating children gave written informed consent for their children to take part. Pupils in Grade 4 were recruited (*M* age = 9 yr., *SD* = 0.7, range = 8–10) and subdivided into two groups, each consisting of 20 children (10 boys, 10 girls).

Procedure

Participants were randomly allocated into two groups (experimental and control) using a web-based computer program, and stratified for gender (male/female) and age (8 and $\leq$9 yr., >9 to 10 yr.). The research program was conducted both in the schoolyard and in the historical centre of the town where the school is located. The two groups were signed up to attend lessons for 6 mo., three times a week for a total of 72 lessons, following the teaching programs proposed in the literature (Drury & Bonney, 2005). For the experimental group doing orienteering (*M* age = 9 yr., *SD* = 0.7), various activities were proposed, beginning with an introduction to the theory and progressing through practice and competitive aspects. They learned to use maps and interpret map contours, studying fieldwork techniques, cartography and designing maps, physical and environmental geography, measuring and locating shapes in space, estimating distance, determining direction and scale, handling data, creative writing, technical terms and symbols, making their own orienteering equipment, and making three-dimensional models from contour maps. Orienteering exercises specifically aimed at memory training, such as running while reading a story and then being asked to summarize the story at the end of the activity, were also included. The children in the control group (*M* age = 9 yr., *SD* = 0.7) did not attend orienteering lessons. Instead, they took a course on an outdoor sports activity, jogging. The lessons were designed to provide information about safety and history of the sport, as well as notions about the technical movements; then the participants did appropriate physical training and practical exercise.

Metrics

Both groups underwent three assessment tests of visuospatial working memory: the Corsi test, administered both Forward and Backward, and the Star-Butterfly Test (Kessels, van Zandvoort, Postma, Kappelle, & de Haan, 2000). The use of these tests for studying visuo-perceptive memory has been validated in the literature (Piccardi, Iaria, Ricci, Bianchini, Zompanti, & Guariglia, 2008; Furley & Memmert, 2010). The teachers were asked not to use the tests during the training courses for the two different groups, and so they were administered only at the pre- and post-tests.

The Corsi Block-tapping Test was described by Corsi as a non-verbal test. The test material consists of nine black blocks (1.25-in. cubes) irregularly distributed and permanently fixed on a black board, as shown in Fig. 1. The Corsi Block-tapping Tests, Forward and Backward, provide a method for measuring visuospatial memory span, i.e., the quantity of information that the participant is able to keep in short-term working memory. On any given trial, the examiner taps some of the blocks in a particular sequence and the participant is required to tap out exactly the same pattern immediately afterwards. The first step is to determine the participant's "spatial span" (i.e., the maximum number of blocks he is able to tap in the correct order), using the same procedure as for conventional digit spans. Then 24 test trials are carried out, in which spatial sequences with one block in excess of the span are presented. The same sequence is repeated every third trial, but the intervening sequences are never repeated. With normal participants, recall of the recurring sequence improves with the increasing number of presentations, whereas recall of the non-recurring sequences remains at the initial low level throughout. The administration procedure requires the examiner to tap the blocks with a rod at a speed of one per second; the hand movement guiding the rod must be sequential, in other words, the examiner must pass from one block to the next, in accordance with the presentation times. At the end of the series, the participant must point with a finger to the same blocks in sequence, repeating them in exactly the same order as the sequence shown by the examiner for the Forward test, and in the reverse order for the Backward test. The test is organized at different levels of complexity that increase with the number of blocks used. The test was started at Level 3 so the first sequence consisted of three-block sequences, and if the participant was successful with this, another sequence was added each time: each level of complexity included three blocks increased by a teacher. Correct repetition of two out of three sequences in a session led to promotion to the next session, whereas the test was interrupted after two failures in the same session. The metric used in both tests is the level of complexity achieved at the end of the whole test.

The Star-Butterfly Test is a working memory exercise that requires the child to complete a path without the aid of a map. In practice, the child must read the map at the start of the course, memorize the first control point, and run to find it. Then the child will return to the start of the course

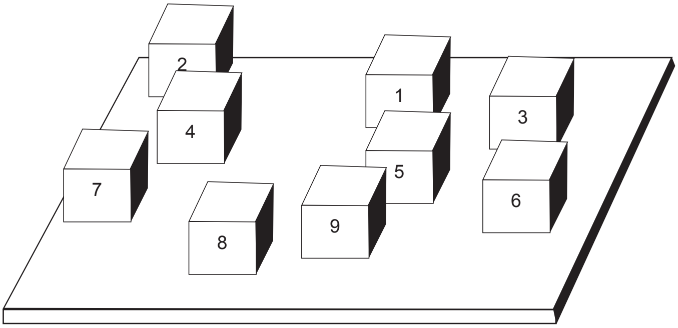

Fig. 1. Corsi test: sketch showing the approximate position of the nine black blocks (1.25-in. cubes) on a black board (8 × 10 in.). The blocks are numbered on the examiner's side for ease of recording, but the participant cannot see the numbers.

and repeat the operation for the second control point. The first points in the test must be searched for one at a time, while the last points in the test have to be memorized so that the child can search for them all together without returning to the start. This test measures the child's memory, since any hesitation during the route from the first to the last control point will be apparent. The time taken to complete the path is expressed in seconds, and any mistakes made were also recorded. This exercise was not used in the orienteering lessons.

All the above described tests were administered to all participants at the time of recruitment (pre-test) and after 6 mo. (post-test). Data were stored in an Excel database and statistical analysis was performed with Epi-info 6.0.

The results were expressed as means, standard deviations, and reference ranges. Bartlett's test was carried out to control the normal distribution of all variables. Student's t test for independent samples was used to compare the groups. Student's t test for dependent samples was used for the pre- versus post-test comparisons within the groups. Chi-squared test was used for the comparison of the proportion of the mistakes reported in the Star-Butterfly Test. Statistical significance was set at $p < .05$.

Results

For the Forward and Backward Corsi tests, the experimental and control groups' pre-test scores (level of complexity) were not statistically significantly different (Table 1). On the Star-Butterfly Test, the two groups' times and mistakes were not statistically different at pre-test (Tables 1 and 2).

At post-test, the groups' scores on the Forward and Backward Corsi tests, as well as the Star-Butterfly Test, were statistically significantly dif-

TABLE 1

MEANS, STANDARD DEVIATIONS, AND RANGES OF TEST SCORES AT PRE- AND POST-TEST FOR THE EXPERIMENTAL AND CONTROL GROUPS, WITH STUDENT *t* TEST COMPARISONS

Test	Experimental Group ($n=20$)		Control Group ($n=20$)		*t*	*p*	Cohen's *d*
	M	*SD*	*M*	*SD*			
Pre-test							
Corsi test							
Forward	4.50	0.94	4.30	0.95	0.34	.73	0.21
Range	3–6		3–6				
Backward	4.30	0.73	4.35	0.81	0.20	.84	−0.06
Range	3–6		3–6				
Star-Butterfly Test							
Time	112.85	4.75	113.15	4.51	0.20	.84	−0.06
Range	103–125		105–126				
Post-test							
Corsi test							
Forward	5.15	0.99	4.55	0.83	2.00	.04	0.66
Range	4–7		3–6				
Backward	4.9	0.72	4.4	0.75	2.15	.04	0.68
Range	4–7		3–6				
Star-Butterfly Test							
Time	106.85	4.93	113.95	3.98	5.00	.001	−1.58
Range	98–118		102–121				

ferent (Table 1). Level of complexity in the Corsi test was higher in the experimental group. Time to complete the Star-Butterfly Test was lower in the experimental group, and this group also made fewer mistakes. At the post-test, the experimental group achieved statistically significantly better scores for all three tests as compared with their own scores at the pre-test. In the control group, no statistically significant difference was observed between the pre- and post-test scores for any of the three tests (Table 3, $p > .05$).

TABLE 2

MISTAKES IN STAR-BUTTERFLY TEST, AT PRE- AND POST-TEST FOR EXPERIMENTAL AND CONTROL GROUPS, WITH CHI-SQUARED COMPARISONS BETWEEN AND WITHIN GROUPS

	Experimental Group ($n=20$)	Control Group ($n=20$)	χ^2	*p*
Pre-test	4	4	0.00	1.00
Post-test	0	3	3.53	0.10
χ^2	5.00	0.22		
p	.04	.5		

DISCUSSION

Discussion, speculation, and research have a long history in the role of cognitive processing in sports (Almeida, 1997). In the different sports

TABLE 3

Comparison of Corsi and Star-Butterfly Tests Pre- and Post-test, in Experimental and Control Groups

Test	t	p	Cohen's d
Experimental group			
Corsi test Forward	1.50	0.14	−0.67
Corsi test Backward	1.80	0.08	−0.82
Star-Butterfly Test	2.77	0.01	1.23
Control group			
Corsi test Forward	0.62	0.53	−0.28
Corsi test Backward	0.14	0.88	−0.06
Star-Butterfly Test	0.42	0.67	−0.18

disciplines, the development of spatial orientation skills is influenced by the situation at play (Mann, *et al.*, 2007). Visual information related to movements of the ball and movements of other team members or of the opposing team allow the player to extract essential indications that will direct his resulting motor behaviour. This is the basis of the tactical action, defined as a technical action carried out in space at the right time and with the right links (Vaeyens, Lenoir, Williams, Mazyn, & Philippaerts, 2007). Moreover, the perception of time is conditioned by the characteristics of the available space. The mental representation of spatial attributes by athletes has been extensively studied and compared with those of non-athletes, novices, and athletes of varying skill levels. Some researchers believe that athletes possess superior visual systems that allow them to recognize information better than their peers (Vaeyens, Lenoir, Williams, & Philippaerts, 2007). Others contend that elite athletes are able to use available information more efficiently and effectively than novices (Kibele, 2006).

Depending on the features of stability and predictability of the environment, sports activities are classified as open or closed skill type (Brady, 1995). In sports of open skill type, the environment is variable and unpredictable. The athlete generally needs to be able to react to changing circumstances and, for this reason, the required skill is described as an *externally paced skill,* in other words, the skill of adapting to external events (Fontani, Lodi, Felici, Migliorini, & Corradeschi, 2006). Typical examples of this type are situation sports (team games, some individual games, and combat sports), in which the technical movements need to be constantly modified and adapted to the changing environmental requirements. In contrast, in closed skill disciplines, like running, marathon, skating, archery, relay racing, artistic gymnastics, throwing and jumping, diving, bowling, and golf, the skill is performed in a stable or largely predictable environmental setting (Spittle & Morris, 2007). The sports movements are also more predictable, take place under fixed environmental conditions, and have clearly defined beginning and ending points. Feedback plays a minor role once the skill is acquired, and the skills are usually *self-paced* in the sense that the performer begins the movement when he is ready. Moreover, the movement patterns can be planned in advance. Automatic processing is so fast it occurs beyond the athlete's conscious control (Spittle & Morris, 2007).

Orienteering combines athletic and analytical skills. It requires information of various kinds that often undergoes rapid changes, to be selected and collected for impromptu, immediate decisions about choices (Ottoson, 1985). In orienteering competitions, using just a map and a compass, the orienteer must track down, as fast as possible, the control points in the forest shown on a map (Seiler, 1996). The control points must be reached in a pre-set order, but the athlete is free to choose the path to get to them, and should, therefore, learn to identify the least fatiguing and fastest route (Murakoshi, 1986). The studies published up to now were focused principally on analyses of differences among physical properties in those practicing the orienteering sport, to verify confounding variables such as age, sex, and type of athletic training (Streeter & Vitello 1987; Zsheliaskova-Koynova, 1991; Strangel, 1996). In a previous work comparing elite and non-elite orienteers, it was demonstrated that elite orienteers had acquired a better mental representation of space (Guzmán, *et al*., 2008). Since orienteering is a sports discipline of open skill type, the ability to choose the fastest or most convenient route for getting from one point to another and reaching a goal is essential to winning. Which route is most convenient needs to be assessed each time on the basis of such elements as the specific environmental situation (obstacles, impervious zones, slopes) and the individual or group resources. The psychological skills required in orienteering include the abilities to read a map correctly and to plan and make rapid decisions, summarized as wayfinding, while the qualities needed include concentration, perseverance, and resistance to fatigue.

Jogging is a closed skill sport that involves taking up a slow, pleasant running pace along a chosen distance; varying rhythms can be adopted (Williams, Davis, & Williams, 2000). The main aim of this sport is to increase the athlete's physical tone but without the stress of true running, which is much faster. It is typically carried out in public parks but can be done in all types of terrain. Jogging has become very popular because it is aerobic, healthy exercise for the heart and lungs, and can be practiced by anyone in a good state of health (Siddiqui, *et al*., 2010).

The first end-point of the present study was to verify whether practicing sport can improve cognitive skills in young people. In a previous meta-analysis of exercise and cognition in children, Sibley and Etnier (2003) found evidence that physical activity resulted in improvements in cognitive performance, with effect sizes higher in children than in adults, and highest during the middle school years. The results of the current study obtained with the two-way Corsi tests and the Star-Butterfly Test show that after a beginner's training course, the children in the orienteering group were able to remember and repeat sequences of events with a greater accuracy than at baseline before starting the training. Instead, in the control group that did jogging, no significant differences emerged in the comparison between the pre-test and post-test scores for the three tests after their training course. The absence of a statistically significant improvement in the jogging group is in line with the evidence that in closed skill activities, complex cognitive processes such as rapid information intake, decision making, and interpersonal interactions are largely absent (Tenenbaum, 2003).

It has already been reported that different types of physical activity may have different influences on cognitive performance in children (Sibley & Etnier, 2003). The current results are explained by the different types of cognitive-motor demands in the two types of sport, emphasizing the importance of selecting suitable sports activities for children depending on the results to be obtained.

The study suffers from some weaknesses. A limitation of most classroom-based research on exercise and cognition is that these studies are often characterized by low methodological rigour in controlling and describing the intensity of the exercise interventions (Tomporowski, 2003). Another limitation is the small sample size: with a larger sample it would be possible to recruit children of different ages and thus verify the influence of training courses at different stages of psycho-physical development. Moreover, long-term follow-up could demonstrate whether the acquired skills are maintained and even further developed over time. Future work could examine the best timing and duration of orienteering training during childhood that could allow children to acquire critical spatial orientation and wayfinding skills and maintain them in adulthood.

In conclusion, physical activity has been linked to mental health benefits for a variety of psychological outcomes. In this work, the study hypothesis was that practicing sport during childhood could improve cognitive skill related to acquiring a mental representation of space. The results show that thanks to stimulating an increasing visuospatial memory, the orienteering sport is highly important as a means of optimizing the overall development of the individual. For this reason, it could beneficially be included in elementary school programs and would provide different mental stimuli that could further enrich the school experience. In this sense, orienteering is not only a game and a sports activity, but also an inter-disciplinary activity and mental training that may serve to restore a better relationship between man and environment.

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