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A Virtual Reality Based Tool for the Assessment of "Survey to Route" Spatial Organization Ability in Younger and Elderly Population

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Introduction

The complex ability to get oriented into the environment allows us to act and move adaptively within the surroundings.

This cognitive function is possible thanks to the ability to create and use the surrounding space mental representations arising from the integration of different sensory modalities. This capability to organize *landmarks* of the environment into mental maps is the main ability of orientation. When we move within environment, we construct a corresponding mental representation that is manipulated, updated and adapted to the situation's demands over time.

At the first developmental stages, children use a limited and self-centered point of view; during the years they develop their knowledge regarding spatial relationships between elements that are present in the environment like "above-below, in front/behind, left-right" and concepts that are independent from the observer as "north-south-east-west". Later, they acquire an increasing awareness of their body, how it moves and how it interacts, through space coordinates, considering the reality that surrounds them, too.

But, even when these concepts are learned, there may be orientation dysfunctions, especially when there is few spatial information and a complex topography, or when we are in new places that we have never experienced before or through simulations (as, for example, road maps).

These concepts are not helpful when a brain is damaged (due to cranial trauma, stroke, neuroplasia, neurodegeneratio) and affects orientation ability and its constituent components.

In order to assessment topographical orientation, we traditionally use "paper and pencil" instruments, as the *Corsi's Test*, the *Manikin's Test*, the *Mazes Learning Test* in WISC-R Battery and the *Road Map Test*.

In the last years, *brain imaging*'s techniques have been introduced to provide important information regarding the study of these abilities and of their deficits.

Moreover there is a growing use of virtual reality programs (*Virtual Reality*, VR), a computer technology which shows to the subject three-dimensional environments within which individuals can move and interact “as if” they were in real environments. The possibility to consider virtual reality as an ecological tool for evaluating topographical orientation is given by the emergence of a sense of “presence”, the feeling of being deployed in a simulated space, similar to physical reality that permit to subjects to obtain knowledge “like as” they become in another real environment.

My thesis project is part of the University program – coordinate by Prof.ssa Francesca Morganti - concerning the topographical orientation in healthy subjects and neurological patients and assumes that some aspects of this ability could be promptly detected with virtual reality computer simulations, able to obtain similar assessment like “paper and pencil” instruments.

This experimental research wants to evaluate if the use of VR system is able to discriminate spazial orientation skills based on ways (*route*) more effectively than traditional “paper and pencil” tests.

The VR technology is used with a particular intention. It must not be considered as a replacement of real environments and does not pretend to be considered at the same level. VR technology and reality are not interchangeable or overlapping. The aim is to use VR technology as a distinct tool to be preferred in all those situations that, otherwise, would have required the reconstruction of real environments or the subject’s presence in outdoor.

Moreover, another goal of my research is to point out the cognitive decline trajectory considering both the age and the socio-demographic conditions of the subjects, with a specific focus about the abilities that constitute and support topographical orientation’s tasks. Through this study, we expect that the use of technological tools could provide us a further possibility of discrimination with respect to age, where young people succeed better than older people to carry out the navigation task.

For this purpose a sample of 120 subjects aged between 30 and 80 years old have been identified and tested. The sample is splitted between males and females on the basis of age with decade range (31-40, 41-50, 51-60; 61-70, 71-80 years).

Subjects were contacted and recruited among the frequenters of ten centers for olders and among acquaintances living in the province of Milan.

They were subjected to two evaluating sessions, each of an hour and half time. During the first meeting, it was given a neuropsychological test battery in order to value the general cognitive state of the subjects and the specific skills involved in the topographical orientation. This *screening* was used to define the cognitive profile and the adequacy of the subjects to be submitted to the second session. Those subjects whose score was below the MMSE (24) were excluded from the sample. In the following session, selected subjects were submitted to two different tests in order to define their spatial orientation: six labyrinths of the *Maze Test* and the *Road Map Test*. The same items were re-presented to the computer through the application of “virtual reality” simulations, where map and mazes were presented in a *route* perspective.

As will be explained during the discussion, the instruments normally used in topographical orientation studies are “ paper and pencil “ tests based on a *survey* perspective, involving the use of plants and environmental maps seen from above, where an “allocentric” vision of the task is stimulated. In this work, however, the instruments used adopt a *route* perspective, where the subject performs the task by taking an “ internal “ view of egocentric type.

Considering the correlation between cognitive performances and socio-demographic characteristics of the sample, it was already clear during the administration of tests that older subjects had more difficulty than younger ones in performing computer tasks, and this was even more true for female subjects over sixty. These observations were confirmed at the end of data elaboration, when with the obtained result it was clear how the orientation task in VR, compared to traditional tasks, had discriminated females more accurately the subjects’ performances.

The essay is divided into two parts: the first part presents an overview of spatial orientation recent studies, the detection of mechanisms that characterize it, the anatomical substrate and its possible dysfunctions, virtual reality, the historical overview, the first areas of employment, technical characteristic, today’s applications, the opportunities offered by new technologies, the real possibility of studying spatial orientation with these computer programs and the construct of presence and its determinants.

Instead the second part outlines the research methodology used, the socio-demographic and neuropsychological characteristics of the sample and the results and the conclusions reached at the end of the investigation.

The aim of my study is to test a new approach regarding the valuations of spatial orientation abilities using virtual reality programs instead of classic "paper and pencil" tests.

With this, we don't want to replace the traditional task, which remains an interesting survey methodology, but we want to detect topographic orientation with the use of virtual reality, which may be the best compromise for the study of spatial orientation between laboratory tests and trials experienced within ecological environments. The first one do not actually reproduce the complexity of real environments, and the second one involve an expenditure of excessive resources for research purposes.

This new methodology wants to reproduces tasks that traditionally were proposed in a *survey* perspective with a *route* one. Indeed, when we explore the surrounding space we use an egocentric perspective (route) rather than an allocentric one (survey), and also in the detection of spatial abilities it is important to refer to the cognitive paradigm that explains how the processes that lead to knowledge derives from the "theory of human activity": through the action, the individual experiences and knows the surrounding environment and he is able to interact with it.

The challenge of my research is this kind of methodology: the egocentric situation typical of virtual performances. How this kind of methodology can better discriminate different spatial orientation abilities levels, is the thesis to be tested.

Before starting the exposure of my research, I would like to express my most heartfelt thanks to the Doctorate Coordinator - Prof. Valeria Ugazio - to have followed with interest and attention to my study training and to have joined me in working groups characterized by great scientific capabilities, I would like to express my thanks also to Prof. Maria Luisa Rusconi who has constantly followed my research works with wisdom and diligence, providing me valuable information and cues for reflection on scientific treated arguments, and to Prof. Francesca Morganti for skilled and passionate supervision contents that are studied by this survey.

Chapter 1

Topographical Orientation

The system of spatial orientation is one of the most complex and sophisticated cognitive functions of human mind. It Involves a large number of attentional, perceptual and memory skills and numerous and different brain's structures.

This chapter discusses theories, cognitive mechanisms and neural structures underlying spatial orientation.

1.1 The human navigation system

The human navigation system is defined by Montello (2005) as " *coordinated and goal-directed body movement through the environment*".

One of his earliest theories is called "*view-dependent place recognition*" that refers to the process of estimating the individual position within the environment and to the choice of direction to follow from a given *landmark*, that is a point of reference (Gallistel, 1990). The limit of this process, however, identifies the need of such environmental references in the immediate moment.

Cognitive psychology studies and functional neuroimaging have instead indicated the existence of multiple and independent processes of human navigation (Wang and Spelke, 2002). Wang and Spelke (2002) suggest the presence of processes of *abstraction* of environmental information, which enable man to navigate in new environments based on verbal descriptions or graphics. Wang e Spelke support the presence of *processes of environmental information's abstraction*, which enable man to navigate into new environments on the basis of verbal or graphic descriptions. Guariglia et al. (2004) introduces the ability to integrate proprioceptive, vestibular and visual information about the environmental geometric characteristics to allow the subject to *re-orient* himself during the process of navigation.

Finally, it was formulated the *path integration*, a process that enables the processing and storage of proprioceptive and vestibular information that contributes to determinate the current location of the subject, thanks to the formulation of inferences made by estimating the subject's movement speed, starting from a position formerly know (Mittelstaedt e Mittelstaedt, 1980; Gallistel, 1990).

In order to obtain a proper functioning of this system, it should be based on three main processes (Calton and Taube, 2009):

- the spatial orientation process, which allows to locate the position taken by the subject within the environment and the destination direction;
- the process of manipulating environmental spatial representations, which allows to establish a particular *route* planning necessary to achieve the goal fixed in advance;
- the motor execution of this plan previously established.

The *path-integration* has important limitations of accuracy, that is strongly dependent on the continuous updating of information and acquisition of motion, consequently, any error during this process will tend to accumulate over time (Calton e Taube, 2009).

1.2 Creation and use of cognitive maps

The opportunity to move, act and orient oneself within the environment, especially those of large scale, is possible thanks to the creation of mental representations that are more than mere visual reproductions of the environment translated in a mental level, but that are the result of Multimodal integration (Lynch, 1960; Downs et Stea, 1973), resulting from the accumulation and assembly of information obtained through different sensory channels (Tversky, 1993).

These representations are called *cognitive maps* (Tolman, 1948) and, although with the passage of time different theoretical definitions of this concept have been formulated, (Tolman, 1948; Down et Stea, 1973; O'Keefe et Nadel, 1978; Golledge, 1987; Kitchin et Freundschuh, 2000), all of them recognize that within the cognitive maps are not represented all of the environmental information, but only those selected that correspond to the intentions and dispositions of the subject in the pursuit of the task (Freundschuh et Egenhofer, 1997). As such, they don't correspond to true reproductions of the external environment, but they are an organized information collection coming from different sources, necessary for spatial *problem-solving* (Tversky, 1993).

Topographical orientation Knowledge is organized through two main types of cognitive maps: *route map* and *survey map* (Golledge, 1990; Taylor et Tversky, 1996; Kitchin et Freundschuh, 2000; Carassa *et al.*, 2002).

Route maps are based on an egocentric perspective and refer to the representation of the object's position considering the subject own body, through the combination of retinal image stimulus with information regarding the eyes, head and neck's position of the subject (Aguirre e D'Esposito, 1999). Instead *Survey maps* are based on an allocentric perspective and are considered large-scale directional maps giving a global view of space (Chown *et al.*, 1995).

These representative capabilities are not present at birth in humans, but are conceived as a result of the ontogenetic development process, in which cognitive changes occur and allow the construction of these maps.

In the early stages of individual development, the child would not be able to create a true topographical representation of space, but he would acquire the spatial knowledge and sense of direction through his body movements (Shemyakin, 1962, Howard and Templeton, 1966).

According with Piaget's developmental conception, during the preoperative period of early childhood the ability to reach a target location is possible thanks to the mental representation of already experienced movements (Piaget, 1960). At this developmental stage, *landmarks* that are needed to orient oneself during navigation would not be organized within a spatial conception of the environment as a whole, but as closely related to their scope for action. Consequently, the child would be able to anticipate spatial relations between two reference points only on the basis of learned motor patterns.

Over time, the child would acquire the ability to build a topographical knowledge of space through the creation of *route maps*.

According to the classical theory, these egocentric spatial representations, in which the objects' position is coded with reference to the subject's body, consist of a mental reconstruction of *routes* based on connecting salient *landmarks* in the environment (Morganti et al., 2003; Vallar and Papagno, 2007).

In order to better understand, this statement may refer to a classic study on the observation of children's drawings related to their neighborhood (Shemyakin, 1962): they haven't adopted a global perspective, from a top view, but a self-centered one, as if they were walking within the neighborhood. This type of cognitive map reflects, therefore, the experience of the subject rather than the use of abstract data, and that seems to explain the use of a coordinate system closely related to the specific subject's position within space (left-right).

Following the emergence of the ability to create *route* maps, a major change occurs in the nature of spatial knowledge acquired by the child: he seems to assume, indeed, Euclidean properties that lead to the creation of *survey* maps (Piaget, 1948; Siegel et White, 1975; Jansen-Osmann *et al*., Schmid et Heil, 2007). Thanks to the spatial information's precision contained within them, they are considered similar to cartographic maps (Chown et al., 1995). These representations, with their allocentric nature, allow the subject to assume a broader spatial perspective if compared to the maps previously described, because they are built on the basis of information concerning the relationships between *landmarks* distant from each other within the environment (Taylor and Tversky, 1996), which are inferred through reasoning processes that allow the creation of multiple configurations of the same environment according to different angles, and extremely flexible (Morganti, 2003).

Survey maps are based on using an extrinsic reference's system generated by canonical axes north - south - east - west (Freundschuh and Kitchin, 2000; Pazzaglia and De Beni, 2001).

It's important to note that the transition period, which elapses between the creation of *route* maps and *survey* ones, is characterized by two important moments that enable an adequate development of human spatial orientation (Chow net al., 1995):

- the understanding of space as a coherent whole is possible through the development of an objective frame of reference, as underlined in the children's drawings analyzed by Shemyakin (1962);
- the development of the ability to determinate spatial relationships between objects that are placed in large environments seems essential.

In fact, one of the main features that differentiate *route* maps from *survey* maps is the information's nature: it appears to be local in the first case and global in the second one. Siegel and White (1975) argue that *survey* maps are built from the subject's exposure to an environment of which he already has a *route* mental representation. Thanks to an environmental increased familiarity, from the creation of *route* maps, the subject would be able to "*identify space's landmarks and to create connections between distant points, in order to realize the sequence of abstract positions which are contained in survey map*" (Morganti, 2003).

The progressive development of spatial orientation's ability seems to be supported by experimental studies on children (Acredolo et al. 1977; Golledge et al, 1985; Garino and McKenzie, 1988; Iaria et al, 2009) and on adults placed in unfamiliar environments (Golledge, 1987). Despite the apparent general agreement on the existence of *route* and *survey* maps, and on their specific features, there are still theoretical doubts concerning the progression from the first to the latter.

Some experimental data seem not to support this hypothesis. It has been demonstrated, for example, that the creation of *route* maps and *survey* maps is not possible in every situation (Moeser, 1988) and that the *survey* map can be constructed even without prior creation of *route* maps (Lindberg and Garling, 1982) .

The type of environmental representation created by an individual also seems to be influenced by several factors: subject's age, exposure to a particular environment, type of task that the subject is asked to perform and the environmental characteristics (Thorndike and Hayes - Roth, 1982; Ferguson and Hegarty, 1994, Aguirre and D'Esposito, 1999).

Concerning this last factor, Heft (1979) suggests that within relatively undifferentiated environments, where there are few *landmarks*, subjects would tend to create and use *survey* maps, and conversely, in environments rich in *landmarks*, there is the tendency to use *route* maps (Acredolo and Evans, 1980).

On the basis of this evidence is important, therefore, to consider the subject's intentions, to analyze the environment in which he is located and within which he acts and the interaction mode, too.

An alternative explanation comes from the Sequential Hierarchical Model, developed by Chow et al. (1995), which considers that the location and the achievement of a target position would be done through a constructive and dynamic learning process. Continuous exposure to a new environment facilitates the development of a number of space representations that integrates the ability to identify *landmarks* to the ability to integrate paths' knowledge that combine single *landmarks*, until the determination of more abstract spatial relationships that encourage higher level of comprehension (Morganti, 2003).

Another approach to study the topographical orientation's ability which emphasizes the dynamic relationship that exists between man and environment, and specifically between the human mind and environment, considers that the outdoor cannot be regarded as an objective element that is processed by human mind to create a stable representation, as traditionally postulated (Gibson, 1977). Consequently, *route* maps are not only characterized by rigid representations based on paths connecting *landmarks* in space, but they are dynamic and allow man to connect different sequences of *landmarks* initially experienced through separate pathways.

Similarly, *survey* maps are conceptualized as representations characterized by a high degree of flexibility, that permit to create new *routes* through the combination of reference points not previously experienced as continuous (Tirassa et al., 2000; Morganti, 2003). It's from this theoretical perspective that my experimental research will be carried out.

1.3 Cognitive processes underlying spatial orientation

Topographical orientation is considered a high-level cognitive function (Morganti, 2003) due to the integration of different attentional, mnemonic and perceptual processes, which contribute to the ability to navigate in familiar and unfamiliar surroundings (Berthoz and Viaud-Delmon, 1999; Corbetta et al., 2002; Burgess, 2006; Lepsien and Nobre, 2006; Iaria et al., 2009). The functional properties of these processes, which favor an increase in the environmental familiarity and the use of different possible navigation strategies are the basis of wayfinding, which is the task of finding a *route* (Berthoz, 2001, Wang and Spelke, 2002) . This is made possible by a set of cognitive processes related to the subject's locomotion within an environment that allows the identification of its position in space and the target destination, and then outlines the planning of the act (Montello, 2005).

The topographical orientation involves selective attention processes of visual-spatial nature, needed to focus our interest in environmental characteristics considered relevant, such as *landmarks* (Shulman et al., 1999, Hopfinger et al, 2000, Petrides, 2000; Morganti, 2003; Brunsdon et al., 2007). The role of attentional control in spatial orientation is confirmed by several studies regarding the focusing on targets in the environment and the tasks of moving from one target to another (Lepsien and Nobre, 2006). Thus, the topographic disorientation disorder seems to be associated with attentional deficits that would not allow the proper processing of spatial information (De Renzi, 1982). Functional neuroimaging studies in *wayfinding* tasks, also show activation of frontal and parietal cortical areas involved in attentional functions (Posner et al., 1984, Shulman et al., 1999, Petrides, 2000; Iaria et al., 2009).

The spatial orientation ability involves mnemonic processes too (Corbetta et al., 2002). In particular, the visuo-spatial sketch pad that constitutes the *Working Memory* (Baddeley, 1990), the procedural memory and visual-spatial long term memory seem to be primarily involved. The visual spatial short term memory allows subject to orient himself within the environment, considering *landmarks* and their spatial relationships (Logie, 1986). Procedural memory appears to be mainly used familiar environments where navigation is automatic (Hartley et al., 2003). Finally, visual-spatial long term memory seems to be needed in the recovery of spatial representations - cognitive maps - previously created by the subject, in order to reuse them at later stages.

The role of mnemonic processes in orientation ability is demonstrated by several studies have shown temporal structures' activation which includes the hippocampus during learning and retrieval of spatial information in *wayfinding* (Maguire at al., 1996; Maguire, 1997; Mellet at el., 2000, Burgess et al., 2002) and subcortical structures, such as the striatum and caudate nucleus, involved in procedural memory function used in familiar environments (Hartley et al., 2003; Iaria et al., 2003).

A mention deserves the vision, one of the first cognitive abilities that develop in childhood and that appears to be the primary sensory modality through which the subject enters into relationship with the surrounding environment. This sensory modality has an important role in the development of human capacities for spatial representation, as it allows to obtain detailed information of the surrounding space and a more direct evaluation of spatial relationships between different points within the same (Chown et al., 1995, Fortin et al., 2006). The vision also seems to assume a key role in the rotation ability of cognitive maps through which spatial knowledge is organized (Kritchevsky, 1988).

The visual perception system is composed of two subsystems, designated respectively by the name of *what* vision system (ventral or occipito-temporal) and so *where* (dorsal or occipito-pariental) (Rueckl et al., 1989). The first allows us to process shape and color objects information, therefore plays an important role in the *landmarks* identification within the environment, the second allows us to process information about the spatial location of the same, allowing to establish relationships between them. It is therefore clear the importance of visual information came from the environment for the development of orientation capacity and, in particular for the creation of cognitive maps (Chown et al., 1995).

A study conducted on blind and visually impaired subjects to evaluate the role of vision in the development of topographical orientation abilities, showed that visual experience is not essential for the development of those skills, and in particular for the mental rotation ability of spatial representations (Fortin et al., 2006). This result is explained as the product of compensatory strategies, which are performed by other sensory modalities in absence of visual information (Rice, 1970; Fletcher, 1980; and Gaunet Thinus-Blanc, 1997). Despite this, however, the use of visual spatial information seems to favor the development of these skills (Fortin et al., 2006), results that are similar to a more recent study conducted on the same type of subjects, where is not observed in blind subjects a reduced efficiency in the ability to create cognitive maps necessary for the orientation (Frank et al., 2009).

Finally, also skills related to the creation of mental images containing environmental information as *landmarks* and *routes*, assume a critical role for this ability (Farah, 1989; Davis and Coltheart, 1999; Redish, 1999; Brunsdon et al., 2007). The role of those, which hence the cognitive maps creation, is confirmed by studies which show that patients with brain injuries affected by topographical disorientation often reported difficulties in creating internal representations of paths and *landmarks* encountered during environmental navigation (De Renzi, 1982, Aguirre and D'Esposito, 1999), and that patients with selective deficits in imaginative ability, as representational *neglect*, usually bring back difficulties regarding navigation and orientation ability (Guariglia et al., 2005). In particular, a study by Palermo et al. (2008) highlights the existence of a significant correlation between the ability to create and use a cognitive map and two specific imagery abilities: the ability to rotate mental images and the ability to imagine ourselves moving within the environment. Such imaginative capabilities are specifically related to the orientation ability more than other similar abilities, such as the ability to generate images from memory or the ability to mentally manipulate objects and comparing spatially them with each others.

1.4 Neural correlates of spatial orientation

Topographical orientation and navigation capabilities involve a large neural network. With imaging technology, in recent years has been possible to have detailed information on the mechanisms underlying orientation. These studies have shown a very large neural network involved in navigation tasks.

Regions primarily involved are:

- The frontal and orbito-frontal cortex. These areas are involved in working memory and attentional processes related to orientation skills (Shulman et al., 1999, Hopfinger et al., 2000, Petrides, 2000, Corbetta et al, 2002);
- The parietal and retrosplenial cortex permitted the spatial perception and addressing the subject's movements within the environment (Corbetta et al., 2000; Maguire, 2001; Culham and Valya, 2006, Epstein et al., 2007 ; Iaria et al., 2007);

- The temporal structures including the hippocampal complex, which are involved in learning and recognition of spatial information during navigation (Maguire, 1997, Burgess et al., 2002);
- Sub-cortical structures such as the caudate nucleus, underlying the procedural memory and enable people to move automatically in familiar environments (Hartley et al., 2003; Iaria et al., 2003).

To summarize, frontal cortex regions are responsible for attention and working memory tasks involved in spatial orientation, while the parietal and retrosplenial cortex have a critical role in spatial perception and control of subjects' movements within the environment.

The hyppocampus and temporal structures are important to learn and bring back to memory the information during navigation. In particular, the hippocampal and retrosplenial areas are involved in the creation of mental maps of places. Subcortical structures such as the caudate nucleus contribute to procedural memory, which allows individuals to move along familiar paths automatically.

Given the complexity of this system, is not surprising that different injuries in different brain districts can contribute to making difficult navigating within the environment, as it will be explained in the next section.

1.5 Deficits of spatial orientation skills

The spatial orientation deficit is characterized by the inability to learn new *routes* and to orient ourselves within familiar surroundings (Guariglia et al., 2004; Vallar and Papagno, 2007; Rusconi et al., 2008).

Generally, spatial deficits that include topographical orientation disorders may arise as a result of acquired bilateral brain injury or localized in the right hemisphere, due to stroke, trauma, surgical treatment of epilepsy, encephalitis or neoplasys, neurodegenerative syndromes (such as Alzheimer's disease) and confusional status.

Given the complexity of interactions between different brain areas involved in orientation and navigation abilities, it's possible to understand how different brain lesions can affect these abilities in different ways (Barrash, 1998), making it unlikely considering the topographical disorientation as a unitary disorder (De Renzi, 1982, Aguirre and 2009; Esposito, 1999; Iaria et al., 2005).

“ Pure “ Topographical disorientation (isolated disorder caused by a focal brain injury) occurred in the presence of two deficits (Paterson and Zangwill, 1945, Landis et al., 1986):

1) *Topographical Agnosia*, characterized by the loss of the ability to identify environmental *landmarks* such as buildings, and generally associated with brain lesions located in the mesial part of the occipito-temporal region, with particular involvement of the lingual and fusiform gyri;

2) *Topographic Amnesia*, characterized by the loss of spatial representations concerning relationships between environmental *landmarks* and and in reference to the subject’s body. It appears to be associated with the presence of lesions in the right posterior cerebral artery, in para-hippocampus gyrus and in the posterior area of the right cingulate (retrosplenial cortex) (Barrash, 1998; Vallar and Papagno, 2007).

According to De Renzi (1982), disorientation could be attributed to selective deficits of underlying processes:

- perceptual and cognitive deficits, could impair the ability to visually explore the environment and to shift the focus of attention from one target to another;
- deficit in the ability to perceive specific characteristics regarding objects and their location, could affect the ability to generate and manipulate visual images;
- mnemonic deficit, found chiefly in response to stroke, post-coma condition and early stages of Alzheimer’s dementia, could lead to topographical orientation difficulties especially in relocating *landmarks*.

Aguirre and D’Esposito (1999), more recently, through a literature review and a comparison with results from neuro-imaging, electrophysiological and functional studies, have reported a detailed taxonomy of topographical orientation disorder, which is declined in four main forms:

- patients suffering from *egocentric disorientation* associated with posterior parietal cortex lesions, despite they are able to recognize a *landmark*, they cannot encode the position taken when using an egocentric coordinate system (Stark, et al. 1996);
- Patients with "*heading disorientation*", following retrosplenial cortex lesions, despite they are able to recognize *landmarks*, they cannot derive information useful for navigation (Takahashi et al., 1997);
- in case of *agnosia for landmarks* associated with medial temporal-occipital cortex lesions, individuals lose the ability to recognize salient environmental *landmarks* (Pallis, 1955);
- and finally, the *anterograde topographical disorientation* due to para-hippocampus lesions, does not allow to learn paths within new environments (Habib and Sirigu, 1987).

Guariglia et al. (2004) consider that the topographical orientation deficits are due to specific aspects of the wider human navigation system, that is: recognition and memorization of *landmarks*, recalling spatial relationships within the environment, changes in components of the navigation system that may alter the ability of encoding spatial information, necessary for their long-term storage.

If topographical disorientation generally seems to be caused by acquired brain injury, recently there have been reports cases of patients with congenital topographical disorientation (Iaria et al., 2009; Incocciati et al., 2009).

1.6 Assessment tools of topographical orientation ability

The instruments used in neuropsychological assessment of subjects with suspected spatial orientation disorders are numerous and heterogeneous in nature, due to the very heterogeneity of the disorder and the variety of cognitive abilities underlying the function investigated.

The literature emphasizes the use of different spatial tests: tests that assesses creation and use of mental imagery creation (Just and Carpenter, 1985; Grossi, 1991), spatial memory tasks (Della Sala et al., 1999); self-assessment questionnaire (Vecchi et al., 1999; Pazzaglia and De Beni, 2001).

The *Mental Rotation Test* (Grossi, 1991) allows us to test the ability to modify mental representations of geometric forms by implementing a rotation of the same, so as to recognize the previously presented target in a series of alternatives.

The test developed by Della Sala et al. (1999) is a memory test for matrices in which, upon the presentation of matrices of increasing size within which half of the squares are black, the subject has to reproduce them by using empty matrices.

Other instruments frequently used for the topographical orientation assessment are the *Maze Learning Test* and the *Road Map Test*.

The first one stems from a subtest that is content on the *Wechsler Intelligence Scale for Children-Revised* (WISC-R) (Wechler, 1974). This assessment tool allows us to evaluate the learning ability of the subjects to which eight different mazes are presented with three repetitions for each one. What seems generally differentiate control subjects and patients is the presence of the learning effect, which is reflected in time decrease to resolve the task and that, in patients, is not detectable.

The *Road Map Test* (Money et al., 1967) requires subject, faced with a *survey* map on which is suggested a specific path, to imagine himself moving within this and then verbally describe the directions taken at any decision point (right-left).

All tests presented so far allow not only the assessment of topographical orientation and navigation, but also about components that form the basis of those skills, such as perceptual, mnemonic and attentional processes, and skills related to the creation of mental images that we discussed about previously. The principal limit of these assessment tools, however, is the inability to provide an ecological measure of capacity or deficit’s impact when the subject moves whitin everyday environments. Moreover, these instruments have the character to be based solely on a *survey* perspective of space.

To overcome these limitations, some experts have recently developed assessment methods based on the use of virtual reality, which favors the observation of the dynamic nature of exploration strategies implemented during navigation (Morganti, 2003; Morganti et al. , 2009). The possibility of consider virtual reality as a tool more ecological than other ones for evaluating topographical orientation, is given by the emergence of a sense of "*presence*", the feeling of being deployed in a simulated space, that can be assimilated to physical reality (Morganti and Riva, 2006).

Based on these needs, some experts have adapted tools such as the *Road Map Test*, and the *Maze Learning Test* to virtual reality. So, they are elaborated:

- the *VR-Maze Test*, which requires the subject, after completing the " paper and pencil " task, to reproduce the same path within the virtual maze (Morganti et al., 2007)
- the *VR-Road Map Test*, proposed the subject to follow a specific path within the virtual environment, using a paper map of the same environment as a guide (ibidem).

The use of these tests permits to assess the subject ability to effectively explore the environment with an egocentric perspective, starting from the use of a *survey* map. We will discuss about these two tools in later chapters.

Finally, another example of test constructed in the virtual modality is represented by the *Cognitive Map Test* (CMT) (Iaria et al., 2007), which permits the assessment of the creation and use of cognitive maps of the environment within which the subject is presented. This test has a virtual city characterized by buildings with the same texture but different shape and size, and only six clearly identifiable *landmarks*. After a first stage of free environmental exploration, which would allow the creation of a corresponding cognitive map, the subject has to locate the *landmarks* with the correct order decided by the examiner.

Although there are many tests to evaluate different aspects related to the topographic orientation and navigation ability, it is important to take into account the incompleteness of this assessment tools to infer the existence of orientation capacities and deficits (Aguirre and D'Esposito, 1999). In general, the performance of the subject, that is submitted to tasks for the assessment of specific skills, may be affected by the use of compensatory strategies extraneous to the ability investigated (Pick, 1993). For this reason, it is desirable to take attention when inferences about capabilities and/or deficits, based on the only use of tests, are formulated.

1.7 Age-related declines in topographic orientation

With age are found structural and functional changes of the brain, that leads to modifications of cognitive skills involved in navigation. Numerous studies in animals and humans have documented the existence of topographic orientation and navigation abilities decline related to advancing age of the subjects (Kirasic et al. 1992; Wilkniss et al., 1997, Barnes et al ., 1997; Tanila et al., 1997, Moffat et al., 2001, Driscoll et al., 2005, Moffat et al., 2006; Iaria et al., 2009). It was found that older individuals require more time and commit more errors than the younger subjects in tasks of locating a specific target.

The use of virtual environment (VE) technology to assess spatial navigation in humans has become increasingly common and provides an opportunity to quantify age-related deficits in human spatial navigation and promote a comparative approach to the neuroscience of cognitive aging.

One of the most important studies conducted by Moffat et al. (2001) assessed age differences in navigational behavior within VE and examined the relationship between this navigational measure and other more traditional measures of cognitive aging. During this study participants were confronted with a VE spatial learning task designed using a modified version of the Game Creation System (Pie in the Sky Software, Fairport, New York, 15334), and completed a battery of cognitive testsregarding verbal and visual memory and mental rotation ability. The VE consisted of a richly textured series of interconnected hallways, some leading to dead ends and others leading to a designated goal location in the environment. Mean age of the participants was 57.8 (ds. 18.5) years (range 22–91 years). The results illustrates that compared to younger participants, older subjects took longer to solve each trial, traversed a longer distance, and made significantly more spatial memory errors. After 5 learning trials, 86% of young and 24% of elderly volunteers were able to locate the goal without error. Ideed performances on the VE navigation task were positively correlated with measures of mental rotation and verbal and visual memory.

The orientation ability decline seems to be confirmed also by functional imaging studies (Driscoll et al., 2003, Moffat et al., 2006) that, during the execution of specific tasks, show a decrease of functional activity of areas that support attentional, perceptual and mnemonic functions involved in spatial navigation, such as the hippocampal complex, the parietal and retro-splenial cortex (Aguirre et al., 1996, Mellet et al., 2000).

In particular, many studies argue that the orientation abilities' decline is due to volume reduction and changes in neurochemical properties which occur on the hippocampus (Driscoll et al., 2003), which allows orientation through the use of *landmarks* and their spatial relationships (Maguire, 1997; Maguire at al., 1999; Mellet at el., 2000).

Moffat et al (2006) conducted an experiment where younger and older subjects were confronted with a virtual environment consisting of several rooms and interconnecting hallways and the presence of six common objects. Participants were instructed to move through the environment using an MR-compatible joystick (Medical College of Wisconsin) and to learn the locations of all the objects and how all the hallways interconnected with one another. Mean age of the young participants was 27 years (range 21–39), and mean age of the elderly participants was 69 years (range 60–78). The results of this study provide evidence of age specific neural networks supporting spatial navigation and identify a putative neural substrate for age-related differences in spatial memory and navigational skills. Indeed, in comparison to younger subjects, elderly participants showed reduced activation in the hippocampus and parahippocampal gyrus, medial parietal lobe and retrosplenial cortex, but increased activation in anterior cingulate gyrus and medial frontal lobe (Moffat et al., 2006).

Also Driscoll et al (2005) provide evidence to the existence of an age-related decline of orientation abilities involved human hippocampal circuitry. They used a computerized (virtual) version of the MWT (VMWT) (Morris et al., 1982) to confirm this Hypothesis through two experiments. In particular in the first experiment, the authors tested participants (20–90 years of age) in the VMWT and compared their performance to that on the Vandenberg Mental Rotation Test (Vandenberg and Kose, 1978), finding an age-related deficit in performance on both tasks, that involved the hippocampal circuitry.

It seems that older individuals needed more time to create cognitive maps and are less efficient in their use in order to orient themselves (Burns, 1999). Studies conducted with the use of virtual reality programs have shown that this effect is reflected primarily on the ability to create and use cognitive maps relating to the environment of reference (Moffat and Resnick, 2002, Moffat et al., 2007; Iaria et al., 2009).

Iaria et al (2009) submitted younger and older individuals to a navigational task in a virtual environment, where they had to orient themselves using cognitive maps. Mean age of the young participants was 23.9 years (range 19-30 year), and mean age of the older ones was 55.8 (range 50-69). Moreover, older participants were questioned regarding memory skills and any change in cognitive function during preceding months to exclude subjects with early dementia or mild cognitive impairments. Results of this study highlight that decreased efficacy in both forming and using cognitive maps makes a significant contribution to the age-related decline in orientation skills.

Although it has therefore been amply demonstrated that there is an important effect on the expression of age-related capacity for orientation and navigation, it remains unclear how this happens (Iaria et al., 2009).

Chapter 2

Virtual reality and spatial orientation

2.1 First applications of virtual reality

Virtual reality (VR) was founded in 1984 by William Gibson when in his romance "*Neuromancer*" is proposed the concept of "*jacking in*", that is the connection of the brain to a dataspace through a jack, and where we read for the first time the term cyberspace , that refers to a "*consensual hallucination of representing data graphically immersive and with high-definition*" (Rheingold, 1991).

On the technical side, the first pioneering devices capable of delivering the virtual experience are constructed by Ivan Sutherland in the late sixties, constructor of displays mounted on helmets and used as a model for subsequent developments in military and aerospace applications, but not yet conceptually linked to the virtual technology.

Currently, virtual reality is recognized by all the people as a believable technology, moving from being a speculative vision to be an inevitable development.

The first application of VR has occurred with the realization of *displays*, connected to *dataspace* and mounted on helmets *Darth Vader*, developed by the U.S. Air Force in the early '80s. The project idea came from Thomas Furness III, who had observed as fighter planes were becoming so complex and powerful that they threatened to go beyond human capacities. Tasks for fighter pilots had become so complex that it needs new ways of flight and weapons control. New systems should allow the rider to access to flight data in a less abstract and more intuitive modality. Thus, the displays mounted on helmets presented, with a simple graphic, the medium position, the speed, the target and the surrounding environment, all of this combined with auditory signals designed to simulate the 3D space (Furness, 1988).

The purpose of *display* mounted on helmets, that is make the pilot more efficient in fight situations, reflected the institutional purposes aimed at defending the nation. Before the VR technology to become marketable, it would have reversed public profile: from military use to mass-market applications.

In the late ‘80s, new VR applications, designing for industry, were made, with virtual masks for welders and automotive design; in medicine with virtual interfaces for assisting surgeries, in education, with virtual libraries; in entertainment, with interactive TV. VR origins came from military sphere and this is evident by the development of *videogames* where you use combat aircraft to shoot and bomb targets. They are widespread not only because players like these games, but mainly because VR was developed mainly for the creation of games for military use.

It follows that VR is more familiar to users who play with video games and who are more inclined to experiment with new interactive technologies. Therefore, within collective imagination the term virtual reality refers to the world of interactive entertainment games or imaginative researchers who experiment with their theories through computer methodologies alternative to the classical standards of laboratory. Moreover, an area where it seems that the application potential of VR has not yet fully understand, is the framework of cognitive science (Morganti and Riva, 2006).

2.2 The technology used in virtual reality

The *input* instruments for the use of virtual reality may be traditional ones, such as mouse and keyboard, or more advanced and more adapted equipment than traditional technologies to collect data for scientific purposes.

The tools used in VR have reached a good level of reliability and precision and they can be divided into three categories, based on the ability to record the:

- body movement within space
- rotational movements of body parts
- objects’ manipulation.

To record the body movement, tools used range from sophisticated mechanical platforms, that move in correspondence to changes of the virtual environment (*Virtual Environment*, VE), to sensors attached to the user's limbs that allow to register with accurate precision deambulation, that will be translated into motion in virtual space.

HMD helmets are equipped with sensors that detect the head rotation, while sensors and stimulators of touch are placed in the "glove" and they reproduce the pressures caused by objects' manipulation.

These technologies allow us to charge more information regarding actions experienced by the user, and thus to increase the possible moves in the VE (Morganti and Riva, 2006).

But these tools are very sophisticated and expensive instruments and are usually used for particular situations, because the advantage of allowing immersion in the VE is opposed to the onset of vestibular manifestations such as nausea and feeling sick. This is caused by a desynchronization between sensory stimulations received from the visual system and proprioceptive stimuli came from body position.

Easier and common applications are known as "*desktop device*" as the monitor, the *joystick*, the *spaceball* and the mouse. They are tools that require a short period of training in the use but are easy to find and especially "*they don't interfere with navigation in VR*" (Morganti and Riva, 2006). In contrast, the difficulty of isolating the user from the outside world and to recreate a three-dimensional perspective on a flat screen do not always give the user the perception of being in a virtual environment.

2.3 Possible experiences in virtual reality

Many authors define virtual reality as "*a set of computing devices capable of allowing a new type of human-computer interaction*" (Steuer, 1992; Ellis, 1994). This definition stresses not so much peculiarities of VR technology, as the instrumentality of VR devices to support the approach and interaction of humans with particular computer systems.

As Morganti and Riva (2006) observed, the definition lends itself to be divided into two parts: “a set of computing devices” and ”*a new type of human-computer interaction*”. The set of tools that allow humans to experience VR rebuke skills and knowledge of technical-computing nature, while the interaction is studied primarily by psychological and social sciences.

There are different types of interaction experience in virtual reality, that are divided into:

- *Immersive*, the subject’s perceptive channels are isolated from the external context through a virtual stimulation involving completely the senses that take part in movement and interaction within an environment. This type of immersion is facilitated by an HMD helmet (*Head Mounted Display*) which provides for the diffusion of images and sounds produced by computer and position detectors (*tracker*) that refer to the processor user’s movements to change the virtual image of the environment within which he moves;
- *Not immersive*, the subject’s perceptive channels are not isolated and instead of using a HMD helmet it is used a display. The user sees the three-dimensional VR environment in a confined visual space, as if it were a “window”;
- *Semi-immersive*, is a compromise between the two types previously discussed, that uses monitors or concave projection plans (*cave*) larger and wrapping, to give the user the widest possible view of virtual images, determining a greater involvement of visual perception.

The perception of the subject to be in an environment similar to reality and to move “as if” he is in a physical context is provided by input instruments, which collect the data input provided by users, and *output*, which provide a new modified representation of *input* data, due to the refinement graphics misleading visual perceptions and awakens in the user a false reconstruction of reality.

As we have seen, the user exploit special equipment that detect motion and transmit the information to the computer program, which integrates and recoded them into new images reintroduced to the user. The more these processing operations are performed in real time, the more is the perception to be and interact with an almost real environment.

The illusion of concomitance thus permits the creation of "*a computer-generated three-dimensional environment in which the subject or subjects interact with each other and with the environment as if they were really within it*" (Riva, 2004).

2.4 Being in the virtual world: the sense of presence

So that the VR is not only experienced by the subject as a technological environment, but also as an environment within which we can acquire knowledge (Morganti and Riva, 2006), it is necessary that the individual's sense of presence is establish in. Presence means the subjective psychological state characterized by the complete, or at least partially, lack of awareness regarding the role played by the technological medium in the determination of subject's perceptual sensations, which really are generated not from a natural environment but from a technological artifact (Morganti and Riva, 2006).

This construct derives from the concept of *telepresence*, which developed in the '80s in conjunction with the spread of *teleoperations*' communicative technology. Those permitt to guide a robot controlled remotely by an operator who, through their perceptual and motor abilities and the machine in his service, is able to operate in environments difficult to reach otherwise (Minsky, 1980, Held and Durlach, 1992, Sheridan, 1992).

The efficient use of robot is highly dependent on the degree of telepresence evolved in the subject who controls it (Riva et al., 2004). Through the robot, the operator deployed in the environment where he feels he cannot be physically present and in which the robot operates like an extension of his own body (Loomis, 1992, Held and Durlach, 1992; Steuer, 1992; Zhao, 2003, Sanchez-Vives and Slater, 2005). Thus, the feeling of telepresence allows the individual to interact with the remote environment as if he were physically present (Riva, 2004). Similarly, the exposure to VR develops a sense of presence within the virtual environment.

The sense of presence depends on the degree of immersion that virtual reality system is capable of eliciting in the subject and is therefore linked to the technological quality characteristic of the system, to achieve a kind of "*perceptual realism*" (Slater and Wilbur, 1997; Schubert et al., 1999, Schubert et al., 1999b). Perceptual realism means the condition in which the characteristics of the virtual environment produced by the system, such as graphics quality and perceptual stimulation provided, present a high degree of quality that ensures a greater immersion's ability.

When using VR, the perception of the subject can overcome the awareness of the intercession of the communicative medium, and then actions are performed as if the technology was not present. All this is made possible thanks to the "*perceptual illusion of non mediation*" (Lombard and Ditton, 1997).

Within this perspective different conceptualizations have been developed over time. Sheridan (1992) and Zelter (1992) believe that the concept of immersion references to the feeling of being located in a different location than the physical one: namely, the virtual presence is experienced when an individual believes he is physically present in a visual, auditory and tactile space generated by a technological instrument.

Witmer and Siegel (1998) argue that the sensation of presence is linked to the possibility for the subject of immersion in VR and to the ability to pay attention to important information contained in it: the presence is, therefore, constructed through the allocation of attentional resources. This approach highlights not only the importance of the VR system's immersive properties for the emergence of presence, but also the role of the activity of the subject in directing selectively his attention in a complex environment, which guarantees a possibility of interaction with the same (Carassa et al., 2005).

Starting from the vision promoted by the two authors, Heeter (1992) notes that the VR system's perceptual realism cannot be considered the only cause of the sense of presence. The possibility of action and their effects on the environment would seem, in fact, increase the degree of perceived presence and Sastry and Boyd (1998) argue that a high level of presence can be presented in virtual environment if "*the user is able to navigate, decide, shift, and move objects intuitively*".

The importance of action for determination of the presence, however, doesn't corresponde to the need to give the subject movement freedom within virtual environment, but also it must give an account of the importance of plausible causal-effect relationships between perception and action (Zahorik and Jenison, 1998). This seems to be in accord with the concept of *affordance* (Gibson, 1977), namely the set of actions that an object invites making to itself, which establishes the relationship between perception and action that occurs within environments in real world. The relationship between perception and elicited motor representation seems to be reflected even within virtual environments (Ellis et al., 2007; Symes et al., 2007; Schubert, 2009). In fact, it was demonstrated that manipulation of motor representations during the experience in VR has repercussions on the sense of presence, and that levels of representations' activation are predictive of the sense of presence experienced within the environment (Schubert, 2009). It is important, however, stressed that the relationship between perception and action is not unidirectional, since even actions of the subject are condificated in terms of sensory effects (Hommel et al., 2001).

Finally, with regard to the interaction between perception and action, it is important to highlight how this seems to be justified by the notion of embodiment, that is the total of the subject's sensorimotor skills that enable him to interact successfully within his environment (Riva, 2006). This concept origins from the "*embodied cognition*" approach (Lakoff and Johnson, 1980), whereby the body, through the senses, is the main link between human mind and world. If it is not possible to conceive of a disembodied nature of mind, it is true that it is closely linked to the body, from which it receives internal and environmental information to process (Damasio, 1999).

If the body can be conceptualized as the interface between world and mind, it is understandable that the development of presence in a virtual environment is based on the illusory perception of physical presence in which the body is experienced as displaced in another location (Morganti and Riva 2006).

Scheridan (1999) included the two visions of the concept of presence previously discussed in *Estimation Theory,* which expresses the human inability to acquire a true knowledge of objective reality which would entice the individual to the construction of mental models of reality. According to the author, what would happen even within VR environments: starting from virtual sensory stimulation, the subject would build mental models of the virtual world on the basis of interaction with it. Consequently, the more the model of the virtual world differs from the representation of the real world possessed by the subject, the lower the experienced level of presence is.

Mantovani and Riva (2000) have proposed a social and cultural analysis of human interaction with the virtual world. According to the authors, in fact, every action performed within the VR context can be placed within a frame of meanings belonging to the culture of subject's reference, from which he derives a sense of presence. The interaction between man and world, whether real or virtual, in fact, is permeated by the culture of reference, through which the meanings attributed to information provided by the environment are negotiated.

Riva and Waterworth (2004), stressing the importance of a subjective reading of the situation experienced by the individual in determining the level of presence, argue that the subject's expectations are the main element of distinction between "internal" and "external" to the sensory stream supplied from virtual environment, through which it is possible to improve the actions' coordination ability. Only if these are confirmed during the interaction with environment, the subject retains the sense of presence.

Carassa et al., (2005) have framed the concept of presence within the perspective called "*situated cognition*", in which the individual would be able to integrate the possibilities of action and interaction in real and virtual world, with the construction of a subjective meaning on the situation experienced. The sense of presence grows, so thanks to its ability to focus attention on the aspects considered significant related to the action, perception and interaction; as well as the isolation methodology and relocation of these issues within a framework of significant reference to the individual.

According to what is discussed above, it is clear that, a coherent and shared vision of the concepts of presence and nature of the relationship between perception and action, that allow to better understand the nature of the interaction between man and virtual environment, has not been formalized yet (Schubert, 2009).

A general agreement seems to have occurred between experts on the possibility of acquiring knowledge through interaction with a VR environment and the sense of presence experienced.

2.5 The acquisition of knowledge within the virtual reality

It should highlight how it is precisely the sense of presence that enables the individual to acquire new spatial knowledge within a not real world (Tlauka and Wilson, 1996), through the use of cognitive modes in part similar to those used for orientation in the real world (Ruddle Payne and Jones, 1997).

The characteristics that underlie spatial representations seem to be the same that are used both in real and simulated environments (Morganti, 2003). Spatial representations may be primary, due to the direct interaction between the agent and the environment, or secondary, abstract in nature due to the creation of symbolic configurations of the surrounding environment (Presson and Sommerville, 1985).

It is unclear whether the acquisition of knowledge created within virtual environment can be attributed to primary or secondary representations, because the representation of computer environments is purely symbolic in nature and there isn't a direct contact with objects of reality. However, by virtue of the considerations outlined above, the electronic *medium* offers a navigation experience perceived as "unmediated" and then learning could be a primary rather than secondary type. Many authors agree on the equivalence between the two types of navigation and the effective presence of visuo-spatial features present in the virtual context as they are present in the real one. In addition, "*the agent maintains, as in reality, a horizontal perspective of environment, building over time a spatial representation through actions and movements made*" (Morganti, 2003, p.112). Thus, even the use of the same cognitive functions used during navigation within both environments, suggests the possibility that the acquisition of spatial knowledge happens in the same manner.

An experiment conducted by Payne et Ruddle Jones (1997) proposes a virtual and real exploration task within a building of 126 empty rooms with the same size and nine rooms containing different furniture, redesigned from a real environment. When tests end, it was found that subjects who had been offered the virtual task with *desktop* mode could estimate the spatial references, distances and directions, in the same way the group of subjects who explored the real building.

This stems from the fact that subjects that explore simulated environments, as well as for those who explore real environments, need to create a map representation to navigate within it. The representation is subject to continuous updates and revisions. This indicates a process of active construction of spatial knowledge, reworked each time on the basis of variation of visual-spatial reference stimuli.

Weysman et al. (1987) have noted that the exploration of real and virtual environments allows to transfer the knowledge from one environment to another. Who did navigation in real environments can also orient himself within the same environments in virtual mode and vice versa.

O'Neill (1992) argues that the repeated navigation leads to the acquisition of spatial knowledge during *wayfinding* tasks also within complex environments. Regia et al. (1992) report the results of an experiment conducted within a virtual environment consisting of twelve rooms well distinct. The subjects were able to recreate a representation of the explored space and recombine *landmarks* to create new paths and shortcuts.

Bliss et al. (1997) have conducted studies on learning of new *routes* by firefighters using three modes; training in VE, training with a topographical map and no training. It was noted that training in virtual environments enable faster exploration of the path than the other two modes of training.

Montello et Hegarty (1999) compares the acquisition of spatial knowledge resulting from navigation in real and virtual environments and the use of a map. The authors found that the amount of knowledge learned through the exploration and the use of map is equivalent. Use of a map, however, experiences a *survey* knowledge, which requires orientation abilities, otherwise the presence of errors in direction estimating capacity; the acquisition of knowledge in "non immersive " virtual mode (*desktop*) appears impoverished compared to the real one, especially when it comes to acquiring information related to buildings with superimposed planes.

Concerning differences experienced within the two environments, Henry and Furness (1993) show that there is a tendency to underestimate the size of a room or *pointing* to objects not visible in the virtual environment, while others highlight the differences expressed by the subjects in estimate large distances displayed in real and virtual environments (Hale and Dittmar, 1994).

In conclusion, it is noted that the exploration of virtual environments effectively determine the acquisition of spatial knowledge. However, this is qualitatively different from that experienced in real environment. One of the major distinguishing characteristics of virtual reality compared to the natural environment is the difficulty of updating the rotation, mainly due to the lack of kinesthetic information accessible to the individual (Montello, and Hegarty, 1999).

2.6 The application of virtual reality for the study of cognitive function

In recent years, VR has experienced an expansion of applications in various fields, for example in clinical and experimental assessment of cognitive functions.

The technological contribution that has occurred in recent decades within the field of neuropsychological assessment and rehabilitation, has been a key element that has allowed to refine existing techniques and expand the boundaries of possible actions. Just on the basis of this claim, in fact, in the case of topographic orientation ability and related disorders, the use of computerized tools that can reproduce three-dimensional environments is very common in clinical practice and in scientific studies (Jansen - Osmann et al., 2007; Riecke et al., 2007; Bosco et al., 2008, Morganti et al., 2007).

A neuropsychological evaluation is a comprehensive assessment of cognitive and behavioural functions using a set of standardized tests and procedures. Various mental functions are systematically tested, including, but not limited to reasoning, language and perception. Neuropsychological evaluation can assist greatly in planning a had-hoc rehabilitative strategy in cognitive function recovery after brain injury. Classical approach to neuropsychological assessment was generally based on the use of pencil and paper tests and the measurement of cognitive/functional processes was based on two criteria: reliability and validity. The first is due to the capacity of consistently return the same results in evaluation, the second is concerned with how well an instrument actually measures what it purports to measure.

Along with interactive technologies growth, and in particular with virtual reality diffusion, a possible perspectives modification for the assessment and rehabilitation of cognitive functions turns possible. Several researchers agree in underline how virtual reality should allow the development of suitable and extremely useful virtual environments for cognitive functions rehabilitation. The main innovation carried out from VR is on the possibility in having a new human-interaction type. All user body movements should become potentially very important during the interaction with a virtual environment, within which all the modification in the VE will change back a new action opportunity for the same user (Morganti, 2009; Kelly *et al.*, 2009).

VR is used in neuropsychological for studing memory, plan and motor abilities, executive functions and spatial knowledge representation.

Table 2.1 will resume VR application for the evaluation and training of impaired cognitive functions (Morganti, 2004, p.60).

Table 2.1 Virtual Reality applications in cognitive neuropsychology

INTERVENTION	APPLICATION	GOALS AUTORS
MEMORY	Assessment	- Perspective memory evaluation (Brooks et al., 2002) - Comparison of incidental memory (Andrews et al., 1995)
	Rehabilitation	- Error free memory recovery approach (Brooks et al.,1999) - Vanishing cues method for memory rehabilitation (Glisky et al., 1994)
PLAN AND MOTOR ABILITIES	Assessment	- Monitor patient's reaction to specific stimuli (Rose et al., 1998) - Haptic stimulation (Broeren et al., 2002)
	Rehabilitation	- Support patient in action performance (Wilson et al., 1997) - How VR can support action simulation process in motor rehabilitation (Morganti, 2003) - Is VR-based motor rehabilitation transferable to real environment? (Zang et al., 2001) The importance of augmented feedback in VR rehabilitation (Holden and Todorov, 2002)
EXETUTIVE FUNCTIONS	Assessment	Dysexecutive syndrome assessment in VR (Lo Priore et al. 2003)
SPATIAL KNOWLEDGE REPRESENTATION	Assessment	- Comparison between traditional assessment and VR-based one (McGee et al., 2000) - Egocentric/allocentric spatial memory (Morris et al., 2002) - Attention assessment in peripersonal/extrapersonal space (Maringelli et al., 2001)
	Rehabilitation	- The importance of observational learning (Golden et al., 1999) - Binocular information in grasping rehabilitation (Wann et al., 2001) - Topographical disorientation (Bertella et al., 2001) - Neglect sindrome rehabilitation (Myers and Bering, 2000) - Crossing street ability recovery in Neglect patients (Weiss et al., 2003)

The benefits of these applications concern primarily the possibility to conduct investigations through the use of objective instruments within ecological context, without altering the task’s nature (Morganti et al., 2009). Moreover, VR allows us to test the subject’s ability to explore in complex environments through an egocentric perspective, unlike other methods of investigation that permit a presentation of the spatial task only in an allocentric perspective (Morganti et al., 2009). The modification of the mode to detecting the ability of individuals to transform spatial knowledge from a *survey* perspective to a *route* one, that is a characteristic feature of topographical disorientation (Morganti, 2003).

Although the major benefits of using VR for the assessment of topographical orientation ability, however, it is important to note also the presence of inherent limits to the same methodology (Woods et al., 2008). Empirical studies, in fact, highlight the risk of overestimating errors than is possible in real environments (Chang et al., 1998); the alteration of the test’s accuracy and the lack of proprioceptive inputs (Grant and Magee, 1998 ; Klatzky et al., 1998) and a possible alteration in the evaluation of distances and proportions (Osmann Jansen-and Berendt, 2002; and Osmann Jansen-Wiedenbauer, 2004).

2.7 The use of virtual reality for the assessment of spatial orientation

During the assessment of the human spatial orientation ability, one of the major limitations for examiners is the difficulty of creating likely environments that allow to an adequate level of experimental control (Bosco et al., 2008). In this regard, the technological development of recent years has been designated virtual reality as a possible solution to the problem. Virtual technologies, in fact, allow the experimenter to create three-dimensional interactive environments which, unlike traditional evaluation instruments used in neuropsychology, seem to be more similar to real-world environments, and within which the subject can implement similar behaviors with those used in everyday situations. Virtual environments, in fact, permit the creation of test and dynamic trainings that reproduce environments of everyday life by allowing control over experimental *settings* (ibid.). In addition, they allow us to collect reliable data regarding the subject's behavior during the exploration which otherwise, in real settings, could not be detected.

The use of VR to assess the spatial orientation ability has highlighted the similarities between the mechanisms underlying navigation within virtual environments and real ones. In these studies, in fact, these are the:

- similarity of spatial representations made within VR environments with those involved in navigation within real ones (Witmer et al., 1996, Arthur et al., 1997, Ruddle et al., 1997; Peruch et al., 2000; Morganti, 2006 , Palermo et al., 2008);
- predictability of measures relating to spatial knowledge in VR compared to the performances in the real world (Waller, 2000);
- activation of same cortical areas during tasks of exploration and navigation in both situations (Burgess et al., 1999, Ekstrom et al., 2003).

It is therefore possible to conceptualize the use of virtual reality as the right compromise between laboratory assessment, which allows us to maintain an adequate control of interfering variables and the observation of strategies adopted by the subject during the exploration of natural environments (Morganti et al., 2007).

It should be noted that VR and real world are not stackable concepts. Biocca (2003) argues that the effectiveness of the first one is not dictated by the need to faithfully reproduce the second one. Virtual reality is not the equivalent of the real world, but it represents a technological tool through which a perceptual illusion is created that elicits a sensory stimulation that lead to the development of cognitive and emotional models consistent with the experience (Mantovani, 1995 ; Morganti, 2006). This supports the involvement of the subject in VR and promotes the partial absence of awareness regarding the medium presence (Lombard and Ditton, 1997; Morganti, 2006).

Sheridan (1992) argues that the virtual environment is a mental model representing a physical environment, but not identical with it. In this sense, both worlds generate mental perceptive models in the subject that, however, differed in their origin: "*real environment is a physical environment coupled with a perceptual model that is generated from this and it represents; virtual environment is a perceptual model* *generated by the presence of a medium that does not coincide with the physical environment that the model represents* “ (ibid.).

Additional elements that differentiate virtual environments and real ones are found in visual characteristics of elements belonging to two worlds: despite the use of advanced technologies, in fact, the visual complexity of elements within the real world, both in the overall characteristics both in detail, it remains however major (Sanchez-Vives and Slater, 2005).

Indeed, the combination of VR to reality would be supported also by the possibility to create a multi-sensory experience that traces the involvement of all human senses as occurs during exposure of the subject to any kind of real-world environment (Matheis et al. , 2007). The possibility of interaction within virtual environments can be considered a combination motif of the two worlds, resulting in mutual modification of the environment according to subject’s actions, and of subject’s actions according to the context in which he is present, resulting in a circular co-determination relationship between environment and individual (Carassa et al., 2004).

Experience in VR, despite it is an illusory one, can be considered convincing from a sensory point of view (Mantovani, 1996), thanks to the inclusive nature of the relationship between subject and environment and which leads to the consideration of virtual reality as a communication medium (Biocca, 1992; Riva, 1999, Riva and Mantovani, 1999). Within this perspective, the subject is not conceived only as a mere receiver of information came from this medium, but as an active participant within events in VR (Morganti, 2006). This is made possible by the high level of immersion of the subject in virtual reality (Slater and Wilbur, 1997, Shubert et al., 1999), that elicits cognitive and favorable emotional responses because of the subjective sensation of virtual experience, defined presence, which we discuss in the next section (Slater et al., 1995; Lombard and Ditton, 1997, Witmer and Singer, 1998, Riva et al., 2003).

Chapter 3

The research methodology

3.1 Sample selection

The survey sample consists of 100 subjects aged between 30 and 80 years, split evenly between males and females by age range with ten-year (31-40, 41-50, 51-60, 61-70; 71-80) residents in the province of Milan.

The subjects of higher age groups (50-80) were contacted and recruited from frequenters of some centers for old people, while the younger ones have been identified among relatives, friends and acquaintances.

The first contact with managers these Centers was done through direct knowledge. It was asked each of them to gather a large number of associates to present the research in progress, during an afternoon meeting of about an hour. During different dates, to adapt to their availability, it was explained the project and the purposes of research, the types of tests and timing of assessments and the need to have volunteers that could be tested.

After presentations, it was given to each of them a preprinted where express consent indicating name, gender, age, phone number, and the day preference for meetings, if in the morning or in the afternoon. Most people have given their willingness to participate in research, so that they were many more people than it serves for the survey's purpose, especially in the age group between 60 and 70. It was thus decided to proceed with recruitment taking into account the order of consent's presentation. On subsequent days, subjects were reached by telephone to arrange time and place of meetings. These were: the council hall in the area "3" in Milan, the senior Center "P. Alive" in Carate Brianza, the physiotherapy Center in Monza and the senior Center "Cascina tre fontanili" in Vimodrone. The administrations began in March and ended in October 2009.

With subjects of lower age range, 30-50 years old, the evaluations were carried out at their homes or the examiner's one, because most people have work commitments until late and have given their availability in the evening after 19.00 and on Saturdays and Sundays.

The assessments are conducted by only one examiner.

3.2 The assessment tools and the administration of tests

The subjects were submitted to two separate evaluation sessions lasting an hour and a half each, carried out in two different days. To assess the general functional state and some specific perceptual, attentive and memory abilities involved in topographical orientation tasks, during the first meeting were administered a battery of standardized neuropsychological tests that were calibrated on the Italian population, consisting of:

1) The MMSE - Mini Mental State Examination (Folstein et al., 1975)
2) The Verbal Fluency Test for categories (Novelli, 1986)
3) Judgment of line orientation (Benton et al., 1983)
4) The Rey Auditory Verbal Learning Test (Rey, 1958, Carlesimo, 1996)
5) The Trail Making Test A e B (Reitan, 1958)
6) Copy of drawings - circle, rhombus, rectangle (Spinnler et al., 1987)
7) The Rey Auditory Verbal Learning Test – deferred test (Rey, 1964)
8) Corsi blocks task (Milaner, 1971)
9) Corsi Supraspan (Capitani *et al*., 1980)
10) The Manikin's Test (Ratcliff, 1979)
11) The Tower of london (Shallice, 1982)
12) The Deux Barrages Test (Zazzo, 1960b)

At the beginning of the meeting, the subjects were made aware of the test operations and it was asked to complete a "declaration of informed consent".

A preliminary screening was used to describe the cognitive profile of candidates. Those who scored below the MMSE cut-off = 24 were excluded from the sample, while those who optained a score that was equal or less than the threshold value was postponed until the second session.

The next session was devoted to assessing spatial orientation abilities. Selected subjects were proposed two types of tests: the first consists of six labyrinths of Maze Learning Test (MLT) and “paper and pencil” version of the Road Map Test (RMT). The MLT is taken from subtest of the Wechsler Intelligence Scale for Children-Revised (WISC-R) (Wechler, 1974), consisted of eight mazes. For this research they have been used six of these- one for “training” and the top five for the tests - (Appendix A). The test is a test time and requires to start from the center of the maze where there is an “X” and to reach as quickly as possible the side exit, following the corridors without crossing the lines. The subject must be drawn with pen or pencil the route that allows him to get out as quickly as possible from the maze. Before the beginning, tha examiner has to explain the subject that the test will be timed and it should take place without delay, starting from the center of the maze where the “X” is placed and still be able to correct the path in case of error. The timing of the test are recorded on a separate ballot paper headed to the subject, on which the seconds used and the success or failure of the task (YES / NO) are recorded.

The second “paper and pencil” test is the Road Map Test (Money et al., 1967), which suggests a map where there are 6x7 rows of rectangles and triangles that ideally represent the houses of a city seen from above (Appendix B). Within the map a line representing a path with 32 turning points (target) is drawn . It is asked the subject to imagine himself as he follows the path and, starting from the No. 1 and taking the paper still in the same position and without the possibility to turn it, to report orally the directions taken- right or left - near each of the 32 turning points. On the appropriate registration form of scores, the examiner records the correctness of answers on each turn (right or left) and the time taken to perform the test.

After “paper and pencil” tests tasks are followed in virtual mode, the VR Maze Learning Test, and the VR Road Map Test. Both tests were developed by Morganti and Riva (Morganti et al. 2007) in a research project includes a collaboration between the University of Bergamo and the IRCCS-Italian Auxologic Institute, in Milan. The tests have been proposed through a 3D simulation presented on computer, in desktop mode. In all tests and with all subjects the computer equipment used consists of a “Sony Vaio” notebook, a model with 15-inch screen, a 1000 Ghz processor and 4 Mega RAM 2007.

The VR Maze Learning Test proposes six paper mazes in virtual mode, through six computer programs that reproduce exactly the same mazes of the Wechsler Intelligence Scale. The virtual environment mimics the lines in the form of high walls that form corridors with green grass floors, all nestled in a mountain landscape, where snowcapped peaks and a blue sky stand out in the background. At the exit of the maze there are a lawn and a large lake. The sun is positioned arbitrarily in the north and it represent the landmark in this test, while the walls configuration that reproduce the lines of mazes allow actors to orient themselves relying on their navigation skills. The viewpoint adopted is of type route, where the subject doesn't see the maze from above but he is inside (vgs fig. 1).

Before beginning the test, the examiner explain the subject that he will hold the maze paper just solved in front of him and follow the path marked out with pencil to orient himself and find the exit within the virtual environment. The subject uses the four arrows on the computer keyboard to move himself within mazes. After the test, it shall be recorded on the ballot paper the time taken. If the subject fails to solve the maze within ten minutes, it stops running and the failure is recorded.

The VR Road Map test reproduces the homologous paper test. The virtual city is characterized by a number of houses all with two floors above ground, with the same texture and different sizes, that is built on the basis of those that are drawn on the paper map. All around the city there is a low wall that delineates the urban perimeter. The landscape is mountainous, as in the previous test, and this time the sun is positioned in the south, where it serves as a reference point (vgs fig. 2).

Fig. 1

Fig.2

Before beginning the test, the examiner explains the subject to follow the path traced on paper and, in the vicinity of each turning point, to report the target’s number and the direction (left or right) that he is about to undertake. On the score sheet the time he takes to get from one point to another is recorded and, after ten minutes, the test stopped and the target achieved is recorded.

In all tests, at the beginning and at the end of the test the examiner records the performance on the computer, pressing the “R” on keyboard. The recording gives birth to a data file that, submitted by an appropriate computer program, plays down a red line on a black background that traces the movements made by the subject within the mazes of the map that allow post-hoc analysis.

The data collected by neuropsychological and computerized tests have been incorporated into a matrix data CxV (cases per variables), a type of database where in each row data from each subject are recorded. At the completion of the data input and of the so-called “cleaning” of the matrix, which includes removal of cases that have not completed the tests - 25 in all - the sample is composed of 100 subjects equally distributed in the ten-year age groups from 30 to 80 years. Of the 25 excluded, 6 of these scored below the MMSE cut-off, while the other 19 could not make the second session for various reasons.

Data analysis were done using the program SPSS version 10.0. The descriptive tables, crossed and summarized, completed by accurate univariate, bivariate and inferential statistics, are reported in the next chapter.

Chapter 4

Sample characteristics

Here, we report information on the socio-demographic data, neuropsychological profiles and the results of "paper and pencil" and virtual reality tests of the sample interviewed.

4.1 Description of socio-demographic characteristics

4.1.1 Age and gender of subjects

Sampling procedures in which the sample is stratified for age and gender have allow to select 100 subjects equally distributed into five cohorts:

1º group: aged between 30 and 40 years
2º group: aged between 41 and 50 years
3º group: aged between 51 and 60 years
4º group: aged between 61 and 70 years
5º group: aged between 71 and 80 years

Each group is composed of ten males and ten females.

Table 4.1.1 - Age and gender of participants

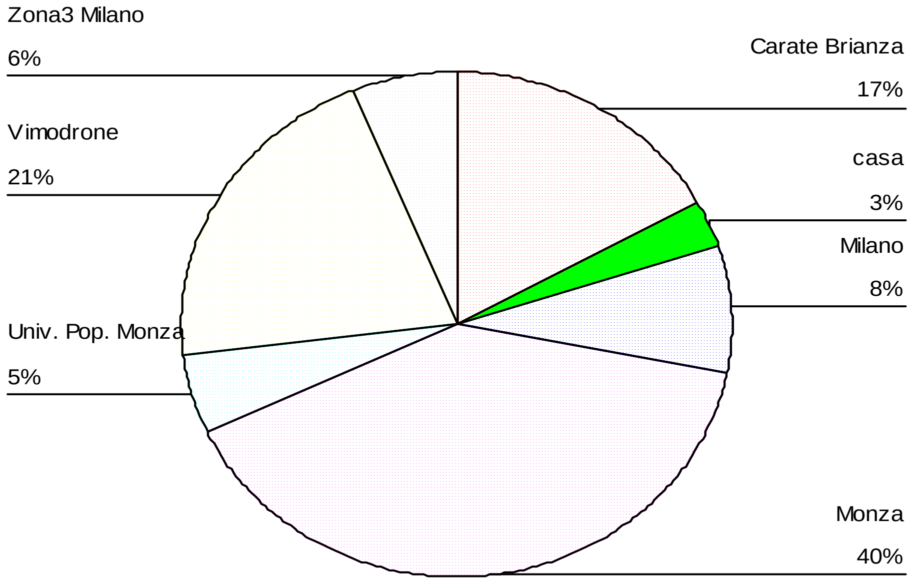
		AGE					Total
		1(30-40)	2(41-50)	3(51-60)	4(61-70)	5 (71-81)	
GENDER	Males	10	10	10	10	10	50
	females	10	10	10	10	10	50
Total		20	20	20	20	20	100

The average age is 55.96 years old, with standard deviation (DS) 14.33. Population indices between males and females differ minimally from the values of the sample: within the group of males, the average age is 56.44, with SD 14.74, and within the females one the average is 55.38 and ds 13.93 .

4.1.2 Geographical areas of origin

The evaluations were made in different places within the province of Milan. Most of these were executed in the city of Monza, at the headquarters of districts 1 and 5 and at the Popular University of Monza. Following that, 21 were made at the "Cascina tre Fontanili" in Vimodrone and 17 at the "P. Aliverti" Center in Carate Brianza. Further, at the headquarters of district 3 in Milan and at the evaluator's home[1]. The distribution of tests is shown in graph 1.

Graphic 4.1.1



[1] Fifteen people were evaluated at the examiner address, twelve of which were not included in the sample because, for lack of time, they didn't finish the second session.

The age distribution is heterogeneous in relation to geographical areas. The youngest people were assessed at home and in Milan, while older people were enrolled at the Popular University of Monza, followed by Vimodrone and Carate Brianza.

This phenomenon is explained by the fact that people "over 50" were found in the Elder Centers of the two towns, while younger ones were contacted from relatives and acquaintances living in Monza.

Table 4.1.2 - average age refers to the geographical

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Monza	40	49,28	13,93	2,20	44,82	53,73	30	80
Vimodrone	21	64,14	7,06	1,54	60,93	67,36	48	75
Carate Brian.	17	62,94	8,95	2,17	58,34	67,55	49	80
Milan	8	48,25	16,83	5,95	34,18	62,32	32	77
Zona3 Mi	6	57,83	15,03	6,13	42,07	73,60	34	74
Univ.Pop. M.	5	71,80	9,58	4,28	59,91	83,69	57	81
Home	3	37,00	2,00	1,15	32,03	41,97	35	39
Total	100	55,91	14,28	1,43	53,08	58,74	30	81

4.1.3 Education

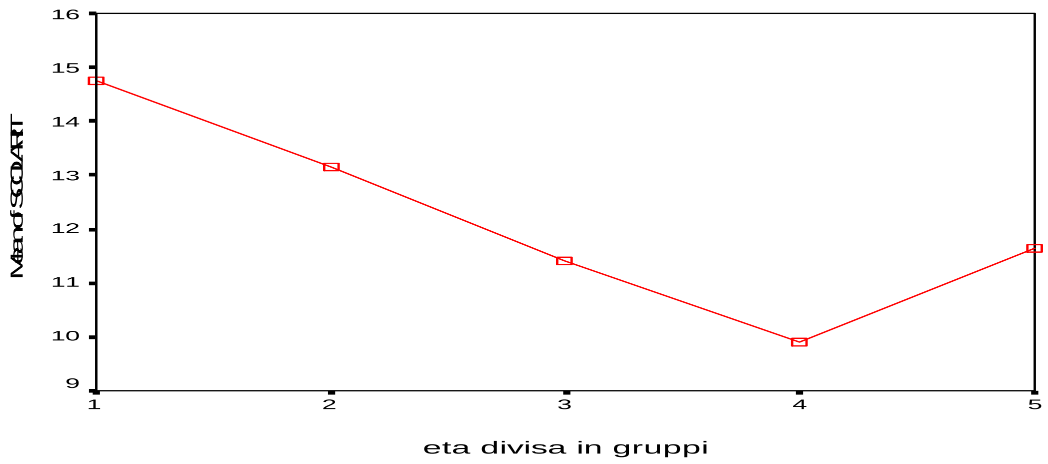
The schooling of participants varies from a minimum of 5 to a maximum of 19 years. The average is 12.17 (median 13) and ds 3.48. Schooling is higher in younger cohorts (minimum 8).

Table 4.1.3 - Schooling averages distinct on the basis of age groups.

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
1 (30-40)	20	14,75	2,61	0,58	13,53	15,97	8	19
2 (41-50)	20	13,15	2,85	0,64	11,82	14,48	8	18
3 (51-60)	20	11,40	3,15	0,70	9,92	12,88	8	18
4 (61-70)	20	9,90	2,22	0,50	8,86	10,94	6	13
5 (71-81)	20	11,65	4,36	0,97	9,61	13,69	5	18
Total	100	12,17	3,48	0,35	11,48	12,86	5	19

The graph 4.1.2 shows visually the distribution of the averages within the five cohorts.

Graph 4.1.2



The difference in schooling between genders is almost nothing: 12.16 for males and 12.18 for females, with ds oscillating for a few cents around the value 3.48.

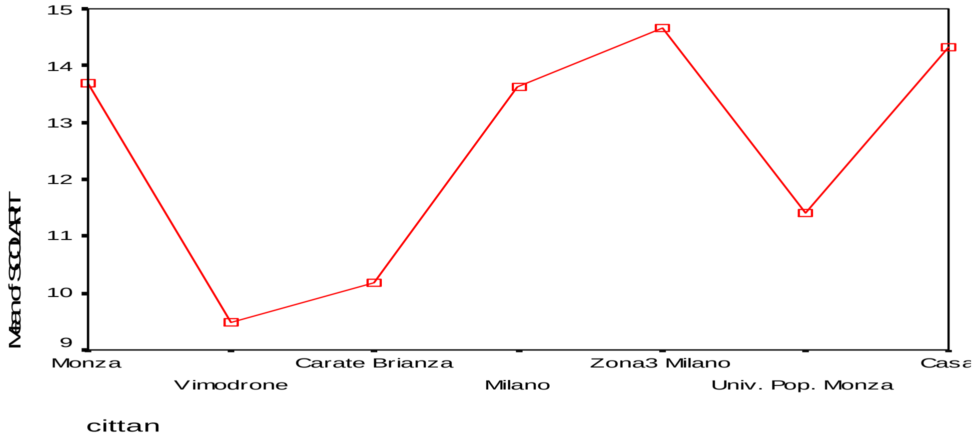
Significant differences are found instead in the distribution of schooling compared to geographic areas of origin. The higher education is noted in Milan and Monza, while these levels are lowest in Vimodrone and Carate Brianza.

Table 4.1.4 - Averages schooling distinct on the basis of geographical areas

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Monza	40	13,70	2,81	0,44	12,80	14,60	8	18
Vimodrone	21	9,48	2,94	0,64	8,14	10,82	5	18
Carate Br.	17	10,18	2,51	0,61	8,89	11,46	5	14
Milan	8	13,63	3,62	1,28	10,60	16,65	8	17
District3 Mi.	6	14,67	4,63	1,89	9,80	19,53	8	19
Pop.Un. M.	5	11,40	2,41	1,08	8,41	14,39	8	14
Home	3	14,33	2,31	1,33	8,60	20,07	13	17
Total	100	12,17	3,48	0,35	11,48	12,86	5	19

The graph 4.1.3 shows the distribution of schooling for urban areas.

Graph 4.1.3



Socio-demographic characteristics, as discussed in following paragraphs, have a role in the covariation of neuropsychological and spatial orientation's tests results.

4.2. Neuropsychological characteristics of the sample

One of the main objectives of this study is to trace the neuropsychological profile of the cohorts and to compare it with performances on spatial orientation's tests.

For exposition ease, the results obtained in neuropsychological tests will be reported separately in two different tables. In the first table, will be summarized test data so-called "general", reported to attentional, perceptual and memory skills, in the second one, the test data more specifically aimed at assessing spatial orientation abilities.

Table 5.2.1 shows the values of central tendency and dispersion of "general" neuropsychological tests: the Verbal Fluency Test, the Rey Test and the Rey Deferred Test, the TMT-A, the TMT-B and the Tower of London.

Table 4.2.1 - Statistical values related to neuropsychological tests

	Verb.f.	T. REY	TMT-A	TMT-B	REY dif	Tower of Lond
N	100	100	100	99	100	100
Missing	0	0	0	1	0	0
Mean	22,54	9,58	33,08	68,57	11,11	32,75
Median	22,00	10,00	32,00	64,00	12,00	34,00
Sd	5,11	1,67	8,51	21,77	2,60	3,21
Minimum	12,00	5,40	19,00	36,00	4,00	20,00
Maximum	39,00	13,00	67,00	160	15,00	36,00

In Table 4.2.2 data for orientation test are shown: *Judgment of Line Orientation* by Benton, the *Corsi Span and Supra-Span Test* and the *Manikin's Test*

Table 4.2.2 - Statistical values on tests for spatial orientation

	Benton	CORSI	Supra-span	MANIKIN	BARRAGE
N	100	100	100	100	100
Missing	0	0	0	0	0
Mean	28,71	5,69	22,64	30,38	36
Median	29,50	5,50	23,21	31,00	36
Std. Dev.	1,93	1,07	4,71	2,26	0
Minimum	18,00	4,75	5,25	20,00	32
Maximum	30,00	15,31	31,16	32,00	36

Copy drawings and Barrage's tests will not be commenting, because the results have mostly been focused on the maximum values, thus reducing to a minimum the variability of scores.

4.2.1 The Mini Mental State Examination

The test consists of 10 tests assessing different aspects of general cognitive functioning: testing temporal and spatial orientation, attentional, intellectual, mnemonic, verbal and prassiche fuctions.

At the beginning of the evaluation, all subjects are submitted to the MMSE, which was also a discriminatory tests for the selection of the sample.

The average value obtained from the sample test is 26.74 with SD 1.36 . Males are made at 26.64 with DS 0.90 and females are made at 26.85 with DS 1.71. Compared to age, it is noted that individuals with less than 50 years old achieved the highest scores, while lower values are attributed to the central age belt - 51-60 and 61-70 - where this last one also has the higher variability (SD 2.53). Surprisingly, the older cohort presents MMSE scores equal to and not lower than the two previous cohorts, as would be expected in accordance to the literature reference.

Table 4.2.3 - Analysis of the MMSE (adjusted) by age cohorts

	N	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
1	20	27,20	0,44	0,10	27,00	27,40	26,20	27,80
2	20	27,17	0,39	0,09	26,99	27,35	25,80	27,80
3	20	26,47	1,10	0,25	25,95	26,98	24,20	27,80
4	20	26,40	1,02	0,23	25,92	26,88	24,80	28,40
5	20	26,47	2,53	0,57	25,28	27,66	24,30	36,50
Total	100	26,74	1,36	0,14	26,47	27,01	24,20	36,50

That fact is also apparent from the correlation index connected with age, where it is found only a weak inverse relationship between increasing age and the reduction of the score (Bravais-Pearson's r = -0.212, p. 0. 000). The same statistics operation confirm a significant relationship between years of schooling and the score at the MMSE.

4.2.2 The Verbal Fluency Test for categories

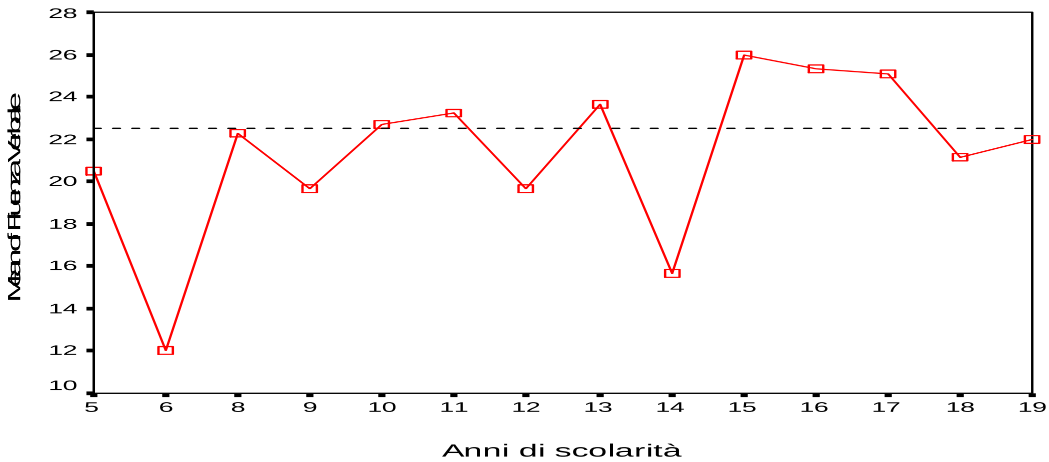
The Verbal Fluency Test evaluates the speed of access to the semantic lexicon. It consists of the fast quote by the subject of all the names that come to mind in a minute that belong to the category of animals. The score is the number of correct words. It was used only one category in this research, rather than three as required by the test in extended form.

The results do not seem influenced by gender. In the sample, being male or female does not condition the verbal fluency for categories.

Contrary to what one would expect, the number of words formulated are not correlated significantly with age and schooling, although it is found that increasing age decreases the average number of verbal elements and with increasing schooling the number of words increases.

The graph 4.2.1 reproduces the distribution of the scores' averages based on years of schooling.

Graph 4.2.1



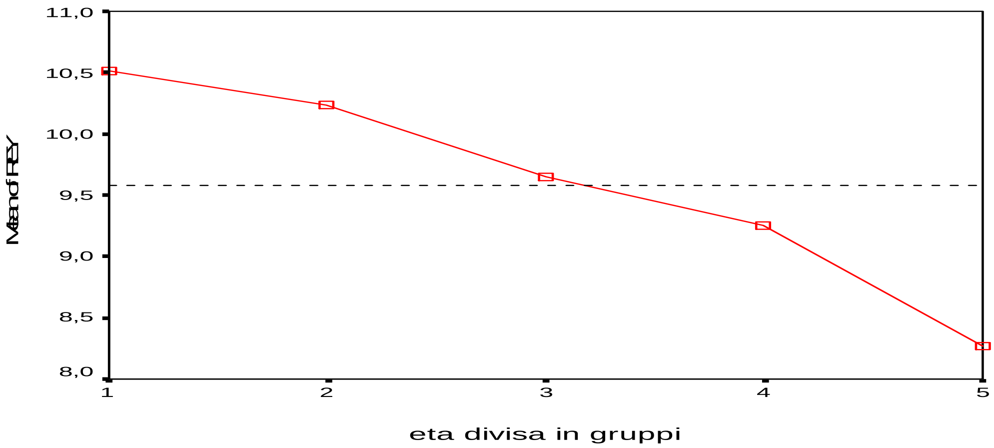
The low values expressed by those who have 6 and 14 years of schooling negatively affect the prediction of a linear correlation between the two variables.

4.2.3 The Rey Auditory Verbal Learning Test

The Rey Auditory Verbal Learning Test is a test that evaluates memory fixation and learning. The score at the Rey Test is the average of words recalled at the end of reading a list of 15 words repeated five times.

The graph 4.2.2 is observed that with increasing age decreases the average of words recalled.

Graph 4.2.2



The score at the Rey Auditory Verbal Learning Test differs significantly (P.0, 00) between males (9.11) and females (10.05), in favor of the latter ones[2].

Although schooling is directly related to test scores, in fact the increase of schooling increases the number of words recalled.

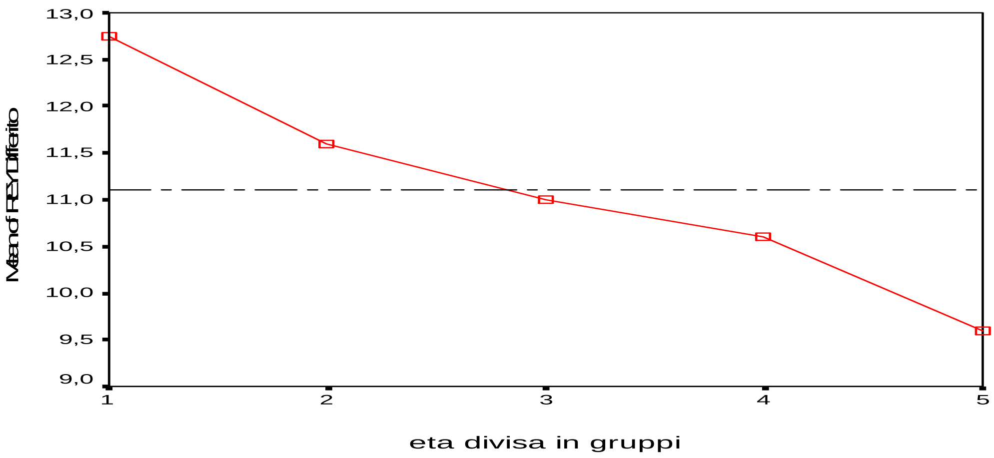
4.2.4 Il Rey Auditory Verbal Learning Test – Deferred

Like the previous the Deferred Rey Auditory Verbal Learning Test is a verbal memory test. The scores of the Deferred Rey Test, which consists in recalling after 15 minutes of the words previously read with the Rey Test, are based on the absolute number of words recalled.

The gender does not affect the deferred trial, while the results confirm the downward trend of performances on memory tests related to the advancing age, as shown in graph 4.2.3.

[2] The Rey Test is the only test in which gender affects the results of neuropsychological tests.

Graph 4.2.3



Another significant finding is related to schooling, which influences the test results. In fact, it was shown that increasing the number of years of schooling increases the number of words recalled, with a expectation force estimates by about 41% (b of regression = 0.413 with p. 0.000)[3].

4.2.5 The Trail Making Test –A Version

The Trail Making Test - A Version (TMT-A) requiring the person to unite in progressive order with the stroke of a pen, in the shortest possible time, 25 numbers randomly scattered on a white paper. The score is the number of seconds used to finish the test. Less time is indicative of greater attentive efficiency.

The time taken by subjects to perform the TMT-A it's about 33.08 seconds. Predictably, with increasing age increases the time required for the resolution of the test. In age groups below 50 years old, the average time is 29 seconds, while in the range above 70 years old the average time reaches 40 seconds.

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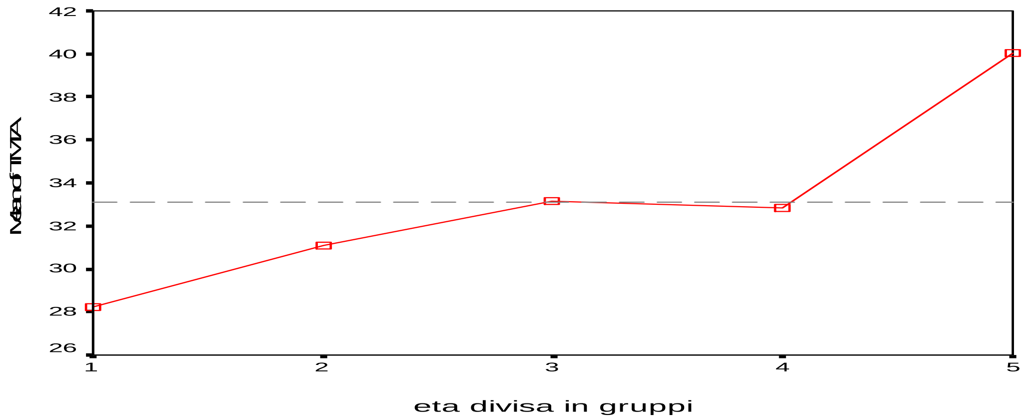
[3] The regression model submits to analysis two or more cardinal variables, from the observed values of the independent variable, it estimated expected values of the dependent variable related to changes in the first one. R2 statistics indicate the proportion of variability of the dependent variable that is explained by the independent variable.

Graph 4.2.4



Years of school affect the speed significantly ($p < 0.05$) but with a weak influence on scores ($r = 0.23$). This means that there are variations in increasing the time taken that depends minimally on the relationship between the two variables.

4.2.6 The Trail Making Test- B Version

Like the previous example, the Trail Making Test - B Version (TMT-B) requires the subject to unite in a progressive order with the pen stroke, as quickly as possible, items scattered randomly on a white paper. In this case, however, there are 13 numbers alternating 12 letters of the alphabet, from A to N.

The candidate combines elements consecutively alternating numbers with letters (es.: 1-A-2-B-3-C, etc.). The score is the number of seconds used to complete the test. Less time is indicative of a greater attentive efficiency. The average time taken by subjects to perform the TMT-B is 68.57 seconds, with ds.21, 77.

There are not observed significant differences between males and females and equally schooling doesn’t correlate with performance on the task.

Predictably, with increasing age also the time required for the resolution of the test increases, but the significance of the correlation (P.0, 07) is lower than the value accepted in the research’s context (P. 0,05).

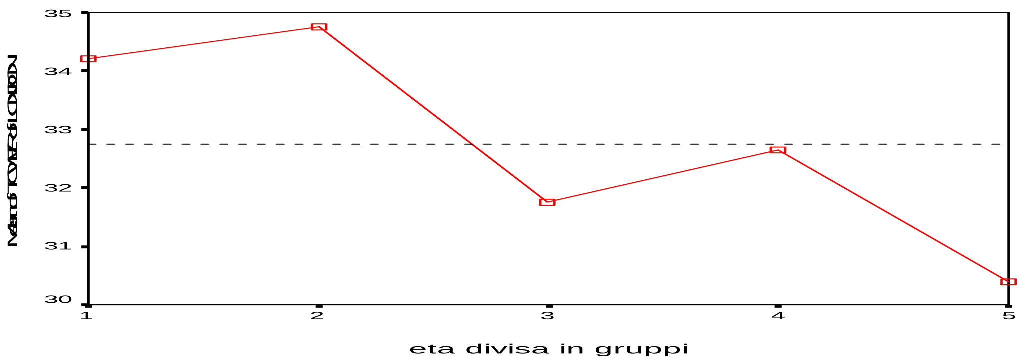
The TMT-B is the only test of the neuropsychological battery that has not been completed by all the subjects (five candidates renounced, three males and two females).

4.2.7 The Tower of London Test

The Tower of London Test (ToL) is composed of a rectangular base, on which are placed three vertical pegs with decreasing heights, and three colored balls stacked in a standard position. The examiner proposes the subject to move the balls and to arrange them as shown in the twelve cards that reproduce configurations of increasing difficulty. The test provides a precise number of moves that the subject can take to realize each configuration. After each test, the balls are placed in the initial order, to resume with the next test.

Although the scores are statistically significant for age groups, they show a discontinuous progression, where the group of 51-60 years old has obtained average scores slightly lower than the next category.

Graph 4.2.5



The average sample score is 32.75 with DS 3.21. the subjects aged under 50 years old obtained scores above average, while those who are above this threshold has recorded average scores below the sample mean.

Even school years influence performance on the test: scores correspond to a higher schooling.

Table 4.2.4 Analysis of results of the Tower of London in relation to education.

Descriptives

TOFLONDO

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
0-5	2	28,00	1,41	1,00	15,29	40,71	27	29
6-8	23	30,87	3,56	,74	29,33	32,41	24	36
9-13	49	33,10	2,97	,42	32,25	33,95	20	36
14-19	26	34,12	2,32	,46	33,18	35,05	28	36
Total	100	32,75	3,21	,32	32,11	33,39	20	36

In the next section the analysis of the ”spatial orientation” variables (the Benton Test, the Corsi blocks Task, the Corsi Supraspan Test and the Manikin’s Test).

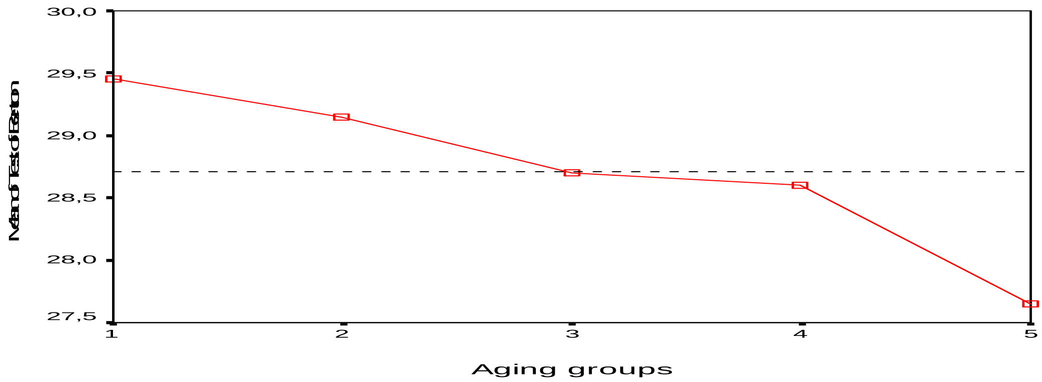
4.2.8 Judgment of line orientation (Benton Test) – H Version

The Benton Test consists of nine lines numbered from 1 to 9, arranged radially on a plane of 180 degrees and it is used to assess the ability to capture the correct spatial orientation of two lines deciding between nine possible alternatives. First five tables are presented for testing and then the next thirty tables of the test. The lines are presented in pairs and the subject has to indicate the numbers they refer to, compared to the nine numbered lines of the test.

The sample has executed easily the task, given that the average scores of 28.71, with ds 1.93 indicates that the majority of respondents answered correctly to all tests.

Age is the only socio-demographic condition that correlates significantly to the test. As age increases, decreases the number of tests performed correctly.

Graph 4.2.6



Gender and education are not related to scores on the Benton Test.

4.2.9 Corsi spatial blocks Test

The Corsi spatial blocks Test aims to assess the short term serial memory for spatial positions. The material consists of a wooden board of 32x25 cm with nine cubes of 4.5 cm side placed in a random order. The examiner touches with forefinger the cubes in a standard sequence, increasing the number of cubes touched every time the subject successfully resolves two tests of the same length. The score is the maximum number of cubes that the subject can correctly recall in sequence.

The average of the scores corrected for age and education is 5.59 and ds 0.44, with a minimum span of 4.75 and a maximum one of 6.75. From the analysis, it is noted that the test doesn't correlate significantly with gender, age and education of the sample.

4.2.10 The Corsi Supraspan Test

This test assesses spatial learning of subjects and uses the same material of the Corsi Span Test. In this case, however, the examiner touches a series of eight cubes in a standard sequence and he repeats it until the subject has not reproduced it properly for three times. The score is the sum of coefficients assigned to the sequences correctly reproduced for each test. The corrected score average that is recorded is 22.78 with DS 4.39, with a minimum score of 14.09 and a maximum one of 31.16. Also in this case, the test doesn't find correlations with the socio-demographic characteristics of the sample.

4.2.11 The Manikin's Test

The Manikin's Test aims to assess the ability of a subject to discriminate the right and the left on a human figure. The test consists of 32 drawings that represent a mannequin from the front or back perspective, which can be positioned up or upside down. In the hands of shapes there are two discs, one that is black and one that is white. The subject must indicate which hand of the human figure has the black disk. The score is the number of correct answers.

The test was relatively easy for subjects, such as the sample mean (30.36 DS 2.26) is near to a maximum score of 32. The minimum score was 20 correct figures. Significant relationships with other socio-demographic variables (gender, age and education) were not reported.

To summarize, in following tables are reported the relationships between demographic variables and the "general" and "spatial" neuropsychological tests.

Table 4.2.5 - Relationships between demographic conditions neuropsychological tests.

	MMSE	Fluen.V.	REY	TMT-A	TMT-B	REY Diff.	T of London
Gender	0	0	1	0	0	0	0
Age	1	1	1	1	1	1	1
Education	1	0	1	1	0	1	1

Table 4.2.6 - Relationships between demographic conditions and "spatial" neuropsychological tests.

	Benton T.	Corsi Span	Supraspan	Manikin's Test
Gender	0	0	0	0
Age	1	0	0	0
Education	0	0	0	0

4.2.11 Correlations between the neuropsychological tests

At the end of the analysis between the neuropsychological tests and socio-demographic characteristics of the sample, the relationships that trials of the test battery entertain each other are analyzed.

Since early findings, it was noted that the correlations, also if they have significance, present statistical indices (r of Bravais-Pearson)[4] characterized by a moderate value probably because they measure different cognitive skills. Indeed, relations between variables stood below the value of r = 0.5, indicating a moderate correlation between scores of the tests, excluding those observed between tests of the same nature as the TMT-A and the TMT - B (r = 0.66) and the Rey Test in immediate and deferred version (r = 0.74).

Analyzing the results of "general" tests (attentional, perceptual and mnemonic) it was noted for example, that the Verbal Fluency Test for categories correlates with the two versions for the TMT and with the two versions of the Rey Test. Logically, the sign of the coefficients is negative, because an increasing of the observations of a variable determine a decrease of the other ones (high scores correspond to low time and vice versa). The Tower of London maintains a correlation with the Rey Test and the two versions of the TMT.

Considering the crossing between "spatial orientation" variables, it is noted that the Verbal Fluency Test doesn't covariate with any other spatial test, while the Rey Test, the TMT and the ToL correlate with the Corsi Supraspan Test and with the Manikin's Test .

[4] The Bravais-Pearson r statistic indicates the existence of concordance between two cardinal variables. The value of r ranges between -1 and + 1, depending on the direction and strength of the relationship.

Table 4.2.7 - Summary of relationships between neuropsychological variables.

	VeFl.	Benton	REY	TMTA	TMTB	REYDeff.	CORSI	Supra	MANIKIN	ToL
Verbal Fluen		1	1	1	0	1	0	1	0	1
Bentos	1		1	1	1	1	0	1	1	1
REY	1	1		1	1	1	0	0	1	1
TMT-A	1	1	1		1	0	1	1	1	1
TMT-B	1	1	1	1		0	0	0	0	1
REY Deferred	1	1	1	0	0		0	1	1	1
CORSISPAN	0	0	0	1	0	0		1	0	0
SUPRASPAN	0	1	1	1	0	1	1		1	1
MANIKIN	0	1	1	1	0	1	0	1		1
Tower of L.	1	1	1	1	1	1	0	1	1	

The Corsi Test correlates only with the TMT-A and the Corsi Supraspan Test, while the latter varies with all the tests except the Verbal Fluency Test and the TMT-B. The correlation table is given in Appendix C - Table 5.C.

4.3 Results to the “paper and pencil” tests

Having completed the first session of neuropsychological tests, subjects were asked a second meeting for the administration of tests related to spatial skills.

4.3.1 Results of the Maze Learning Test

Subjects were proposed six trials of the Maze Learning Test (MLT), one is a training test and 5 are experimental ones, described in the previous chapter. The results, expressed in seconds, are summarized in Table 4.3.1.

Table 4.3.1 - Summary of univariate statistics regarding the five mazes of the MLT

Statistics

		CM1	CM2	CM3	CM4	CM5
N	Valid	100	100	98	98	98
	Missing	0	0	2	2	2
Mean		32,22	38,10	87,72	67,18	66,02
Median		23,50	28,00	61,00	44,50	43,50
Std. Deviation		24,01	31,92	71,14	51,44	71,53
Minimum		10	11	27	18	15
Maximum		154	171	400	280	608

At the beginning of the assessment it was administered a maze of training to familiarize the subjects with the task and to make sure they have learned instructions.

Each administration of “paper and pencil” tests (CM) has been alternating with the corresponding “virtual reality” performance (VR).

As can be seen from the previous table, six subjects didn’t complete three of the five mazes (one subject didn’t execute the last three tests, another didn’t complete the 3rd and 4th maze and another one didn’t concluded the 5th maze). The reasons for the failure were reported to fatigue and mental confusion.

The five tests present different difficulties, not necessarily in an increasing order. The 1st and the 2nd mazes have equal difficulties but different from the 3rd, the 4th and the 5th.

In the tables 4.3.2 and 4.3.3 are reported the values for age and education, where the values of significance (column sign.) are less than p. 0,05.

Table 4.3 2 - ANOVA Table of CM mazes based on 5 age groups.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
CM1	Between Groups	18097,660	4	4524,415	11,030	,000
	Within Groups	38967,500	95	410,184		
	Total	57065,160	99			
CM2	Between Groups	8411,700	4	2102,925	2,160	,079
	Within Groups	92479,300	95	973,466		
	Total	100891,0	99			
CM3	Between Groups	51476,961	4	12869,240	2,724	,034
	Within Groups	439376,6	93	4724,480		
	Total	490853,6	97			
CM4	Between Groups	50416,783	4	12604,196	5,684	,000
	Within Groups	206237,9	93	2217,612		
	Total	256654,7	97			
CM5	Between Groups	44800,281	4	11200,070	2,307	,064
	Within Groups	451453,7	93	4854,341		
	Total	496254,0	97			

Table 4.3.3 – ANOVA table of CM mazes based on education.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
CM1	Between Groups	4951,943	3	1650,648	3,041	,033
	Within Groups	52113,217	96	542,846		
	Total	57065,160	99			
CM2	Between Groups	6349,046	3	2116,349	2,149	,099
	Within Groups	94541,954	96	984,812		
	Total	100891,0	99			
CM3	Between Groups	50688,057	3	16896,019	3,608	,016
	Within Groups	440165,5	94	4682,612		
	Total	490853,6	97			
CM4	Between Groups	34225,752	3	11408,584	4,821	,004
	Within Groups	222428,9	94	2366,265		
	Total	256654,7	97			
CM5	Between Groups	30728,892	3	10242,964	2,068	,110
	Within Groups	465525,1	94	4952,394		
	Total	496254,0	97			

From elaborations it is noted that the labyrinths “2” and “5” have not passed the threshold of significance ($p < 0.05$) compared to both age groups and schooling. This could depend on circumstances that are very similar to the immediately preceding two tests, mazes “1” and “4” and we might be facing a “learning effect”.

Regarding age, the youngest cohorts have spent less time solving mazes, as was the case for those with a higer schooling. For example, to solve the CM1, subjects with an age inferior of 50 years old took about 20 seconds to find the exit, less than half the time spent by the "over 70" (58 seconds). This happened also for the other mazes.

Table 4.3.4 - Time (seconds) taken by subjects for the CM MLT vs age divided into groups.

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
CM1	1	20	19,80	11,62	2,60	14,36	25,24	10	59
	2	20	21,70	7,88	1,76	18,01	25,39	15	51
	3	20	30,45	12,87	2,88	24,43	36,47	16	63
	4	20	31,70	32,31	7,22	16,58	46,82	10	154
	5	20	57,45	25,38	5,68	45,57	69,33	20	99
	Total	100	32,22	24,01	2,40	27,46	36,98	10	154
CM2	1	20	29,10	11,54	2,58	23,70	34,50	15	63
	2	20	33,15	33,42	7,47	17,51	48,79	15	171
	3	20	35,20	21,78	4,87	25,01	45,39	12	103
	4	20	37,45	39,66	8,87	18,89	56,01	11	170
	5	20	55,60	39,62	8,86	37,06	74,14	22	170
	Total	100	38,10	31,92	3,19	31,77	44,43	11	171
CM3	1	20	64,70	57,09	12,77	37,98	91,42	27	273
	2	20	64,55	48,77	10,91	41,72	87,38	32	207
	3	20	90,80	88,32	19,75	49,46	132,14	32	400
	4	20	94,75	52,84	11,82	70,02	119,48	35	257
	5	18	127,83	87,77	20,69	84,18	171,48	45	325
	Total	98	87,72	71,14	7,19	73,46	101,99	27	400
CM4	1	20	50,30	39,86	8,91	31,64	68,96	26	210
	2	20	46,20	16,72	3,74	38,37	54,03	28	95
	3	20	67,30	49,86	11,15	43,96	90,64	18	212
	4	20	64,80	48,54	10,85	42,08	87,52	19	199
	5	18	111,78	68,06	16,04	77,93	145,62	42	280
	Total	98	67,18	51,44	5,20	56,87	77,50	18	280
CM5	1	20	39,50	25,32	5,66	27,65	51,35	15	134
	2	20	42,55	19,57	4,38	33,39	51,71	27	116
	3	20	86,05	128,56	28,75	25,88	146,22	19	608
	4	20	74,50	64,59	14,44	44,27	104,73	23	251
	5	18	89,89	47,71	11,25	66,16	113,62	36	212
	Total	98	66,02	71,53	7,23	51,68	80,36	15	608

It is noted that education influenced the time used to complete the task. Individuals with 5 years of study took on average 54 seconds to solve the 1st maze, while those with schooling between 14 and 19 years after arrived at the end of the task in just over 27 seconds.

In cross-analysis with the gender as variable, there were no significant data between males and females regarding the speed of solving mazes.

Data for the five mazes correlate with the results obtained in neuropsychological tests related to attentional, perceptual and mnemonic abilities.

Table 4.3.5 - Relationships between CM and neuropsychological tests.

	MMSE	VERB.FL.	REY	TMTA	TMTB	REYDEFF.	T.OFLOND.
CM1	1	1	1	1	1	1	1
CM2	0	0	1	1	1	0	0
CM3	0	0	1	1	1	1	1
CM4	1	0	1	1	1	1	1
CM5	0	0	1	1	1	1	1

Almost all the tests correlate with the two versions of the Rey Test, with the two TMT and with the Tower of London. Instead, it wasn't found a correlation with the MMSE score.

Levels of significance between tasks within the same test results different. For example, for the Deferred Rey Test the probability value of the five mazes range from p. 0.000 and p. 0.035, indicating that its tasks require different levels of abilities to be solved.

The results of neuropsychological tests known as "spatial" correlated with the five mazes. In particular, there has been a negative correlation (-0.504) between the CM3 and the Benton Test, as it was the case with the Corsi Supraspan Test (-0.308).

Table 4.3.6 - Relationships between CM and "spatial" neuropsychological tests

	BENTON	CORSISPAN	SUPRASPAN	MANIKIN'S TEST
CM1	1	0	1	1
CM2	1	0	1	1
CM3	1	0	1	1
CM4	1	0	1	1
CM5	0	0	0	1

The third CM maze has obtained the highest statistical value (-0.504) with the Manikin's Test, while the Corsi Span Test does not maintain a linear relationship with mazes.

The complete correlation's tables of the statistical indicators and of significance are reported in Appendix D.

4.3.2 Results of the Road Map Test

The Road Map Test was administered at the end of the Maze Learning Test. It need to be remember that the test consists of an articulated path on 32 turning points within a city map. The subject has to mentally retrace the path and to indicate aloud the turning direction (left or right) at each deviation point (target).

The test was performed by only 72 subjects, since it was decided to administer the RMT trough CM modality in the pipeline, after that 28 people had already been tested. It was decided to accept the presence of missing values (missing) and therefore to not recontact the subjects to submit them to the test, because doing so would have altered the experimental conditions of administration compared to the rest of the sample.

The subjects performed the test in an average time of 139 seconds (median 110 sec.) with DS 85.29. The minimum time was 55 sec. and the maximum one was eight minutes (480 seconds).

Compared to the number of targets indicated correctly, it is noted that on average 27 turns were reported correctly, with a ds 4.6. The minimum number of correct turns is 16. Seven players have achieved a performance below the cut-off of the test (20 target).

Table 4.3.7 - Statistics of the Road Map Test based on target and time.

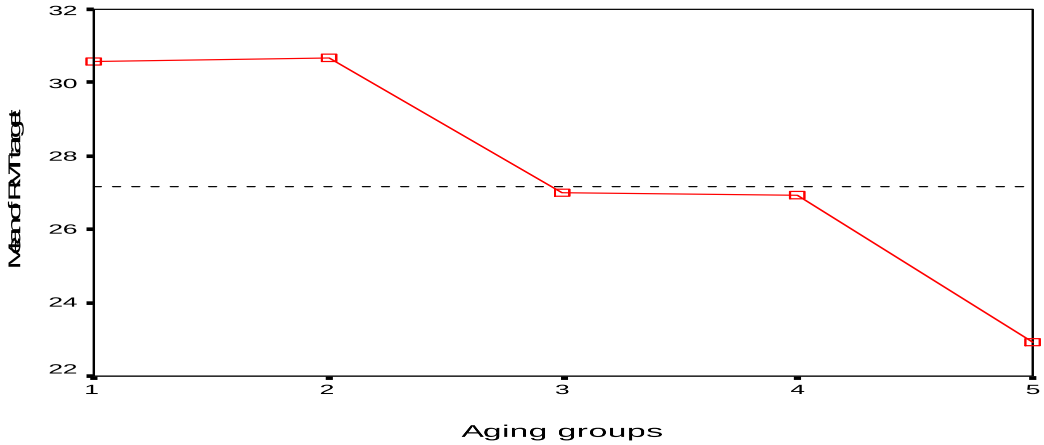
Statistics

		RMCLTARG	RMCLTIME
N	Valid	62	62
	Missing	38	38
Mean		27,16	138,90
Median		28,00	110,00
Std. Deviation		4,60	85,29
Minimum		16	55
Maximum		32	480
Percentiles	25	24,00	83,50
	50	28,00	110,00
	75	31,00	160,25

It was found that males are faster than females, while there is no correspondence between gender and number of correct target.

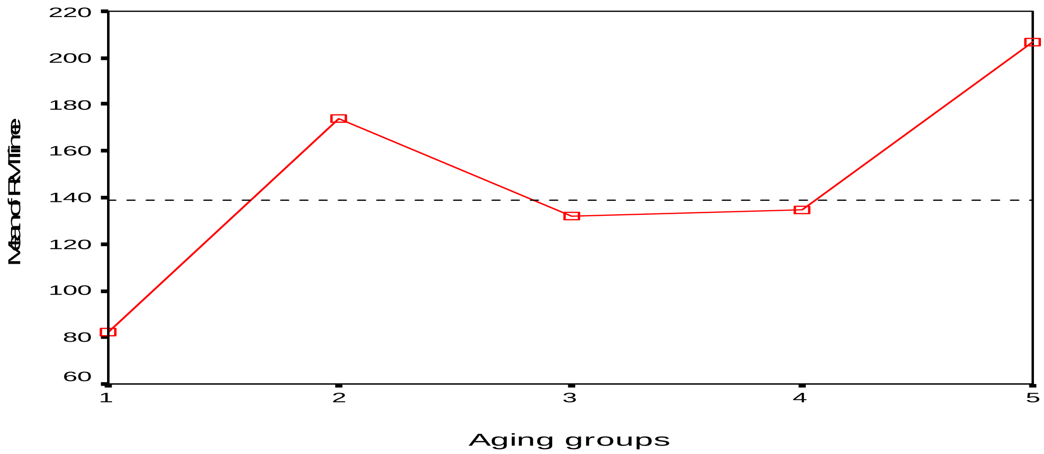
Regarding the age, it is noted that with increasing seniority decreases the accuracy of the test. While the “under 50” have recorded scores above average, with 31 correct turns, the “over 70” have obtained scores much lower than average.

Graph 4.3.1



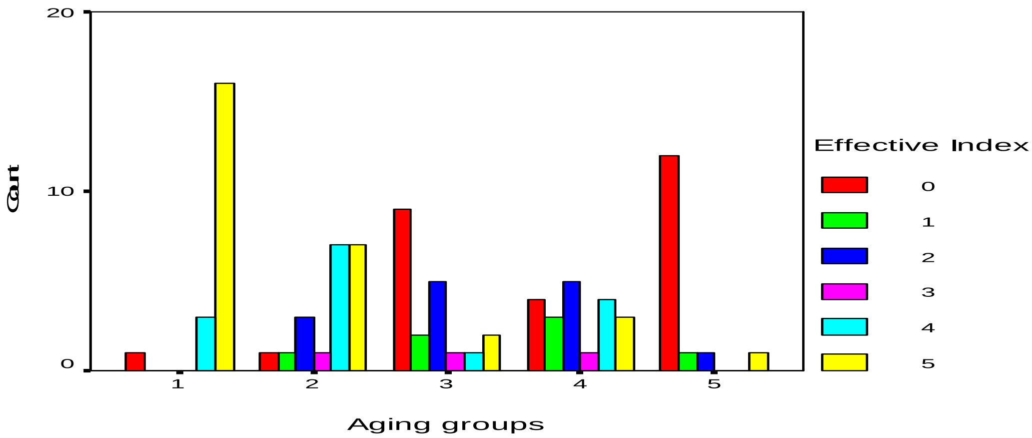
Even the execution time depends on age. Over the years go the greater the time required to complete the test (p.001). The first age group, between 30 and 40 years old took an average of 82 seconds. The last group, more than 70 years old, has solved the RMT in an average time of 206 seconds.

Graph 4.3.2



The graph 4.3.4 shows the values of the efficiency index related with age. Increasing the seniority the number of mazes completed seems to be reduced.

Graph 4.3.4



Similarly, the education level of the subjects affects the performances of the task: a high education corresponds to a high number of correct target and to a reduction in execution time.

Regarding the "general" neuropsychological tests, it is noted that the number of targets of the RMT correlates with the MMSE, with the TMT-A and B and the TOL, while the execution time covariate only with the Rey Test and the ToL.

Table 4.3.8 - Relationships between the Road Map Test and neuropsychological tests.

	MMSE	Flu.Verb.	REY	TMTA	TMTB	REY Differ.	ToL
RM Target	1	0	1	1	1	0	1
RM Time	0	0	1	0	0	0	1

Regarding "spatial" tests, the variable "target" increases itself with the scores of the Benton Test, of the Corsi Supraspan Test and of the Manikin's Test, but the times don't correlate with all these, except that with the Corsi Supraspan Test. It isn't found any relationship between both target both times and the Corsi Test (vgs Appendix F).

Table 5.3.9 - Relationships between the Road Map Test and "spatial" neuropsychological tests.

	Benton	CORSI	SUPRAspan	Manikin
RM Target	1	0	1	1
RM Time	0	0	1	1

4.4 Results of virtual reality tests

This paragraph represents the central theme of the research work, as it includes the analysis regarding the experimental tests carried out with virtual reality programs to test spatial orientation abilities.

At the beginning of the session subjects were asked if they had familiarity with video games, to know whether the computer approach to perform the tests would be easier thanks to previous computer experiences.

From the responses, it was found that only 14% of the sample use electronic games, while the remaining 86% doesn't use this kind of equipment. In particular, it was found that the subjects that use video games are especially those aged under 50 years (11/14), while only one case within people over 60 said he plays with electronic software.

Table 4.4.1 - Contingency table regarding the use of video games and related ages.

		Age group					Total
		30-40	41-50	51-60	61-70	71-81	
Videogames	NO	11	18	18	19	20	86
	SI	9	2	2	1	0	14
Total		20	20	20	20	20	100

Another preliminary data regards the fluidity, that is the manual ability with which the subjects use the four directional arrows on the keyboard to move around in the virtual environment. Most experts use three fingers, while those who are not familiar with videogames use only one finger. Consistent with these behaviors it was assigned a value 3,2,1 to the fluidity. In particular, it was noted that 73% of subjects use only one finger to move arrows, 14% two fingers, and only 13% three fingers.

The gender of subjects is not relevant on the fluidity (chi sq = 3.08 p. 0.214)[5], while there is a bivariate relationship between fluidity and age, as increasing age, the level of fluidity decreases (Spearman r = - 0.605 p. 0,000)[6].

[5] Chi-square is a measure of connection that assesses the relationship between two categorical variables. The value ranges between 0 and a maximum number that depends on the degrees of freedom of the contingency table.

[6] Spearman r is an concordance's index that measures the relationship between two ordinal variables. The value ranges between -1 and + 1 and indicates the direction and the strength of the relationship

Table 4.4.2 Age divided into 5 groups by Fluidity.

			FLUIDITY			Total
			1	2	3	
Aging groups	30-40	Count	5	7	8	20
		Expected Count	14,6	2,8	2,6	20
	41-50	Count	11	5	4	20
		Expected Count	14,6	2,8	2,6	20
	51-60	Count	18	1	1	20
		Expected Count	14,6	2,8	2,6	20
	61-70	Count	19	1	0	20
		Expected Count	14,6	2,8	2,6	20
	71-81	Count	20	0	0	20
		Expected Count	14,6	2,8	2,6	20
Total		Count	73	14	13	100

4.4.1 Results of the VR Maze Learning Test

At the end of each "paper and pencil" maze the subject was submitted to the same test in virtual mode (subsequently, the mazes will be indicated with VR - Virtual Reality – followed by the number of reference: "training", 1, 2, 3, 4 and 5).

The following table shows the data on the six mazes. In the first line, the number of cases that have done the test could be read. The "missing" are referred to subjects that didn't complete the task to fatigue or a feeling of confusion. The third line shows the sum of cases that have passed each maze.

Table 4.4.3 - Amount of mazes that are successfully completed.

Statistics

		VRTRFATT	VR1FATTO	VR2FATTO	VR3FATTO	VR4FATTO	VR5FATT
N	Valid	100	98	98	95	95	96
	Missing	0	2	2	5	5	4
Sum		47	60	65	36	44	44

Compared to "paper and pencil" tests, virtual tasks have not been passed by all the subjects. Indeed, on average about 50% of cases have completed the tests.

To assess the efficiency of each subject to the VR MLT an “efficiency index” was made that is constructed from the sum of the number of tests successfully completed. The index ranges from 0 to 5, with mean 2.96 and ds 2.49 .

From the intersection between the efficiency index and the socio-demographic characteristics of the sample, it appeared that the gender has no effect on the successful of the task, while this seems to be significantly influenced by the chronological age of subjects (r = - 0.706 p. 0.000).

Table 4.4.4 - Table of contingency between age and efficiency index

Aging groups * Effective Index Crosstabulation

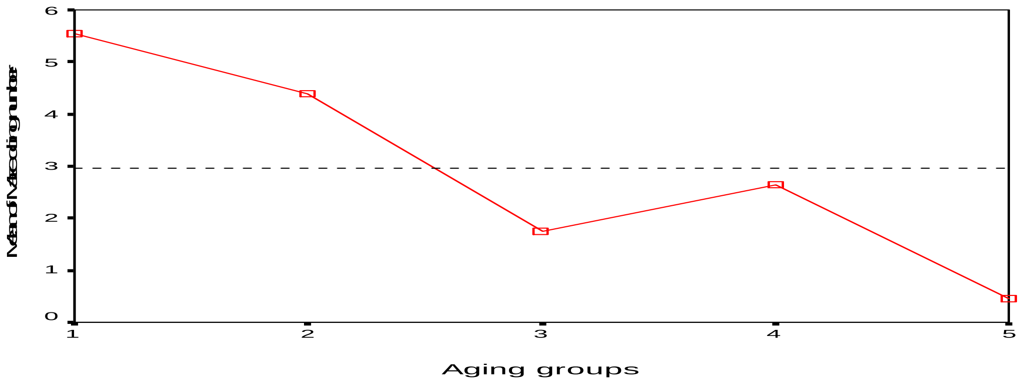
			Effective Index						Total
			0	1	2	3	4	5	
Aging groups	1	Count	1	0	0	0	3	16	20
		Expected Count	5,7	1,5	2,9	,6	3,2	6,1	20,0
	2	Count	1	1	3	1	7	7	20
		Expected Count	5,7	1,5	2,9	,6	3,2	6,1	20,0
	3	Count	9	2	5	1	1	2	20
		Expected Count	5,7	1,5	2,9	,6	3,2	6,1	20,0
	4	Count	4	3	5	1	4	3	20
		Expected Count	5,7	1,5	2,9	,6	3,2	6,1	20,0
	5	Count	12	1	1	0	0	1	15
		Expected Count	4,3	1,1	2,2	,5	2,4	4,6	15,0
Total		Count	27	7	14	3	15	29	95
		Expected Count	27,0	7,0	14,0	3,0	15,0	29,0	95,0

If there was no a relationship between this two variables, the observed frequencies and those expected should coincide, but as it could be seen in the table these values differ significantly, and this gives evidence of a relationship between the two conditions.

Even the Gamma[7] statistic, that is applied at the above table of contingency, indicates a significant negative relationship between age and efficiency index (value G = - 0.645 with p. 0.000). The graph 5.4.1 shows averages of the index for each age group.

[7] Gamma is a concordance index that evaluates the relationship between two ordinal variables. The value ranges between -1 and +1, according to the strength and the direction of the relationship.

Graph 4.4.1



As it can be seen, the subjects below 50 years old passed on average all the five tests, while the group "over 60" completed only one maze within the five ones presented.

Even the education plays a major role on performances of VR tests. Those who have an higher degree of education have also obtained greater levels of efficiency (r = 0.451 p. 0.000).

Table 4.4.5 Statistics of the values of the efficiency index related to education

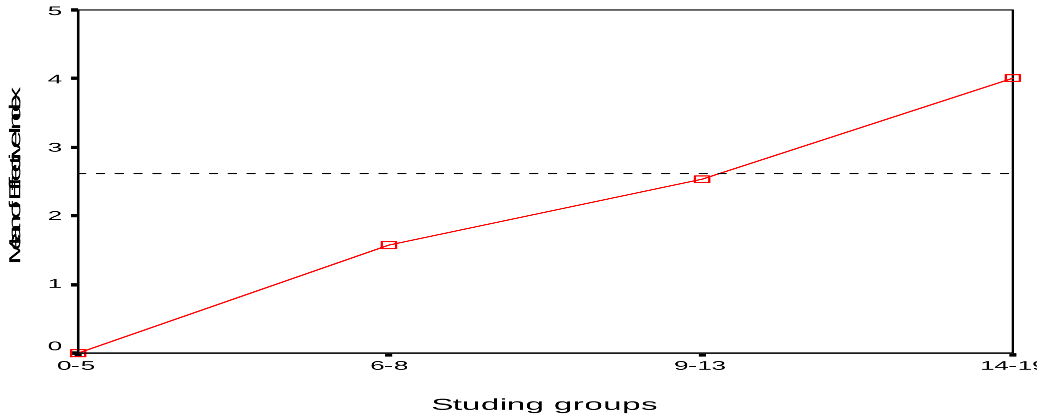
Descriptives

Effective Index

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
0-5	2	,00	,00	,00	,00	,00	0	0
6-8	21	1,57	1,83	,40	,74	2,41	0	5
9-13	49	2,53	1,95	,28	1,97	3,09	0	5
14-19	23	4,00	1,81	,38	3,22	4,78	0	5
Total	95	2,62	2,07	,21	2,20	3,04	0	5

The relationship is reported in the graph 4.4.2, where it can be clearly seen that the bands of higher education receive scores above the average of the sample.

Graph 4.4.2



The regression analysis is then applied on "age" and "education" independent variables in relation to the efficiency index and it was noted that the two demographic conditions, together, explain for almost 50% of the efficiency for virtual testing (R^2 = 0.480 p. 0.000). This also means that, starting from a value of age and education, the efficiency index achievable by a certain subject can be predicted with a probability of 48%.

Table 4.4.6 - Regression analysis for age and education with the efficiency index.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,692[a]	,480	,468	1,51	,480	42,385	2	92	,000

a. Predictors: (Constant), SCOLARIT, ETA

b. Dependent Variable: Effective Index

For the success of these tests it is also important the degree of confidence that subjects have with interactive games. For example, people who have good fingers fluidity with the arrows on the keyboard, they generally obtain efficiency values greater than those who are not familiar with these technologies (r = 0.522 p. 0.000).

Then it was analyzed the efficiency index with neuropsychological tests and it was observed that it correlates with most of them.

It was found that this index is correlated with the MMSE, with the two Rey Tests, with the TMT-A and B and with the Tower of London, but it doesn't correlate with the Verbal Fluency Test.

Table 4.4.7 - Relationships between the efficiency index and "general" neuropsychological tests.

	MMSE	VERB.FL.	REY	TMTA	TMTB	REYDEFFE	Tower L.
Effective Index	1	0	1	1	1	1	1

Among "spatial" tests, the efficiency index correlates with the Benton test, with the Supraspan and with the Manikin's Test, but in this case, no significance was found with the Corsi Test.

Table 4.4.8 – Relationships between the efficiency index and "spatial" neuropsychological tests.

	Benton	Corsi Span	Supraspan	Manikin's Test
Effective Index	1	0	1	1

Tables of correlations with the statistical and significance indicators are listed in Appendix G - Table 3.G.

To simplify the results, the labyrinths were grouped on the basis of the level of difficulty: the first and the second maze (VR1 and VR2) and the remaining three (VR3, VR4 and VR5) and it is given the value "0" if the subject didn't resolved at least two mazes for each group and the value "1" if at least two mazes were completed.

It was found that 57 subjects completed the VR1 and VR2 mazes, while fewer subjects (44) completed the last three mazes, reflecting the fact that the first two are actually less complex than the other three mazes.

Regarding the execution time, it is noted that the maze that required the most time is the third maze (VR3), while the easiest was the first one. It is also noted that the third maze was the only one that obtained fewer successes, it is certainly more complex than the others because it requires the subject a change of strategy to cope with its greatest extent.

Table 4.4.9 – Execution time of VR mazes.

Statistics

		VR1	VR2	VR3	VR4	VR5
N	Valid	60	65	36	44	44
	Missing	40	35	64	56	56
Mean		289,43	307,05	411,89	372,93	350,66
Median		224,00	263,00	419,00	376,00	333,50
Std. Deviation		169,78	151,94	141,96	131,72	157,86
Minimum		65	80	141	146	105
Maximum		652	599	599	599	599

The gender doesn't mean differences, while age is correlated to performances. But this correlation doesn't be present with all the mazes, infact any significant value was found with the labyrinth VR3 (p.> 0.05)).

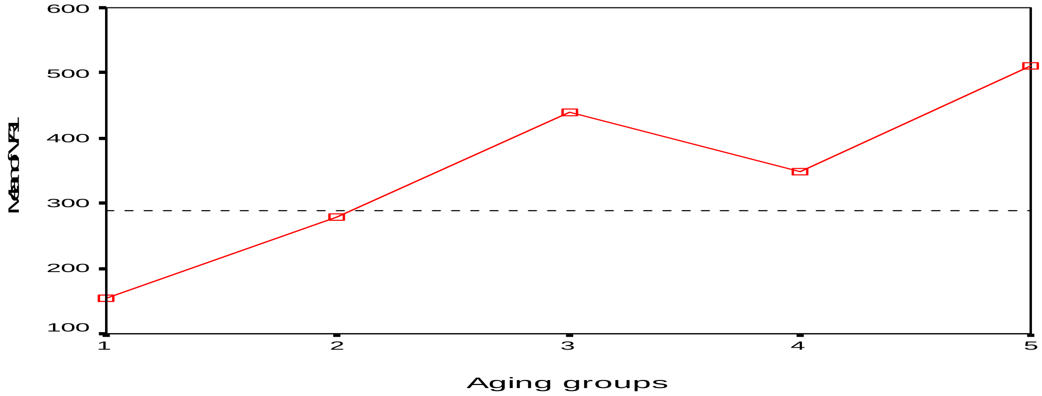
Table 4.4.10 - ANOVA between age groups and execution time of 5 mazes.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
VR1	Between Groups	736387,1	4	184096,766	10,499	,000
	Within Groups	964383,7	55	17534,249		
	Total	1700771	59			
VR2	Between Groups	508875,3	4	127218,831	7,881	,000
	Within Groups	968531,5	60	16142,192		
	Total	1477407	64			
VR3	Between Groups	61838,202	4	15459,550	,745	,569
	Within Groups	643485,4	31	20757,592		
	Total	705323,6	35			
VR4	Between Groups	176168,3	4	44042,081	3,014	,029
	Within Groups	569880,5	39	14612,320		
	Total	746048,8	43			
VR5	Between Groups	337036,4	4	84259,094	4,474	,005
	Within Groups	734483,5	39	18832,911		
	Total	1071520	43			

The graph 4.4.3 shows the averages of the time taken by subjects to perform the five virtual tasks, differentiated by age groups.

Graph 4.4.3



Compared to the neuropsychological tests, the speed of execution correlates differently according to the labyrinth examined. For example, the VR1 and the VR2 are correlate significantly with the MMSE, with the Rey Deferred Test and the Tower of London; the VR3 correlates with the Verbal Fluency Test and the TMT-A; the VR4 correlates only with the TMT-A and the VR5 correlates with the MMSE, with the Verbal Fluency Test and with the TMT-A.

Table 4.4.11 - Relationships between the 5 mazes and neuropsychological tests

	MMSE	Verbal Fl.	REY	TMT-A	TMT-B	REY Diff.	T of London
VR1	1	0	0	0	0	1	1
VR2	1	0	0	0	0	1	1
VR3	0	1	0	1	0	0	0
VR4	0	0	0	1	0	0	0
VR5	1	1	0	1	0	0	0

The “spatial” neuropsychological tests are correlated alternately with virtual reality tests.

Table 4.4.12 - Relationships between the 5 mazes and “spatial” neuropsychological tests

	Benton	Corsi	Supraspan	MANIKIN
VR1	1	0	1	1
VR2	1	0	1	1
VR3	1	0	0	0
VR4	0	0	0	0
VR5	0	0	0	1

The first two mazes correlate with the Benton Test, with the Supraspan Test and with the Manikin's Test, while the other three mazes correlate with the Benton Test (the VR3) and with the Manikin's Test (the VR5).

4.4.2 Results of the VR Road Map Test

The VR Road Map Test was administered at the end of the five Maze Learning Test, and after making the "classic" Road Map Test.

The virtual test, as the "paper and pencil" one, offers a path consisting on 32 turning points within a town reproduction. The subject has to follow the path by moving with the four directional arrows within the virtual environment, indicating the number of targets and the turning direction (right or left) aloud.

The time available to perform the test was ten minutes, after which the test was interrupted. 80 subjects have completed the test, one was able to reach the 32 ° target in less than 600 seconds and 19 were withdrawn before the time, because of fatigue or mental confusion.

Table 4.4.13 – Statistics of the VR Road Map Test based on target and time.

Statistics

		RMTARGET	RMTIME
N	Valid	99	100
	Missing	1	0
Mean		12,06	541,96
Median		10,00	600,00
Std. Deviation		7,73	132,24
Minimum		2	0
Maximum		32	699

Compared to the number of targets achieved, it is noted that on average 12 correct turns were conducted, with DS 7.7. The minimum number of correct turns is 2 and the maximum one is 32.

It was found that males have identified more targets than females within the path (14.16 against 9.92), the opposite result than the CM version where the number of targets reported correctly was not significant if compared with gender.

Even with age, it is noted that the increasing of seniority decreases the accuracy of the test. subjects with less than 40 years old have reached an average of 20 targets, while the over seventy had an average of 5.85 targets (p. 0.000).

Table 4.4.14 - Statistics of the VR Road Map Test based on age.

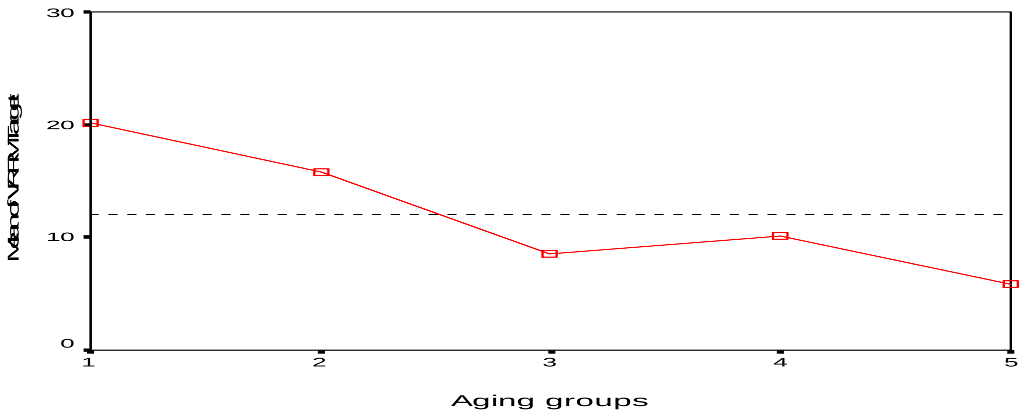
Descriptives

RMTARGET

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	20	20,15	7,99	1,79	16,41	23,89	5	32
2	19	15,84	6,91	1,58	12,51	19,17	4	32
3	20	8,55	4,77	1,07	6,32	10,78	4	26
4	20	10,10	5,11	1,14	7,71	12,49	5	27
5	20	5,85	3,13	,70	4,38	7,32	2	14
Total	99	12,06	7,73	,78	10,52	13,60	2	32

As noted in the graph 4.4.4, over the years the length of the correct path and thus the number of targets achieved reduced.

Graph 4.4.4



Similarly, the education of the subjects affects the task performance: an high schooling corresponds to a high number of correct targets (P.0, 015), as can be seen from the table and the graph below.

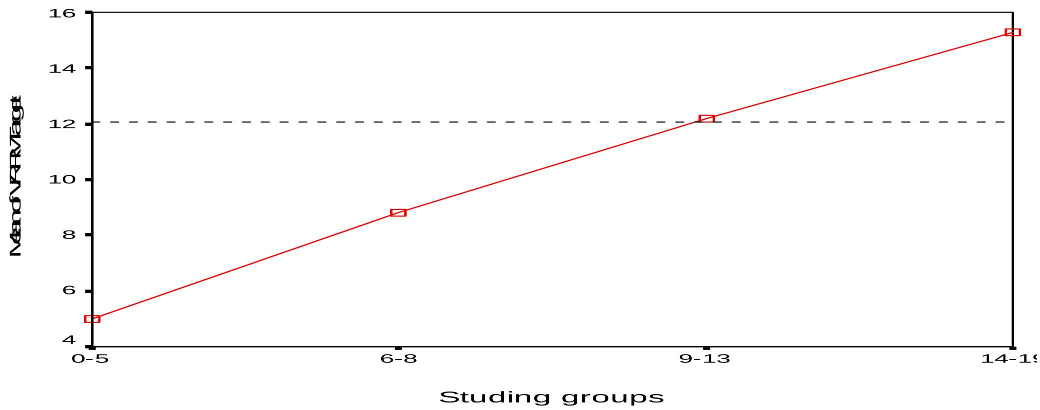
Table 4.4.15 – Statistics of the VR Road Map Test based on education.

Descriptives

RMTARGET

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
0-5	2	5,00	,00	,00	5,00	5,00	5	5
6-8	23	8,83	6,12	1,28	6,18	11,47	3	31
9-13	48	12,17	6,80	,98	10,19	14,14	4	32
14-19	26	15,27	9,50	1,86	11,43	19,11	2	32
Total	99	12,06	7,73	,78	10,52	13,60	2	32

Graph 4.4.5



Regarding "general" neuropsychological tests, it is noted that the number of targets of the RMT correlates with the MMSE, with the TMT-A and version B and the TOL, while the execution time covariate only with the Rey Test and the Tol.

Table 4.4.16 - Relationships between the VR Road Map test and neuropsychological tests.

	MMSE	Verb.Fl.	REY	TMTA	TMTB	REY Deffer.	ToL
VR RM Targ	1	1	1	1	1	1	1

Regarding the "spatial" tests, the "target" variable increases along with the points of the Benton Test, with the Supraspan Course Test and with the Manikin's Test, while no relation was found with the Corsi Test (Appendix H).

Table 4.4.17 - Relationships between the VR Road Map Test and "spatial" neuropsychological tests.

	Benton	CORSI	SUPRAspan	MANIKIN
RM Target	1	0	1	1

Considerations on the findings regarding this chapter and the research will be objects of a qualitative analysis in the next chapter.

Chapter 5

Discussion and conclusion

This study wanted to test a new approach to the evaluation of spatial disorientation, using virtual reality programs that offer a point of observation located within the environment, with an egocentric perspective in a route mode, unlike traditional tasks based on an allocentric perspective, in a survey mode, with representation of environments seen from above.

Within the literature regarding this argument there are a large number of publications that offer an allocentric perspective for the study of spatial abilities, while studies conducted with a route mode are almost absent. The limit of the first type of assessment tools is the difficulty of providing a measure of the subjects' orientation ability within everyday environments, ecological ones, within which the subject experiences an allocentric perspective rather than an egocentric one.

This work instead proposes spatial orientation tasks with an egocentric approach, in which subjects are able to experience the motion within a non-immersive virtual space that is characterized by perceptual references that are likely the real environments. VR tasks shows a greater difficulty in resolving the task if compared to "paper and pencil" tests.

These different degrees of difficulty could be attributed to both the tasks' types, where the route perspective requires a greater commitment of subjects in orienting themselves by taking short stretches rather than the survey perspective that allows an overall view of the map. It is noted, however, that the exposure to the virtual MLT results in a learning of spatial nature, because the two labyrinths VR2 and VR5, that are similar to previous VR1 and VR4, are executed more easily by the subjects. This could be attributed to the learning of spatial characteristics that the tested subjects experienced during previous tasks.

Another key point of this research relates to the detection of spatial orientation abilities according to the subjects' age. The working assumption was that with aging the subjects were less skilled in orientation tasks. In fact, it was found that cohorts show a significant drop in performance as we proceed from younger to older. In reference to what is reported in the literature, the experimental work has pointed out the levels of decay based on the subjects' age.

The analysis also wonders if this decline in performance is due to less ability of elderly people with electronic devices or is perhaps due to other factors. To test the impact of the medium, datas on the five cohorts have been examined and the age ranges have been divided into two groups: "under 50" and "over 50". Assuming that expert subjects in x virtual tasks use multiple fingers to move with the arrow keys inside the virtual environment, subjects have also been separated between those who use only one finger to move the arrows from those who instead use 2 -3 fingers.

As a result it is found that just 16 subjects among 40 of the "under 50" use only one finger, while are 57 among 60 the subjects of the "over 50" (there aren't subjects with motor deficit). These datas clearly argue for a lesser ability of older people to use the technological medium. This could affect performances in virtual tasks and then alter the results that could not be due to cognitive performances but that could be influenced by familiarity with the computer use. However, from the results of analysis carried out within the age groups "under 50", it is showed that there are no significant differences in performances in virtual tasks between subjects with different levels of skills, that is the number of fingers used to move within the virtual environment. From this, it could be inferred that it isn't the ease to use computers to determine higher or lower performances in virtual tasks, but other aspects of purely cognitive nature.

From the analysis, however, it is confirmed the performance difference between the subjects "under" and "over" 50.

The administration of virtual reality tests (the MLT and the RMT) involved differences in the attitude of the subjects. The younger individuals, under the age of 50 years old, confronted themselves with the task through an attitude of challenge and commitment. They ventured into tasks and they referred amusement during the execution.

Instead, most of those over 50 years old commented on the performance saying that the task was difficult and that they wouldn't have been able to complete it.

Whatever is the importance of these attitudes of mistrust regarding the use of virtual technologies we do not know, but it would certainly be worth investigated.

5.1 Considerations on sampling procedures

The type of sample selection is defined as "intentional sampling" (Boncori, 1993). This procedure, that isn't randomized, is also called " of convenience" and it is used when the selection of a random sample from the reference population, that has to be surveyed, it's difficult .

This procedure has advantages and disadvantages. The benefit is the easy access to a large number of subjects in a relatively short time. However, there are negative elements that affect the results of data analysis. First, as it has been possible to reach a large number of subjects, we cannot conclude that the sample is representative of the general population: we do not know what are the characteristics of the individuals of other aggregation Centers and of those people who didn't want to participate in the investigation or who were not present during the recruitment procedures. It is therefore likely that the sample's profile is distorted due to errors of: accessibility (some subjects have become available and others not), absence of answer (the subjects of a certain type have refused to participate), self-selection (the subjects were voluntary and so many subjects with certain characteristics may have participated rather than others), visibility (some were more easily accessible than others).

Although the intentional sampling has then rendered possible to reach a large number of subjects in a short time, it has all the disadvantages that a non-probability sampling involves. Ercolani (1997) warns that this type of sampling could lead to errors for estimating parameters, such as the mean of the distribution. The consequence is that the values for the confidence levels affects the statistical validity, since they include units-sample that could over-represent or under-represent the kind of subject interviewed referred to the whole population.

The different problems on the sample selection, however, don't invalidate the research datas, which are indicative of the existence of the phenomena under investigation, they only have to be interpreted with caution when making inferences on the population.

5.2 Considerations on neuropsychological tests

Another item of discussion regards neuropsychological profiles of the sample. Spatial orientation abilities have been investigated with “paper and pencil” and “virtual reality” tests, correlating them with neuropsychological tests that evaluate the attentional, perceptual and memory skills involved in navigation, and more specific tests of spatial orientation such as the Benton Test, the Corsi Test (Spatial Span and Supraspan) and the Manikin’s Test.

The results of these analysis show that neuropsychological tests correlate moderately with each other. However, given that the tests used detect different cognitive abilities, the modest correlation between them argues in favour of a convergence of tasks to those who are the attentional, perceptual and memory constructs within the “general” abilities and the constructs of learning and spatial memory, of orientation’s recognition of lines and the construct of discrimination right-left within spatial abilities.

The aim is to underline the criticality of correlations, between the first test a certain “weakness” could be observed in validity of the TMT-B and the Rey Deferred Test compared with other tests, as well as the Corsi Span Test didn’t correlate with any of the other spatial tasks. Excluding these three tests, the others show significant correlations between each other.

In particular, with regard to the “paper and pencil” tests of spatial orientation (the Maze Learning Test, MLT) it is noted that two of these tasks (CM2 and CM4) are statistically not significant, because they are very similar to their former ones, and therefore they are less discriminative. This result can be attributed to the acquisition of knowledge by the subjects. Similar tests gave almost identical results since subjects had previously learned the characteristics of the task.

The classic tests correlated with almost all tests (except with the Verbal Fluency Test for categories and with Corsi Span Test). The Road Map Test was correlated with all tests, except the Rey Auditory Learning Test - Deferred and the Corsi Span Test.

The results of the “virtual” tests are different from the results of traditional ones. The data related to virtual mazes are much less correlated with general and spatial cognitive ability tests. In fact, only the first two mazes (VR1 and VR2) were correlated with three of the seven general tests (the MMSE, the Rey Deferred Test and the Tower of London), while the other three mazes (VR3, VR4 and VR5) were correlated only with the TMT-A and with the Verbal Fluency Test .

Compared to spatial tests, the first two virtual tasks were correlated with almost all tests (except the Corsi Span Test), while the remaining three tasks were correlated with three of four tests.

In general, regarding the 55 tasks of the VR Maze Learning Test, only 26 of these were correlated, approximately 50% of the tests. The VR Road Map test correlated with almost all tests, except for the Corsi Span Test.

These conditions may be determined by the greater difficulty of virtual tests, a fact that argues in favour of a greater discrimination of these abilities compared to “paper and pencil” tests which seem to be easier to execute. It could be, however, that neuropsychological and “virtual” tests do not assess the same abilities, it would be desirable to redraw the map of abilities and tools to analyze.

Another important question concerns the attitude of the subjects during virtual reality tasks, which will be discussed in the next section.

5.3 Conclusions

The experimental research has found useful information regarding the issues under investigation. The use of virtual reality tasks represented a discriminating methodology for assessing spatial orientation compared to the classical “paper and pencil” tests. It was found that the situation proposed by the computer, compared to the survey perspective proposed on paper, represents an approach more similar to the way through which subjects orient themselves in daily real environments.

In fact, when a subject moves in space, implements a number of complex strategies that involve different cognitive functions, while performing paper tasks requires the limited involvement of planning abilities. For this reason, virtual reality tasks would be more difficult than “paper and pencil” tests, because they are tasks that require more involvement from the cognitive point of view. To support these considerations the perspective of the “activation theory” shows that in order to perform a complex cognitive task, such as that proposed in virtual reality compared to “paper and pencil” test, more cognitive functions are involved. These functions alone are not sufficient to determine the orientation, but they must be integrated and combined into a single “sovracognitive” framework. This condition allows to aggregate and use the different components of perception, memory and movement that are useful for navigation. When these functions are efficient and undamaged, it is possible to plan the route, to pay attention to environmental features and to recall landmarks that are necessary for orientation, as well as to implement the motor patterns for achieving targets for the advancement within the path. In this perspective, the decay in topographical orientation tasks may be due, in addition to the decline of individual skills, to the deterioration of the ability to integrate all the cognitive components involved.

In order to test this complex system of navigation, made up of single activities and of cognitive integration system, subjects need to use tools that allow to retrieve the activation of all components of the system. A subject orients himself within real environments only when uses the tools that reproduce as much as possible the conditions that are present. For this reason, the experience in virtual reality, though it is not equal to the real one, represents the best compromise to present these environments and proper to enable the multitude of cognitive functions involved in human navigation. That’s because the tools used in this research make it possible to activate and detect the functioning of cognitive areas that are not detectable through classical “paper and pencil” tests.

Besides, if it is true that over the years it is showed a decline of cognitive functions, the complexity of the interactive tasks proposed during the research has made it clear that the elderly subjects expected to have found it harder to carry out the tests. The younger ones took less time and were more effective, while the majority of elderly subjects failed even to complete the task. In contrast, in traditional tasks all the subjects have performed the tests and there was only a variation in the execution time depending on age. The elderly subjects were slower in tracing the path on the maze compared to younger people. Moreover, it was found that subjects under 50 years have carried out the tests with the same execution time taken by the elderly ones. That fact has not been verified by VR tasks, where it was found that after the age of fifty years old one subject on two failed to complete the task, distinguishing clearly between the performance of the cohorts according to age and schooling.

Another interesting fact revealed by the use of interactive tools offered by the computerized medium, which reduce the suspicion/suspect that it was mainly the impact of computer technology to make trouble for the elderly people, regards the results of the analysis of data obtained from subjects of cohorts "Under 50". The levels of confidence with computer tools are heterogeneous: someone has a good familiarity with the computer use while other people are quite unrelated to this type of technology. This situation permitted to detect performance in virtual tests and to understand if the ability of use it was discriminatory for the results obtained. It was noted that the result of test didn't correlate with different levels of the use of computers' ability. Hence, if the implementation difficulty was due only to the computerized medium, we would expect that the more experienced subjects would better perform virtual tasks, but this doesn't occur. Contrarily to what was expected and to what would have been legitimated to guess, it seems that familiarity with technology does not influence the results, since the greater possible ability to discriminate results of virtual tests compared to "paper and pencil" ones, due to greater cognitive complexity of the task.

However, although initially the use of technology seemed to be an interference variable, due to the fact that elderly people today have little familiarity with computer technologies, the data analisys have shown that this factor hasn't got an important role and it would not involve a greater interaction difficulty with computerized tests. However, this doubt about the role of interaction difficulty will be resolved with the passing of years, because the elderly people of tomorrow will be technologically advantaged and similar tests will provide results based on the actual degree of skills in the topographical orientation, so reducing the effect due to the medium used.

Even if interesting, however, for the purposes of this research it would be impractical to wait for the aging population to test the skills with the use of virtual reality tools. One possible solution, with a programmatic perspective of research, would be to extend the period of training of subjects "over 50", giving them the possibility to have not a session of ten minutes of practice, but two or three preparatory meetings to familiarize them with the use of computer and therefore benefit them from the technological point of view. This would minimize the difficulties of interacting with the machine and it would make possible a comparison between subjects of different ages based on the actual ability to orient themselves.

At the end of this study, therefore, it is reasonable to conclude that it is the cognitive decline to lead to a worse performance the elderly cohorts, rather than the difficulties associated with the use of information technology and that the use of virtual reality would remain a valuable method to completely investigate the complex system of skills that combine to determine the human navigation.

Moreover, the development of virtual technologies, always keeping in mind a programmatic perspective, would have possible clinical implications both in the stimulation of the skills involved in the orientation and in the delay of cognitive deterioration in both neurocognitive rehabilitation area for people who have suffered neurological damages and that compromised navigation functions.

The use of virtual technology, with the inclusion of elements that are similar to “reality” in tasks of stimulation and rehabilitation, would make the clinical work closer to the actual activities involved in navigational procedures.

The use of virtual reality, however would not replace “paper and pencil” tests, standardized and effectively used in clinical practice, but it supports them to detect issues and stimulate functions that traditional tests actually do not use.

Appendix A

– CM Maze Learning Test

Appendix B

– Road Map Test

Appendix C

– Neuropsychological Test

Table 1.C – Neuropsychological tests for 5 aging-groups

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Verbal Fl.	**1**	20	24,35	5,20	1,16	21,91	26,79	16	39
	2	20	23,80	4,56	1,02	21,67	25,93	16	35
	3	20	22,50	5,65	1,26	19,85	25,15	14	36
	4	20	21,60	5,27	1,18	19,14	24,06	12	31
	5	20	20,45	4,22	0,94	18,47	22,43	13	28
	Total	100	22,54	5,11	0,51	21,53	23,55	12	39
REY	**1**	20	10,51	0,93	0,21	10,07	10,95	9	12
	2	20	10,23	1,04	0,23	9,74	10,72	7	12
	3	20	9,65	1,68	0,38	8,86	10,43	7	13
	4	20	9,25	1,88	0,42	8,37	10,13	6	13
	5	20	8,27	1,72	0,38	7,47	9,07	5	13
	Total	100	9,58	1,67	0,17	9,25	9,91	5	13
TMT-A	**1**	20	28,25	4,01	0,90	26,37	30,13	22	38
	2	20	31,10	5,42	1,21	28,56	33,64	22	45
	3	20	33,15	9,66	2,16	28,63	37,67	19	54
	4	20	32,85	8,84	1,98	28,71	36,99	23	57
	5	20	40,05	8,98	2,01	35,85	44,25	30	67
	Total	100	**33,08**	8,51	0,85	31,39	34,77	19	67
TMT-B	**1**	19	65,84	9,40	2,16	61,31	70,37	48	82
	2	20	59,85	10,43	2,33	54,97	64,73	44	78
	3	19	71,21	28,41	6,52	57,52	84,90	36	154
	4	19	67,21	30,20	6,93	52,65	81,77	44	160
	5	18	79,78	18,56	4,38	70,55	89,01	50	112
	Total	95	68,57	21,77	2,23	64,13	73,00	36	160
REY Deffer.	**1**	20	12,75	1,48	0,33	12,06	13,44	8	15
	2	20	11,60	1,43	0,32	10,93	12,27	8	13
	3	20	11,00	2,43	0,54	9,86	12,14	7	15
	4	20	10,60	2,84	0,63	9,27	11,93	5	15
	5	20	9,60	3,36	0,75	8,03	11,17	4	15
	Total	100	**11,11**	2,60	0,26	10,59	11,63	4	15
Tower of L.	**1**	20	34,20	1,79	0,40	33,36	35,04	30	36
	2	20	34,75	1,94	0,43	33,84	35,66	28	36
	3	20	31,75	3,08	0,69	30,31	33,19	24	36
	4	20	32,65	2,62	0,59	31,42	33,88	28	36
	5	20	30,40	4,12	0,92	28,47	32,33	20	36
	Total	100	**32,75**	3,21	0,32	32,11	33,39	20	36

Table 2.C – ANOVA: neuropsychological tests for 5 aging groups

ANOVA						
		Sum of Squares	Df	Mean Square	F	Sig.
Verbal Fluency	Between Groups	202,34	4,00	50,59	2,02	0,10
	Within Groups	2382,50	95,00	25,08		
	Total	2584,84	99,00			
REY	Between Groups	62,38	4,00	15,60	6,90	0,00
	Within Groups	214,64	95,00	2,26		
	Total	277,03	99,00			
TMT-A	Between Groups	1517,76	4,00	379,44	6,37	0,00
	Within Groups	5655,60	95,00	59,53		
	Total	7173,36	99,00			
TMT-B	Between Groups	4090,80	4,00	1022,70	2,27	0,07
	Within Groups	40464,50	90,00	449,61		
	Total	44555,31	94,00			
REY Differ.	Between Groups	109,64	4,00	27,41	4,65	0,00
	Within Groups	560,15	95,00	5,90		
	Total	669,79	99,00			
Tower of London	Between Groups	252,70	4,00	63,18	7,83	0,00
	Within Groups	766,05	95,00	8,06		
	Total	1018,75	99,00			

Table 3.C – Neuropsychological tests for gender

Descriptives									
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Verbal fl.	maschi	50	21,90	5,38	0,76	20,37	23,43	12	39
	femmine	50	23,18	4,80	0,68	21,82	24,54	14	36
	Total	100	22,54	5,11	0,51	21,53	23,55	12	39
Benton	maschi	50	28,84	2,10	0,30	28,24	29,44	18	30
	femmine	50	28,58	1,75	0,25	28,08	29,08	22	30
	Total	100	28,71	1,93	0,19	28,33	29,09	18	30
REY	maschi	50	9,11	1,84	0,26	8,59	9,63	5	12
	femmine	50	10,05	1,35	0,19	9,67	10,44	7	13
	Total	100	9,58	1,67	0,17	9,25	9,91	5	13
TMT-A	maschi	50	34,32	8,01	1,13	32,04	36,60	19	57
	femmine	50	31,84	8,89	1,26	29,31	34,37	20	67
	Total	100	33,08	8,51	0,85	31,39	34,77	19	67
TMT-B	maschi	47	71,47	25,86	3,77	63,88	79,06	44	160
	femmine	48	65,73	16,64	2,40	60,90	70,56	36	112
	Total	95	68,57	21,77	2,23	64,13	73,00	36	160
REY Differ.	maschi	50	10,42	2,78	0,39	9,63	11,21	4	15
	femmine	50	11,80	2,23	0,32	11,17	12,43	4	15
	Total	100	11,11	2,60	0,26	10,59	11,63	4	15
CORSISPA	maschi	50	5,73	1,44	0,20	5,32	6,14	5	15
	femmine	50	5,66	0,46	0,06	5,53	5,79	5	7
	Total	100	5,69	1,07	0,11	5,48	5,90	5	15
SUPRASPA	maschi	50	22,03	4,79	0,68	20,67	23,39	5	31
	femmine	50	23,25	4,60	0,65	21,94	24,56	14	31
	Total	100	22,64	4,71	0,47	21,71	23,58	5	31
MANIKIN	maschi	50	30,32	2,46	0,35	29,62	31,02	20	32
	femmine	50	30,44	2,06	0,29	29,85	31,03	24	32
	Total	100	30,38	2,26	0,23	29,93	30,83	20	32
Tower of L.	maschi	50	32,84	3,41	0,48	31,87	33,81	20	36
	femmine	50	32,66	3,03	0,43	31,80	33,52	24	36
	Total	100	32,75	3,21	0,32	32,11	33,39	20	36

Table 4.C – ANOVA: neuropsychological tests for gender

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Verbal fl.	Between Groups	40,96	1	40,96	1,58	0,21
	Within Groups	2543,88	98	25,96		
	Total	2584,84	99			
BENTON	Between Groups	1,69	1	1,69	0,45	0,50
	Within Groups	366,90	98	3,74		
	Total	368,59	99			
REY	Between Groups	22,15	1	22,15	8,52	0,00
	Within Groups	254,88	98	2,60		
	Total	277,03	99			
TMT-A	Between Groups	153,76	1	153,76	2,15	0,15
	Within Groups	7019,60	98	71,63		
	Total	7173,36	99			
TMT-B	Between Groups	782,12	1	782,12	1,66	0,20
	Within Groups	43773,18	93	470,68		
	Total	44555,31	94			
REY Differ.	Between Groups	47,61	1	47,61	7,50	0,01
	Within Groups	622,18	98	6,35		
	Total	669,79	99			
CORSISPA	Between Groups	0,11	1	0,11	0,10	0,76
	Within Groups	112,52	98	1,15		
	Total	112,63	99			
SUPRASPA	Between Groups	37,05	1	37,05	1,68	0,20
	Within Groups	2161,68	98	22,06		
	Total	2198,73	99			
MANIKIN	Between Groups	0,36	1	0,36	0,07	0,79
	Within Groups	505,20	98	5,16		
	Total	505,56	99			
Tower of L.	Between Groups	0,81	1	0,81	0,08	0,78
	Within Groups	1017,94	98	10,39		
	Total	1018,75	99			

Table 5.C – Neuropsychological tests correlations

Correlat.		SCHOOL	VERBAL F.	BENTON	REY	TMTA	TMTB	REYDiff.	CORSISPA	Supraspan	Manikin	Tower L.
SCHOOL	Pearson	1,00	0,14	0,22	0,32	-0,23	-0,11	0,41	0,05	-0,44	0,17	0,38
	Sig. (2-tail)		0,16	0,03	0,00	0,02	0,28	0,00	0,63	0,00	0,10	0,00
	N	100	100	100	100	100	95	100	100	100	100	100
VERBAL Fl	Pearson	0,14	1,00	0,03	0,34	-0,29	-0,23	0,21	-0,02	-0,17	0,12	0,10
	Sig. (2-tail)	0,16	,	0,76	0,00	0,00	0,02	0,03	0,88	0,10	0,24	0,31
	N	100	100	100	100	100	95	100	100	100	100	100
BENTON	Pearson	0,22	0,03	1,00	0,30	-0,28	-0,28	0,31	0,06	-0,36	0,35	0,38
	Sig. (2-tail)	0,03	0,76	,	0,00	0,01	0,01	0,00	0,56	0,00	0,00	0,00
	N	100	100	100	100	100	95	100	100	100	100	100
REY	Pearson	0,32	0,34	0,30	1,00	-0,41	-0,37	0,74	0,08	-0,33	0,36	0,44
	Sig. (2-tail)	0,00	0,00	0,00	,	0,00	0,00	0,00	0,41	0,00	0,00	0,00
	N	100	100	100	100	100	95	100	100	100	100	100
TMT-A	Pearson	-0,23	-0,29	-0,28	-0,41	1,00	0,66	-0,15	-0,21	0,25	-0,32	-0,24
	Sig. (2-tail)	0,02	0,00	0,01	0,00	,	0,00	0,14	0,04	0,01	0,00	0,02
	N	100	100	100	100	100	95	100	100	100	100	100
TMT-B	Pearson	-0,11	-0,23	-0,28	-0,37	0,66	1,00	-0,11	-0,16	0,15	-0,18	-0,31
	Sig. (2-tail)	0,28	0,02	0,01	0,00	0,00	,	0,27	0,12	0,15	0,08	0,00
	N	95	95	95	95	95	95	95	95	95	95	95
REYDiff.	Pearson	0,41	0,21	0,31	0,74	-0,15	-0,11	1,00	0,03	-0,30	0,38	0,38
	Sig. (2-tail)	0,00	0,03	0,00	0,00	0,14	0,27	,	0,80	0,00	0,00	0,00
	N	100	100	100	100	100	95	100	100	100	100	100
CORSISPA	Pearson	0,05	-0,02	0,06	0,08	-0,21	-0,16	0,03	1,00	-0,24	0,03	0,11
	Sig. (2-tail)	0,63	0,88	0,56	0,41	0,04	0,12	0,80	,	0,02	0,78	0,28
	N	100	100	100	100	100	95	100	100	100	100	100
SUPRASPA	Pearson	-0,44	-0,17	-0,36	-0,33	0,25	0,15	-0,30	-0,24	1,00	-0,46	-0,41
	Sig. (2-tail)	0,00	0,10	0,00	0,00	0,01	0,15	0,00	0,02	,	0,00	0,00
	N	100	100	100	100	100	95	100	100	100	100	100
MANIKIN	Pearson	0,17	0,12	0,35	0,36	-0,32	-0,18	0,38	0,03	-0,46	1,00	0,56
	Sig. (2-tail)	0,10	0,24	0,00	0,00	0,00	0,08	0,00	0,78	0,00	,	0,00
	N	100	100	100	100	100	95	100	100	100	100	100
Tower L.	Pearson	0,38	0,10	0,38	0,44	-0,24	-0,31	0,38	0,11	-0,41	0,56	1,00
	Sig. (2-tail)	0,00	0,31	0,00	0,00	0,02	0,00	0,00	0,28	0,00	0,00	,
	N	100	100	100	100	100	95	100	100	100	100	100
*	Correlation is significant at the 0.05 level (2-tailed).											
**	Correlation is significant at the 0.01 level (2-tailed).											

Appendix D

- “Paper and Pencil” Test

Table 1.D – ANOVA: “Maze Learning Test” for gender

Descriptives

						95% Confidence Interval for Mean			
		N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
CMTRAIN	maschi	50	73,20	62,38	8,82	55,47	90,93	14	316
	femmine	50	85,48	78,25	11,07	63,24	107,72	16	390
	Total	100	79,34	70,67	7,07	65,32	93,36	14	390
CM1	maschi	50	32,48	21,94	3,10	26,25	38,71	10	99
	femmine	50	31,96	26,14	3,70	24,53	39,39	10	154
	Total	100	32,22	24,01	2,40	27,46	36,98	10	154
CM2	maschi	50	32,78	21,74	3,07	26,60	38,96	11	127
	femmine	50	43,42	39,10	5,53	32,31	54,53	13	171
	Total	100	38,10	31,92	3,19	31,77	44,43	11	171
CM3	maschi	50	85,66	77,56	10,97	63,62	107,70	27	400
	femmine	48	89,88	64,52	9,31	71,14	108,61	27	325
	Total	98	87,72	71,14	7,19	73,46	101,99	27	400
CM4	maschi	50	68,32	53,29	7,54	53,18	83,46	20	280
	femmine	48	66,00	49,97	7,21	51,49	80,51	18	210
	Total	98	67,18	51,44	5,20	56,87	77,50	18	280
CM5	maschi	49	69,49	92,19	13,17	43,01	95,97	15	608
	femmine	49	62,55	42,60	6,09	50,31	74,79	23	212
	Total	98	66,02	71,53	7,23	51,68	80,36	15	608

<u>Table 2.D – ANOVA: "Maze Learning Test" for gender</u>

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
CMTRAIN	Between Groups	3769,960	1	3769,960	,753	,388
	Within Groups	490728,5	98	5007,433		
	Total	494498,4	99			
CM1	Between Groups	6,760	1	6,760	,012	,914
	Within Groups	57058,400	98	582,229		
	Total	57065,160	99			
CM2	Between Groups	2830,240	1	2830,240	2,828	,096
	Within Groups	98060,760	98	1000,620		
	Total	100891,0	99			
CM3	Between Groups	435,091	1	435,091	,085	,771
	Within Groups	490418,5	96	5108,526		
	Total	490853,6	97			
CM4	Between Groups	131,814	1	131,814	,049	,825
	Within Groups	256522,9	96	2672,113		
	Total	256654,7	97			
CM5	Between Groups	1179,592	1	1179,592	,229	,634
	Within Groups	495074,4	96	5157,025		
	Total	496254,0	97			

Table 3D - ANOVA: "Maze Learning Test" for 5 aging groups

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
CMTRAIN	1	20	57,85	80,70	18,05	20,08	95,62	19	390
	2	20	48,10	40,90	9,14	28,96	67,24	18	180
	3	20	73,85	57,11	12,77	47,12	100,58	14	226
	4	20	69,70	56,80	12,70	43,11	96,29	16	260
	5	20	147,20	69,73	15,59	114,57	179,83	67	316
	Total	100	79,34	70,67	7,07	65,32	93,36	14	390
CM1	1	20	19,80	11,62	2,60	14,36	25,24	10	59
	2	20	21,70	7,88	1,76	18,01	25,39	15	51
	3	20	30,45	12,87	2,88	24,43	36,47	16	63
	4	20	31,70	32,31	7,22	16,58	46,82	10	154
	5	20	57,45	25,38	5,68	45,57	69,33	20	99
	Total	100	32,22	24,01	2,40	27,46	36,98	10	154
CM2	1	20	29,10	11,54	2,58	23,70	34,50	15	63
	2	20	33,15	33,42	7,47	17,51	48,79	15	171
	3	20	35,20	21,78	4,87	25,01	45,39	12	103
	4	20	37,45	39,66	8,87	18,89	56,01	11	170
	5	20	55,60	39,62	8,86	37,06	74,14	22	170
	Total	100	38,10	31,92	3,19	31,77	44,43	11	171
CM3	1	20	64,70	57,09	12,77	37,98	91,42	27	273
	2	20	64,55	48,77	10,91	41,72	87,38	32	207
	3	20	90,80	88,32	19,75	49,46	132,14	32	400
	4	20	94,75	52,84	11,82	70,02	119,48	35	257
	5	18	127,83	87,77	20,69	84,18	171,48	45	325
	Total	98	87,72	71,14	7,19	73,46	101,99	27	400
CM4	1	20	50,30	39,86	8,91	31,64	68,96	26	210
	2	20	46,20	16,72	3,74	38,37	54,03	28	95
	3	20	67,30	49,86	11,15	43,96	90,64	18	212
	4	20	64,80	48,54	10,85	42,08	87,52	19	199
	5	18	111,78	68,06	16,04	77,93	145,62	42	280
	Total	98	67,18	51,44	5,20	56,87	77,50	18	280
CM5	1	20	39,50	25,32	5,66	27,65	51,35	15	134
	2	20	42,55	19,57	4,38	33,39	51,71	27	116
	3	20	86,05	128,56	28,75	25,88	146,22	19	608
	4	20	74,50	64,59	14,44	44,27	104,73	23	251
	5	18	89,89	47,71	11,25	66,16	113,62	36	212
	Total	98	66,02	71,53	7,23	51,68	80,36	15	608

Table 4.D - ANOVA: "Maze Learning Test" for 5 aging groups

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
CMTRAIN	Between Groups	123316,1	4	30829,035	7,890	,000
	Within Groups	371182,3	95	3907,182		
	Total	494498,4	99			
CM1	Between Groups	18097,660	4	4524,415	11,030	,000
	Within Groups	38967,500	95	410,184		
	Total	57065,160	99			
CM2	Between Groups	8411,700	4	2102,925	2,160	,079
	Within Groups	92479,300	95	973,466		
	Total	100891,0	99			
CM3	Between Groups	51476,961	4	12869,240	2,724	,034
	Within Groups	439376,6	93	4724,480		
	Total	490853,6	97			
CM4	Between Groups	50416,783	4	12604,196	5,684	,000
	Within Groups	206237,9	93	2217,612		
	Total	256654,7	97			
CM5	Between Groups	44800,281	4	11200,070	2,307	,064
	Within Groups	451453,7	93	4854,341		
	Total	496254,0	97			

Table 5.D - ANOVA: descrittive "Maze Learning Test" for 4 schooling groups

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
CMTRAIN	0-5	2	137,00	38,18	27,00	-206,07	480,07	110	164
	6-8	23	112,78	70,01	14,60	82,51	143,06	24	260
	9-13	49	71,33	73,35	10,48	50,26	92,39	16	390
	14-19	26	60,42	57,32	11,24	37,27	83,58	14	280
	Total	100	79,34	70,67	7,07	65,32	93,36	14	390
CM1	0-5	2	53,50	33,23	23,50	-245,10	352,10	30	77
	6-8	23	43,22	30,83	6,43	29,88	56,55	15	154
	9-13	49	29,12	20,61	2,94	23,20	35,04	10	99
	14-19	26	26,69	19,71	3,87	18,73	34,65	10	94
	Total	100	32,22	24,01	2,40	27,46	36,98	10	154
CM2	0-5	2	45,00	14,14	10,00	-82,06	172,06	35	55
	6-8	23	51,83	41,89	8,73	33,71	69,94	19	170
	9-13	49	31,88	23,55	3,36	25,11	38,64	11	171
	14-19	26	37,15	34,13	6,69	23,37	50,94	12	170
	Total	100	38,10	31,92	3,19	31,77	44,43	11	171
CM3	0-5	2	85,50	34,65	24,50	-225,80	396,80	61	110
	6-8	23	128,48	92,86	19,36	88,32	168,64	45	400
	9-13	49	76,88	55,50	7,93	60,94	92,82	32	273
	14-19	24	71,00	66,39	13,55	42,97	99,03	27	291
	Total	98	87,72	71,14	7,19	73,46	101,99	27	400
CM4	0-5	2	76,00	29,70	21,00	-190,83	342,83	55	97
	6-8	23	100,48	63,68	13,28	72,94	128,02	29	212
	9-13	49	57,51	38,64	5,52	46,41	68,61	18	210
	14-19	24	54,29	51,35	10,48	32,61	75,98	20	280
	Total	98	67,18	51,44	5,20	56,87	77,50	18	280
CM5	0-5	2	74,50	37,48	26,50	-262,21	411,21	48	101
	6-8	23	97,13	62,22	12,97	70,22	124,04	38	251
	9-13	49	53,43	35,34	5,05	43,28	63,58	22	174
	14-19	24	61,21	117,77	24,04	11,48	110,94	15	608
	Total	98	66,02	71,53	7,23	51,68	80,36	15	608

<u>Table 6.D – ANOVA: "Maze Learning Test" for 5 schooling groups</u>

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
CMTRAIN	Between Groups	44823,405	3	14941,135	3,190	,027
	Within Groups	449675,0	96	4684,115		
	Total	494498,4	99			
CM1	Between Groups	4951,943	3	1650,648	3,041	,033
	Within Groups	52113,217	96	542,846		
	Total	57065,160	99			
CM2	Between Groups	6349,046	3	2116,349	2,149	,099
	Within Groups	94541,954	96	984,812		
	Total	100891,0	99			
CM3	Between Groups	50688,057	3	16896,019	3,608	,016
	Within Groups	440165,5	94	4682,612		
	Total	490853,6	97			
CM4	Between Groups	34225,752	3	11408,584	4,821	,004
	Within Groups	222428,9	94	2366,265		
	Total	256654,7	97			
CM5	Between Groups	30728,892	3	10242,964	2,068	,110
	Within Groups	465525,1	94	4952,394		
	Total	496254,0	97			

Appendix E

- “Paper & Pencil” Test for neuropsychological Test

<u>Table 1.E – Correlations: “Maze Learning Test” CM for neuropsichological tests</u>

Correlations

		CM1	CM2	CM3	CM4	CM5	MMSE	FLUVERB	REY	TMTA	TMTB	REYDIFFE	TOFLONDO
CM1	Pearson Correlation	1,000	,520**	,373**	,503**	,299**	-,324**	-,233*	-,342**	,477**	,392**	-,299**	-,403**
	Sig. (2-tailed)	,	,000	,000	,000	,003	,001	,020	,001	,000	,000	,003	,000
	N	100	100	98	98	98	100	100	100	100	95	100	100
CM2	Pearson Correlation	,520**	1,000	,454**	,534**	,181	-,156	-,068	-,209*	,409**	,257*	-,148	-,179
	Sig. (2-tailed)	,000	,	,000	,000	,075	,121	,500	,037	,000	,012	,141	,075
	N	100	100	98	98	98	100	100	100	100	95	100	100
CM3	Pearson Correlation	,373**	,454**	1,000	,742**	,499**	-,163	-,054	-,283**	,273**	,227*	-,300**	-,422**
	Sig. (2-tailed)	,000	,000	,	,000	,000	,108	,598	,005	,006	,029	,003	,000
	N	98	98	98	98	97	98	98	98	98	93	98	98
CM4	Pearson Correlation	,503**	,534**	,742**	1,000	,397**	-,206*	-,113	-,382**	,386**	,252*	-,326**	-,356**
	Sig. (2-tailed)	,000	,000	,000	,	,000	,042	,270	,000	,000	,015	,001	,000
	N	98	98	98	98	97	98	98	98	98	93	98	98
CM5	Pearson Correlation	,299**	,181	,499**	,397**	1,000	-,107	-,194	-,391**	,240*	,226*	-,213*	-,254*
	Sig. (2-tailed)	,003	,075	,000	,000	,	,295	,056	,000	,017	,029	,035	,012
	N	98	98	97	97	98	98	98	98	98	93	98	98
MMSE	Pearson Correlation	-,324**	-,156	-,163	-,206*	-,107	1,000	,155	,475**	-,269**	-,220*	,537**	,472**
	Sig. (2-tailed)	,001	,121	,108	,042	,295	,	,123	,000	,007	,032	,000	,000
	N	100	100	98	98	98	100	100	100	100	95	100	100
FLUVERB	Pearson Correlation	-,233*	-,068	-,054	-,113	-,194	,155	1,000	,341**	-,292**	-,231*	,211*	,103
	Sig. (2-tailed)	,020	,500	,598	,270	,056	,123	,	,001	,003	,025	,035	,307
	N	100	100	98	98	98	100	100	100	100	95	100	100
REY	Pearson Correlation	-,342**	-,209*	-,283**	-,382**	-,391**	,475**	,341**	1,000	-,414**	-,373**	,741**	,437**
	Sig. (2-tailed)	,001	,037	,005	,000	,000	,000	,001	,	,000	,000	,000	,000
	N	100	100	98	98	98	100	100	100	100	95	100	100
TMTA	Pearson Correlation	,477**	,409**	,273**	,386**	,240*	-,269**	-,292**	-,414**	1,000	,663**	-,150	-,240*
	Sig. (2-tailed)	,000	,000	,006	,000	,017	,007	,003	,000	,	,000	,135	,016
	N	100	100	98	98	98	100	100	100	100	95	100	100
TMTB	Pearson Correlation	,392**	,257*	,227*	,252*	,226*	-,220*	-,231*	-,373**	,663**	1,000	-,115	-,306**
	Sig. (2-tailed)	,000	,012	,029	,015	,029	,032	,025	,000	,000	,	,268	,003
	N	95	95	93	93	93	95	95	95	95	95	95	95
REYDIFFE	Pearson Correlation	-,299**	-,148	-,300**	-,326**	-,213*	,537**	,211*	,741**	-,150	-,115	1,000	,385**
	Sig. (2-tailed)	,003	,141	,003	,001	,035	,000	,035	,000	,135	,268	,	,000
	N	100	100	98	98	98	100	100	100	100	95	100	100
TOFLONDO	Pearson Correlation	-,403**	-,179	-,422**	-,356**	-,254*	,472**	,103	,437**	-,240*	-,306**	,385**	1,000
	Sig. (2-tailed)	,000	,075	,000	,000	,012	,000	,307	,000	,016	,003	,000	,
	N	100	100	98	98	98	100	100	100	100	95	100	100

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 2.E – correlations: "Maze Learning Test" CM for neuropsichological "spatial" tests

Correlations

		CM1	CM2	CM3	CM4	CM5	LINEORIZ	CORSISPA	SUPRASPA	MANIKIN
CM1	Pearson Correlation	1,000	,520**	,373**	,503**	,299**	-,413**	-,085	,396**	-,412**
	Sig. (2-tailed)	,	,000	,000	,000	,003	,000	,401	,000	,000
	N	100	100	98	98	98	100	100	100	100
CM2	Pearson Correlation	,520**	1,000	,454**	,534**	,181	-,276**	-,015	,259**	-,292**
	Sig. (2-tailed)	,000	,	,000	,000	,075	,005	,879	,009	,003
	N	100	100	98	98	98	100	100	100	100
CM3	Pearson Correlation	,373**	,454**	1,000	,742**	,499**	-,312**	,074	,308**	-,504**
	Sig. (2-tailed)	,000	,000	,	,000	,000	,002	,469	,002	,000
	N	98	98	98	98	97	98	98	98	98
CM4	Pearson Correlation	,503**	,534**	,742**	1,000	,397**	-,333**	-,052	,283**	-,491**
	Sig. (2-tailed)	,000	,000	,000	,	,000	,001	,614	,005	,000
	N	98	98	98	98	97	98	98	98	98
CM5	Pearson Correlation	,299**	,181	,499**	,397**	1,000	-,117	-,054	,187	-,209*
	Sig. (2-tailed)	,003	,075	,000	,000	,	,249	,599	,065	,039
	N	98	98	97	97	98	98	98	98	98
LINEORIZ	Pearson Correlation	-,413**	-,276**	-,312**	-,333**	-,117	1,000	-,006	-,363**	,354**
	Sig. (2-tailed)	,000	,005	,002	,001	,249	,	,954	,000	,000
	N	100	100	98	98	98	100	100	100	100
CORSISPA	Pearson Correlation	-,085	-,015	,074	-,052	-,054	-,006	1,000	,269**	-,092
	Sig. (2-tailed)	,401	,879	,469	,614	,599	,954	,	,007	,360
	N	100	100	98	98	98	100	100	100	100
SUPRASPA	Pearson Correlation	,396**	,259**	,308**	,283**	,187	-,363**	,269**	1,000	-,472**
	Sig. (2-tailed)	,000	,009	,002	,005	,065	,000	,007	,	,000
	N	100	100	98	98	98	100	100	100	100
MANIKIN	Pearson Correlation	-,412**	-,292**	-,504**	-,491**	-,209*	,354**	-,092	-,472**	1,000
	Sig. (2-tailed)	,000	,003	,000	,000	,039	,000	,360	,000	,
	N	100	100	98	98	98	100	100	100	100

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendice F

– "Paper & Pencil" Road Map Test

Table 1.F – ANOVA: "Road Map Test" P&P for 5 aging groups

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
RMCLTARG	1	17	30,59	1,77	,43	29,68	31,50	26	32
	2	3	30,67	1,53	,88	26,87	34,46	29	32
	3	14	27,00	3,09	,83	25,22	28,78	22	31
	4	13	26,92	4,41	1,22	24,26	29,59	20	32
	5	15	22,93	5,15	1,33	20,08	25,78	16	30
	Total	62	27,16	4,60	,58	25,99	28,33	16	32
RMCLTIME	1	17	82,00	19,27	4,67	72,09	91,91	55	126
	2	3	174,00	119,62	69,06	-123,14	471,14	62	300
	3	14	131,93	51,63	13,80	102,12	161,74	77	255
	4	13	134,69	73,95	20,51	90,00	179,38	61	340
	5	15	206,53	113,58	29,33	143,63	269,43	72	480
	Total	62	138,90	85,29	10,83	117,24	160,56	55	480

Table 2.F – ANOVA: "Road Map Test" P&P for 5 aging groups

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
RMCLTARG	Between Groups	505,746	4	126,437	9,208	,000
	Within Groups	782,641	57	13,731		
	Total	1288,387	61			
RMCLTIME	Between Groups	128260,0	4	32064,997	5,794	,001
	Within Groups	315451,4	57	5534,236		
	Total	443711,4	61			

Table 3.F – ANOVA: "Road Map Test" P&P for 4 schooling groups

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
RMCLTARG	0-5	1	17,00	,	,	,	,	17	17
	6-8	17	24,76	4,93	1,20	22,23	27,30	16	32
	9-13	28	28,07	3,64	,69	26,66	29,48	20	32
	14-19	16	28,75	4,30	1,07	26,46	31,04	16	32
	Total	62	27,16	4,60	,58	25,99	28,33	16	32
RMCLTIME	0-5	1	149,00	,	,	,	,	149	149
	6-8	17	187,12	113,70	27,58	128,66	245,57	61	480
	9-13	28	128,61	73,64	13,92	100,05	157,16	61	340
	14-19	16	105,06	44,39	11,10	81,41	128,72	55	212
	Total	62	138,90	85,29	10,83	117,24	160,56	55	480

Table 4.F – ANOVA: "Road Map Test" P&P for 4 schooling groups

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
RMCLTARG	Between Groups	264,471	3	88,157	4,994	,004
	Within Groups	1023,916	58	17,654		
	Total	1288,387	61			
RMCLTIME	Between Groups	60912,039	3	20304,013	3,076	,035
	Within Groups	382799,4	58	6599,989		
	Total	443711,4	61			

Table 5.F – correlations: “Road Map Test” P&P for neuropsychological tests

Correlations

		RMCLTARG	RMCLTIME	MMSE	FLUVERB	REY	TMTA	TMTB	REYDIFFE	TOFLONDO
RMCLTARG	Pearson Correlatio	1,000	-,676**	,349**	,142	,248	-,270*	-,091	,240	,452**
	Sig. (2-tailed)	,	,000	,006	,271	,052	,034	,496	,060	,000
	N	62	62	62	62	62	62	58	62	62
RMCLTIME	Pearson Correlatio	-,676**	1,000	-,208	-,242	-,294*	,245	,014	-,159	-,289*
	Sig. (2-tailed)	,000	,	,106	,058	,021	,055	,914	,217	,023
	N	62	62	62	62	62	62	58	62	62
MMSE	Pearson Correlatio	,349**	-,208	1,000	,155	,475**	-,269**	-,220*	,537**	,472**
	Sig. (2-tailed)	,006	,106	,	,123	,000	,007	,032	,000	,000
	N	62	62	100	100	100	100	95	100	100
FLUVERB	Pearson Correlatio	,142	-,242	,155	1,000	,341**	-,292**	-,231*	,211*	,103
	Sig. (2-tailed)	,271	,058	,123	,	,001	,003	,025	,035	,307
	N	62	62	100	100	100	100	95	100	100
REY	Pearson Correlatio	,248	-,294*	,475**	,341**	1,000	-,414**	-,373**	,741**	,437**
	Sig. (2-tailed)	,052	,021	,000	,001	,	,000	,000	,000	,000
	N	62	62	100	100	100	100	95	100	100
TMTA	Pearson Correlatio	-,270*	,245	-,269**	-,292**	-,414**	1,000	,663**	-,150	-,240*
	Sig. (2-tailed)	,034	,055	,007	,003	,000	,	,000	,135	,016
	N	62	62	100	100	100	100	95	100	100
TMTB	Pearson Correlatio	-,091	,014	-,220*	-,231*	-,373**	,663**	1,000	-,115	-,306**
	Sig. (2-tailed)	,496	,914	,032	,025	,000	,000	,	,268	,003
	N	58	58	95	95	95	95	95	95	95
REYDIFFE	Pearson Correlatio	,240	-,159	,537**	,211*	,741**	-,150	-,115	1,000	,385**
	Sig. (2-tailed)	,060	,217	,000	,035	,000	,135	,268	,	,000
	N	62	62	100	100	100	100	95	100	100
TOFLONDO	Pearson Correlatio	,452**	-,289*	,472**	,103	,437**	-,240*	-,306**	,385**	1,000
	Sig. (2-tailed)	,000	,023	,000	,307	,000	,016	,003	,000	,
	N	62	62	100	100	100	100	95	100	100

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 6.F – Correlations: “Road Map Test” P&P for neuropsychological spatial tests

Correlations

		RMCLTARG	RMCLTIME	LINEORIZ	CORSISPA	SUPRASPA	MANIKIN
RMCLTARG	Pearson Correlation	1,000	-,676**	,395**	-,038	-,503**	,406**
	Sig. (2-tailed)	,	,000	,001	,767	,000	,001
	N	62	62	62	62	62	62
RMCLTIME	Pearson Correlation	-,676**	1,000	-,194	,017	,454**	-,356**
	Sig. (2-tailed)	,000	,	,131	,895	,000	,004
	N	62	62	62	62	62	62
LINEORIZ	Pearson Correlation	,395**	-,194	1,000	-,006	-,363**	,354**
	Sig. (2-tailed)	,001	,131	,	,954	,000	,000
	N	62	62	100	100	100	100
CORSISPA	Pearson Correlation	-,038	,017	-,006	1,000	,269**	-,092
	Sig. (2-tailed)	,767	,895	,954	,	,007	,360
	N	62	62	100	100	100	100
SUPRASPA	Pearson Correlation	-,503**	,454**	-,363**	,269**	1,000	-,472**
	Sig. (2-tailed)	,000	,000	,000	,007	,	,000
	N	62	62	100	100	100	100
MANIKIN	Pearson Correlation	,406**	-,356**	,354**	-,092	-,472**	1,000
	Sig. (2-tailed)	,001	,004	,000	,360	,000	,
	N	62	62	100	100	100	100

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix G

- Maze Learning Test in VR

Table 1.G - correlations "Maze Learning Test" in VR for neuropsychological tests

Correlations

		VR1	VR2	VR3	VR4	VR5	MMSE	FLUVERB	REY	TMTA	TMTB	REYDIFFE	TOFLONDO
VR1	Pearson Correlation	1,000	,723**	,411*	,411**	,612**	-,538**	-,121	-,163	,138	-,027	-,328*	-,354**
	Sig. (2-tailed)	,	,000	,019	,008	,000	,000	,359	,214	,292	,837	,011	,006
	N	60	57	32	41	41	60	60	60	60	59	60	60
VR2	Pearson Correlation	,723**	1,000	,545**	,504**	,669**	-,460**	-,084	-,175	,137	-,001	-,377**	-,372**
	Sig. (2-tailed)	,000	,	,001	,000	,000	,000	,506	,164	,278	,993	,002	,002
	N	57	65	36	44	44	65	65	65	65	64	65	65
VR3	Pearson Correlation	,411*	,545**	1,000	,661**	,640**	-,142	-,454**	-,073	,426**	,072	-,176	-,168
	Sig. (2-tailed)	,019	,001	,	,000	,000	,408	,005	,671	,010	,682	,305	,329
	N	32	36	36	34	32	36	36	36	36	35	36	36
VR4	Pearson Correlation	,411**	,504**	,661**	1,000	,812**	-,125	-,226	-,041	,460**	,122	-,010	-,152
	Sig. (2-tailed)	,008	,000	,000	,	,000	,420	,140	,791	,002	,436	,950	,325
	N	41	44	34	44	42	44	44	44	44	43	44	44
VR5	Pearson Correlation	,612**	,669**	,640**	,812**	1,000	-,368*	-,328*	-,150	,426**	-,004	-,210	-,179
	Sig. (2-tailed)	,000	,000	,000	,000	,	,014	,030	,332	,004	,978	,171	,245
	N	41	44	32	42	44	44	44	44	44	43	44	44
MMSE	Pearson Correlation	-,538**	-,460**	-,142	-,125	-,368*	1,000	,155	,475**	-,269**	-,220*	,537**	,472**
	Sig. (2-tailed)	,000	,000	,408	,420	,014	,	,123	,000	,007	,032	,000	,000
	N	60	65	36	44	44	100	100	100	100	95	100	100
FLUVERB	Pearson Correlation	-,121	-,084	-,454**	-,226	-,328*	,155	1,000	,341**	-,292**	-,231*	,211*	,103
	Sig. (2-tailed)	,359	,506	,005	,140	,030	,123	,	,001	,003	,025	,035	,307
	N	60	65	36	44	44	100	100	100	100	95	100	100
REY	Pearson Correlation	-,163	-,175	-,073	-,041	-,150	,475**	,341**	1,000	-,414**	-,373**	,741**	,437**
	Sig. (2-tailed)	,214	,164	,671	,791	,332	,000	,001	,	,000	,000	,000	,000
	N	60	65	36	44	44	100	100	100	100	95	100	100
TMTA	Pearson Correlation	,138	,137	,426**	,460**	,426**	-,269**	-,292**	-,414**	1,000	,663**	-,150	-,240*
	Sig. (2-tailed)	,292	,278	,010	,002	,004	,007	,003	,000	,	,000	,135	,016
	N	60	65	36	44	44	100	100	100	100	95	100	100
TMTB	Pearson Correlation	-,027	-,001	,072	,122	-,004	-,220*	-,231*	-,373**	,663**	1,000	-,115	-,306**
	Sig. (2-tailed)	,837	,993	,682	,436	,978	,032	,025	,000	,000	,	,268	,003
	N	59	64	35	43	43	95	95	95	95	95	95	95
REYDIFFE	Pearson Correlation	-,328*	-,377**	-,176	-,010	-,210	,537**	,211*	,741**	-,150	-,115	1,000	,385**
	Sig. (2-tailed)	,011	,002	,305	,950	,171	,000	,035	,000	,135	,268	,	,000
	N	60	65	36	44	44	100	100	100	100	95	100	100
TOFLONDO	Pearson Correlation	-,354**	-,372**	-,168	-,152	-,179	,472**	,103	,437**	-,240*	-,306**	,385**	1,000
	Sig. (2-tailed)	,006	,002	,329	,325	,245	,000	,307	,000	,016	,003	,000	,
	N	60	65	36	44	44	100	100	100	100	95	100	100

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 2.G – Correlations: “Maze Learning Test” for neuropsychological spatial tests

Correlations

		VR1	VR2	VR3	VR4	VR5	LINEORIZ	CORSISPA	SUPRASPA	MANIKIN
VR1	Pearson Correlation	1,000	,723**	,411*	,411**	,612**	-,515**	,077	,593**	-,507**
	Sig. (2-tailed)	,	,000	,019	,008	,000	,000	,560	,000	,000
	N	60	57	32	41	41	60	60	60	60
VR2	Pearson Correlation	,723**	1,000	,545**	,504**	,669**	-,345**	,126	,611**	-,476**
	Sig. (2-tailed)	,000	,	,001	,000	,000	,005	,318	,000	,000
	N	57	65	36	44	44	65	65	65	65
VR3	Pearson Correlation	,411*	,545**	1,000	,661**	,640**	-,353*	,019	,098	-,301
	Sig. (2-tailed)	,019	,001	,	,000	,000	,035	,914	,568	,074
	N	32	36	36	34	32	36	36	36	36
VR4	Pearson Correlation	,411**	,504**	,661**	1,000	,812**	-,180	-,285	-,102	-,259
	Sig. (2-tailed)	,008	,000	,000	,	,000	,241	,061	,509	,089
	N	41	44	34	44	42	44	44	44	44
VR5	Pearson Correlation	,612**	,669**	,640**	,812**	1,000	-,287	-,001	,241	-,358*
	Sig. (2-tailed)	,000	,000	,000	,000	,	,059	,995	,115	,017
	N	41	44	32	42	44	44	44	44	44
LINEORIZ	Pearson Correlation	-,515**	-,345**	-,353*	-,180	-,287	1,000	-,006	-,363**	,354**
	Sig. (2-tailed)	,000	,005	,035	,241	,059	,	,954	,000	,000
	N	60	65	36	44	44	100	100	100	100
CORSISPA	Pearson Correlation	,077	,126	,019	-,285	-,001	-,006	1,000	,269**	-,092
	Sig. (2-tailed)	,560	,318	,914	,061	,995	,954	,	,007	,360
	N	60	65	36	44	44	100	100	100	100
SUPRASPA	Pearson Correlation	,593**	,611**	,098	-,102	,241	-,363**	,269**	1,000	-,472**
	Sig. (2-tailed)	,000	,000	,568	,509	,115	,000	,007	,	,000
	N	60	65	36	44	44	100	100	100	100
MANIKIN	Pearson Correlation	-,507**	-,476**	-,301	-,259	-,358*	,354**	-,092	-,472**	1,000
	Sig. (2-tailed)	,000	,000	,074	,089	,017	,000	,360	,000	,
	N	60	65	36	44	44	100	100	100	100

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 3.G – correlations: “Effectiveness Index”, demogr. Var. for neuropsycholog. tests

Correlations

		numero di labirinti fatti	ETA	SCOLARIT	FLUIDITA	MMSE	FLUVERB	REY	TMTA	TMTB	REYDIFFE	TOFLONDO
Effective Index	Pearson Correlation	1,000	-,706**	,451**	,522**	,505**	,152	,481**	-,398**	-,337**	,466**	,530**
	Sig. (2-tailed)	,	,000	,000	,000	,000	,130	,000	,000	,001	,000	,000
	N	100	100	100	100	100	100	100	100	95	100	100
ETA	Pearson Correlation	-,706**	1,000	-,392**	-,613**	-,662**	-,298**	-,482**	,436**	,246*	-,437**	-,439**
	Sig. (2-tailed)	,000	,	,000	,000	,000	,003	,000	,000	,016	,000	,000
	N	100	100	100	100	100	100	100	100	95	100	100
SCOLARIT	Pearson Correlation	,451**	-,392**	1,000	,340**	,352**	,140	,323**	-,227*	-,112	,413**	,385**
	Sig. (2-tailed)	,000	,000	,	,001	,000	,164	,001	,023	,278	,000	,000
	N	100	100	100	100	100	100	100	100	95	100	100
FLUIDITA	Pearson Correlation	,522**	-,613**	,340**	1,000	,390**	,235*	,381**	-,313**	-,163	,342**	,270**
	Sig. (2-tailed)	,000	,000	,001	,	,000	,019	,000	,002	,115	,000	,007
	N	100	100	100	100	100	100	100	100	95	100	100
MMSE	Pearson Correlation	,505**	-,662**	,352**	,390**	1,000	,155	,475**	-,269**	-,220*	,537**	,472**
	Sig. (2-tailed)	,000	,000	,000	,000	,	,123	,000	,007	,032	,000	,000
	N	100	100	100	100	100	100	100	100	95	100	100
FLUVERB	Pearson Correlation	,152	-,298**	,140	,235*	,155	1,000	,341**	-,292**	-,231*	,211*	,103
	Sig. (2-tailed)	,130	,003	,164	,019	,123	,	,001	,003	,025	,035	,307
	N	100	100	100	100	100	100	100	100	95	100	100
REY	Pearson Correlation	,481**	-,482**	,323**	,381**	,475**	,341**	1,000	-,414**	-,373**	,741**	,437**
	Sig. (2-tailed)	,000	,000	,001	,000	,000	,001	,	,000	,000	,000	,000
	N	100	100	100	100	100	100	100	100	95	100	100
TMTA	Pearson Correlation	-,398**	,436**	-,227*	-,313**	-,269**	-,292**	-,414**	1,000	,663**	-,150	-,240*
	Sig. (2-tailed)	,000	,000	,023	,002	,007	,003	,000	,	,000	,135	,016
	N	100	100	100	100	100	100	100	100	95	100	100
TMTB	Pearson Correlation	-,337**	,246*	-,112	-,163	-,220*	-,231*	-,373**	,663**	1,000	-,115	-,306**
	Sig. (2-tailed)	,001	,016	,278	,115	,032	,025	,000	,000	,	,268	,003
	N	95	95	95	95	95	95	95	95	95	95	95
REYDIFFE	Pearson Correlation	,466**	-,437**	,413**	,342**	,537**	,211*	,741**	-,150	-,115	1,000	,385**
	Sig. (2-tailed)	,000	,000	,000	,000	,000	,035	,000	,135	,268	,	,000
	N	100	100	100	100	100	100	100	100	95	100	100
TOFLONDO	Pearson Correlation	,530**	-,439**	,385**	,270**	,472**	,103	,437**	-,240*	-,306**	,385**	1,000
	Sig. (2-tailed)	,000	,000	,000	,007	,000	,307	,000	,016	,003	,000	,
	N	100	100	100	100	100	100	100	100	95	100	100

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Tabella 4.G – correlations: "Maze Learning Test-fatti" in VR for neurops.tests

Correlations

		numero di labirinti fatti	LINEORIZ	CORSISPA	SUPRASPA	MANIKIN
numero di labirinti fatti	Pearson Correlation	1,000	,436**	-,001	-,613**	,508**
	Sig. (2-tailed)	,	,000	,991	,000	,000
	N	100	100	100	100	100
LINEORIZ	Pearson Correlation	,436**	1,000	-,006	-,363**	,354**
	Sig. (2-tailed)	,000	,	,954	,000	,000
	N	100	100	100	100	100
CORSISPA	Pearson Correlation	-,001	-,006	1,000	,269**	-,092
	Sig. (2-tailed)	,991	,954	,	,007	,360
	N	100	100	100	100	100
SUPRASPA	Pearson Correlation	-,613**	-,363**	,269**	1,000	-,472**
	Sig. (2-tailed)	,000	,000	,007	,	,000
	N	100	100	100	100	100
MANIKIN	Pearson Correlation	,508**	,354**	-,092	-,472**	1,000
	Sig. (2-tailed)	,000	,000	,360	,000	,
	N	100	100	100	100	100

**. Correlation is significant at the 0.01 level (2-tailed).

Appendice H

– Road Map Test in VR

Tabella 1.H – Correlations: "Road Map Test" in VR, socio-demogr. And neurops. tests

Correlations

		RMTARGET	RMTIME	MMSE	ETA	SCOLARIT	FLUIDITA
RMTARGET	Pearson Correlation	1,000	,233*	,407**	-,632**	,366**	,641**
	Sig. (2-tailed)	,	,020	,000	,000	,000	,000
	N	99	99	99	99	99	99
RMTIME	Pearson Correlation	,233*	1,000	-,125	-,088	,109	,105
	Sig. (2-tailed)	,020	,	,215	,386	,279	,297
	N	99	100	100	100	100	100
MMSE	Pearson Correlation	,407**	-,125	1,000	-,662**	,352**	,390**
	Sig. (2-tailed)	,000	,215	,	,000	,000	,000
	N	99	100	100	100	100	100
ETA	Pearson Correlation	-,632**	-,088	-,662**	1,000	-,392**	-,613**
	Sig. (2-tailed)	,000	,386	,000	,	,000	,000
	N	99	100	100	100	100	100
SCOLARIT	Pearson Correlation	,366**	,109	,352**	-,392**	1,000	,340**
	Sig. (2-tailed)	,000	,279	,000	,000	,	,001
	N	99	100	100	100	100	100
FLUIDITA	Pearson Correlation	,641**	,105	,390**	-,613**	,340**	1,000
	Sig. (2-tailed)	,000	,297	,000	,000	,001	,
	N	99	100	100	100	100	100

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Tabella 2.H – Correlations: "Road Map Test" in VR for neuropsychological tests

Correlations

		RMTARGET	MMSE	FLUVERB	REY	TMTA	TMTB	REYDIFFE	TOFLONDO
RMTARGET	Pearson Correlation	1,000	,407	,224	,343	-,383	-,247	,295	,409
	Sig. (2-tailed)	,	,000	,026	,001	,000	,016	,003	,000
	N	99	99	99	99	99	94	99	99
MMSE	Pearson Correlation	,407	1,000	,155	,475	-,269	-,220	,537	,472
	Sig. (2-tailed)	,000	,	,123	,000	,007	,032	,000	,000
	N	99	100	100	100	100	95	100	100
FLUVERB	Pearson Correlation	,224	,155	1,000	,341	-,292	-,231	,211	,103
	Sig. (2-tailed)	,026	,123	,	,001	,003	,025	,035	,307
	N	99	100	100	100	100	95	100	100
REY	Pearson Correlation	,343	,475	,341	1,000	-,414	-,373	,741	,437
	Sig. (2-tailed)	,001	,000	,001	,	,000	,000	,000	,000
	N	99	100	100	100	100	95	100	100
TMTA	Pearson Correlation	-,383	-,269	-,292	-,414	1,000	,663	-,150	-,240
	Sig. (2-tailed)	,000	,007	,003	,000	,	,000	,135	,016
	N	99	100	100	100	100	95	100	100
TMTB	Pearson Correlation	-,247	-,220	-,231	-,373	,663	1,000	-,115	-,306
	Sig. (2-tailed)	,016	,032	,025	,000	,000	,	,268	,003
	N	94	95	95	95	95	95	95	95
REYDIFFE	Pearson Correlation	,295	,537	,211	,741	-,150	-,115	1,000	,385
	Sig. (2-tailed)	,003	,000	,035	,000	,135	,268	,	,000
	N	99	100	100	100	100	95	100	100
TOFLONDO	Pearson Correlation	,409	,472	,103	,437	-,240	-,306	,385	1,000
	Sig. (2-tailed)	,000	,000	,307	,000	,016	,003	,000	,
	N	99	100	100	100	100	95	100	100

Table 3.H – Correlations: “Road Map Test” in VR for neuropsychological tests

Correlations

		RMTARGET	LINEORIZ	CORSISPA	SUPRASPA	MANIKIN
RMTARGET	Pearson Correlation	1,000	,387**	,055	-,571**	,410**
	Sig. (2-tailed)	,	,000	,589	,000	,000
	N	99	99	99	99	99
LINEORIZ	Pearson Correlation	,387**	1,000	-,006	-,363**	,354**
	Sig. (2-tailed)	,000	,	,954	,000	,000
	N	99	100	100	100	100
CORSISPA	Pearson Correlation	,055	-,006	1,000	,269**	-,092
	Sig. (2-tailed)	,589	,954	,	,007	,360
	N	99	100	100	100	100
SUPRASPA	Pearson Correlation	-,571**	-,363**	,269**	1,000	-,472**
	Sig. (2-tailed)	,000	,000	,007	,	,000
	N	99	100	100	100	100
MANIKIN	Pearson Correlation	,410**	,354**	-,092	-,472**	1,000
	Sig. (2-tailed)	,000	,000	,360	,000	,
	N	99	100	100	100	100

**. Correlation is significant at the 0.01 level (2-tailed).

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