 doi:10.20944/preprints202104.0790.v1

Article

Does the high level of navigational strategy depend on the number of flight hours or on an innate predisposition? The case of military pilots.

Marco Giancola[1], Paola Verde[2**†], Luigi Cacciapuoti[3], Gregorio Angelino[4], Laura Piccardi[5], Alessia Bocchi[6], Massimiliano Palmiero[7] and Raffaella Nori[8]**

1 Department of Biotechnological and Applied Clinical Sciences, University of L'Aquila, L'Aquila, Italy; marco.giancola@graduate.univaq.it
2 Italian Air Force, Aerospace Test Division, Aerospace Medicine Department, Pratica di Mare, Italy; paola.verde@aeronautica.difesa.it
3 Italian Air Force, Aerospace Test Division, Aerospace Medicine Department, Pratica di Mare, Italy; luigi.cacciapuoti@aeronautica.difesa.it
4 Italian Air Force, Aerospace Test Division, Aerospace Medicine Department, Pratica di Mare, Italy; gregorio.angelino@aeronautica.difesa.it
5 Department of Psychology "Sapienza" University of Rome, Italy and Cognitive and Motor Rehabilitation and Neuroimaging Unit, IRCCS Fondazione Santa Lucia, Rome; laura.piccardi@uniroma1.it
6 Department of Psychology "Sapienza" University of Rome, Italy; alessia.bocchi@gmail.com
7 Department of Biotechnological and Applied Clinical Sciences, University of L'Aquila, L'Aquila, Italy; massimiliano.palmiero@unibg.it
8 Department of Psychology, University of Bologna, Bologna, Italy; raffaella.nori@unibo.it

† Correspondence: paola.verde@aeronautica.difesa.it; Aerospace Test Division, Aerospace Medicine Department, Pratica di Mare, AFB, 00071, Pomezia, Italy
**These authors contributed equally to this work.

Abstract:

Background: Military pilots show high visuo-spatial skills. Previous studies demonstrate that they are better in mental rotating a target, in taking different perspectives, in estimating distances, in travel planning and in topographic memory. Here, we compared navigational cognitive styles between military pilots and people without flight experience. Pilots were expected to be more *survey* users than non-pilots, showing higher navigational strategies. **Method:** 106 jet military pilots of Italian Air Force and 92 non-pilots were enrolled in order to investigate group differences in navigational styles. Participants were asked to perform a reduced version of the Spatial Cognitive Style Test – SCST, consisting of six tasks that allow to distinguish individuals in *landmark* (people orient themselves by using a figurative memory for environmental objects), *route* (people use an egocentric representation of the space) and *survey* (people have a map-like representation of the space) users. **Results:** In line with our hypothesis, military pilots mainly adopt a survey style, whereas non-pilots mainly adopt the route style. In addition, pilots outperformed non pilots in both the 3D-Rotation task and Map Description Task. **Conclusion:** Military flight expertise influences some aspects of the spatial ability, leading to enhance human navigation. Although, it must be considered that they are a population whose navigational skills were already high at the time of selection at the academy before formal training began.

Keywords: Cognitive style; Spatial Cognition; Sense of Direction; Spatial Orientation; Mental Rotation; Individual Differences

1. Introduction

Navigation in spatial surroundings is a cognitive process that requires a prolonged maturation with the progression of skills, strategies and proficiency over the lifespan. Several theoretical frameworks have been advanced to explain how environmental knowledge is acquired and what stages encompass. One of the first seminal theoretical model still considered today was the one advanced by Siegel and White [1]. These authors hypothesized that environmental knowledge is acquired following three separate and hierarchical steps. The first one is focused on *landmark knowledge* and is characterized by a figurative memory of environmental objects (i.e., buildings, fountains, shops, monuments). At this knowledge step, individuals may beacon towards a salient landmark, but they lack the egocentric and allocentric information allowing to build up relationships between the individual and subsequent landmarks, as well as the relationship between landmarks along a path or absolute relationships between landmarks. The second step is a *route knowledge* in which, through an egocentric perspective, the self-position allows to determine the relation between landmarks met along the path. Finally, the last step is the *survey knowledge*, in which a map-like representation is built, and through an allocentric perspective the mental environmental representation exists in spite of the self-position. When individuals reach this last step, they are able to find shortcuts and to master a metric knowledge of the environment itself. This model, although still adopted, is not free from criticism and since 1990 a series of other theoretical models have been proposed in order to explain how the acquisition of environmental information and the creation of a representation of the surrounding world takes place [2-4]. Specifically, Tversky [2] suggests that for human beings it is mandatory to take into account language, thus in order to develop environmental knowledge a further stage would be based on the linguistic spatial categories. Montello [3], on the contrary, disagrees on the hierarchical rigidity of the model and suggests that *survey knowledge* can be achieved even after a fleeting exposure of an environmental map and that not necessarily an individual has to cross the 3 steps assumed by the Siegel and White's Model.

Undoubtedly, regardless of the theoretical model concerning the environmental knowledge, several factors intervene in determining proficiency during spatial orientation. In general, such factors have been distinguished in internal and external

factors. Among external factors, there are environment configuration, landmarks visual accessibility, circulation systems, and sign age [5-6]. Differently, between internal factors, there are: the individual's inclination to capture some environmental information rather than others (field dependence/independence: [7-11]), gender ([12-19]), age ([20-25]`, familiarity with the environment and job-related expertise ([4, 26-33]). Internal factors can also include the navigational strategies that the individual prefers to use to navigate. Indeed, according to some authors, the three environmental knowledge steps proposed by Siegel and White correspond to three different strategies or spatial cognitive styles (SCSs) that the individuals use when moving through the environment [34-35] in spite of their level of environmental knowledge. As a consequence, individuals may be distinguished in *landmark* (LS), *route* (RS) and *survey* (SS) users, which correspond to three different levels of navigational skills. *Landmark style* users are less able than *route* and *survey style* users. Analysing navigational behaviour *landmark style* users are poor navigators and experience very often the feeling of getting lost, while *route style* users are more skilled at estimating the place and the time in which they have to turn right or left at a specific reference point in an egocentric perspective. Finally, *survey style* users are good navigators, they have an external perspective, such as a bird's-eye view, which allows for direct access to the global spatial layout [36] and are able to plan more flexible and efficient navigational strategies [7]. Moreover, Bocchi et al. [7] found that the navigational style also affects the sense of direction (SOD). People with *survey style* have better sense of direction than people with *landmark* or *route styles* (e.g.[37]) and they are more proficient in solving navigational problems, as well as in travel planning [38-39].
There is no doubt that the most of studies of spatial cognition have focused on internal factors, while external factors are of more interest to architects and geographers. Specifically, among internal factors, familiarity with the environment and job-related expertise deserves great attention because they are the most modifiable and least stable over the lifespan. For example, as familiarity and exposure time with the environment increase, women who are generally less able than men to navigate achieve performance comparable to that of men [4,40]. Of course, familiarity and job-related experience are not really the same thing because while job-related experience allows one to generalise specific knowledge to similar situations, familiarity means that the person has only acquired high skills in that environment and is not able to transfer them to other environments, so the landmark user will remain a landmark user when approaching a new environment for the first time. In particular, navigational trainings that are similar to the experience gained at work have wider effects by producing jumps in the developmental stages that are acquired before time (e.g., [41]). This is noteworthy in terms of cognitive reserve and successful ageing as well as in terms of fallout of the effects on other skills. For example, it is known that mathematical disciplines are related to some aspects of spatial orientation [42-43] that could be potentiated through spatial cognition training. Among the internal factors, navigational strategies and cognitive styles play an important role because they can also influence other aspects of everyday life.

In a recent work, Nori et al. [44] have highlighted how being able to have a mental survey representation allows making fewer mistakes and infractions when driving a car. Similarly, Bocchi et al. [45] found that having a mental survey representation allows to implement an efficient strategy to search for a lost object. Generally speaking, cognitive style is the way people perceive the world, organise environmental information and process it. Even cognitive style can influence the appreciation of a work of art (e.g., [46]) and with respect to spatial orientation make individuals able to grasp different aspects of the environment and consequently extrapolate some spatial clues rather than others. It is a pervasive psychological dimension of individual, it is relatively stable across life, although it may adapt to environmental changes and pressures [47-48].

Although some spatial abilities may be innate, most navigational skills require time to fully mature and develop gradually and at distinct time points during childhood and early adolescence, even if spatial training may proficiently improve them [41-49] allowing some navigational milestones to be reached before normal maturity.

Considering navigational strategies, for some authors (e.g. [34-35]), they correspond to actual cognitive styles that trace the stages of acquisition of environmental knowledge described by the Siegel and White's model individuating three different styles (landmark; route; survey) with distinguished competences. Specifically, survey users have better performance at perspective taking and spatial orientation tasks, are good at finding their way back to a starting position along a path they experienced just once, they build more complex and flexible map-like representation, and they study a map exploring it with a more efficient eye-movement pattern [50-51-52]. Undoubtedly, literature on spatial orientation and military pilots highlights their higher levels of spatial skills than general population. Indeed, in order to be able to fly on a military jet, they need a better visuo-spatial working memory and attention, they must be very quick to mentally rotate 3D objects and process environmental information, as well as to make directional judgements [29, 53]. Furthermore, they have a better topographic memory than non-pilots [28]. Gender differences are absent in these population suggesting that the type of selection to be admitted to the flight training only allows entry to those individuals who have very good visual-spatial skills [28]. When asked through informal interviews about their navigational skills, they spontaneously report that they have always a very good sense of direction and believe that this is something innate, although they recognise that there are many people in the world who are not so good at moving around in a new city or in their own city. They also imagine that this ability is also linked to the type of work they do, which has certainly contributed to increase their ability, although studies in the literature do not always find a relationship between flight hours and navigational ability [28-29]. In this vein, also Sutton et al. [54] reported that even undergraduate student pilots were more accurate at estimating directions between landmarks in a virtual town when compared with non-pilot controls. Furthermore, military pilots are more able in recognizing 180° rotated objects than non-pilots when they have to estimate directional judgments of points learnt in a different environmental perspective [29].

In this special population, the gender differences that are observed in the general population with respect to mental rotation and navigation are not present, and this would suggest the existence of a higher cognitive style and the use of survey strategy that would partially explain their spatial skills. For example, Glicksohn and Naor-Ziv [55] found that pilots were more field independent than other populations, they scored lower on Neuroticism, and they scored higher on Experience Seeking. These authors also found a distinctive profile for military pilots relative to others who had served in combat units in the military.

To our knowledge, no studies have investigated which navigational style military pilots adopt during navigation. In several studies, Verde and co-workers [28-29-30] hypothesize that military pilots should be survey style users taking into account for their efficiency in mental rotation, topographic memory and taking perspective tasks. However, in their studies just self-report measures have been used, therefore authors could not draw any conclusion about the percentage of survey stile users in this population.

In the present paper, we intend to investigate if military pilots have developed higher navigational strategies than general population, and whether these strategies have been developed as a consequence of their job-related training or are innate and already existing at the time of selection to enter at the military academy. As a consequence, we formulate the following hypothesis: military pilots, that are more skilled in cognitive processes underlying navigation, adopt more survey navigational strategies than non-pilots and distribution of the three styles is significantly different from that in the non-pilots group. Indeed, in previous studies military pilots self-reported to be more prone to use survey than route or landmark navigational strategies (see in [28]). In the present study, we also explore the weight of flight hours on their performance in navigational tasks investigating whether, as flight hours increase, their ability in space tasks increases in terms of accuracy and timing, or whether this ability is independent of related work experience but is the consequence of a selection of certain cognitive characteristics that make an individual a good pilot.

2. Materials and Methods

2.1. Participants

One hundred ninety-eight healthy men (mean age=29.22 ± 6.94; age range=19-50) were enrolled for the experiment. Participants have been divided into two groups: 92 non-pilots (mean age=25.92 ± 4.73; age range=19-40) without flight experience and 106 jet military pilots of the Italian Air Force (mean age=32.08 ± 7.30; age range=20-50), with the following flight experience: mean hours of flight=724.11 ± 1205.02.; flight range=15-6000. All participants signed written informed consent before undergoing the experiment. As indicated by the anamnestic questionnaire, none of the participants had a history of neurological or psychiatric disease. All subjects gave their written informed consent before taking part in the experimental testing. The local Ethics committee, in agreement with the Declaration of Helsinki, approved this study.

2.2 Procedure

Before the experimental session, participants were informed about the aim, procedure of the study, their rights and the possibility to stop the experiment at any time they need. Afterward, participants signed a written informed consent and a brief anamnestic questionnaire in which they had to indicate age, educational level, addictions and state of health. Then, the Spatial Cognitive Style Test – SCST [56] was administered individually for each participant of both groups in a quiet room.

2.3 Measures

The Spatial Cognitive Style Test – SCST was designed in order to evaluate the three navigational cognitive styles (LS, RS, SS) used by people to move successfully through the environment. More specifically, in this study, we adopt a short version of the SCST, which includes six different tasks (the Photo Task, Figure Task, Sequence Task, Map Description task, Three-Dimensional- 3D Rotation Task, and Sum and Straighten Task), two for each navigational style. Seven items randomly presented composed every task, and for each subtest, the accuracy and the execution time scores were considered. The subtest of the SCST, divided for navigational strategies, are described in detail below.

2.3.1. *Landmark tasks*

Photo Task. Participants were asked to study for 3 seconds a photo representing a building. Afterward, they had to recognize the building previously studied amongst four similar photos (seven trials; see Figure 1 A).

Figure Task. Participants had to study seven shapes for 75 seconds and were asked to recognize them amongst 50 different figures, including the seven shapes previously studied (seven targets and 43 fillers; see Figure 1 B).

2.3.2. Route tasks

Sequence Task. Participants were asked to study a photo representing the environmental scene from a first-person perspective for 15 seconds. Then, participants have presented the photo divided into separate parts (3,4, or 5 parts). The aim was to arrange the parts correctly, reconstructing the previously studied photo (seven trials; Figure 1 C).

Map Description Task. Participants were required to describe a pathway depicted on a map. Starting from a purple dot, participants had to describe the route to reach a black dot by reporting the correct sequence of seven right–left turning points. Rotation of the map was explicitly required to perform the task (see Figure 1 D).

2.3.3. Survey tasks

Three Dimensional (3D) Rotation Task. Participants were asked to observe a picture of a TV on the left of the A4 paper. Afterward, they had to mentally rotate the shape in the direction indicated by one or two arrows following four possible rotations (90° to the left on the vertical axis; 90° to the right on the vertical axis; 90° from the top down on the horizontal axis: 90° from the ground upwards on the horizontal axis). Then, participants had to choose the correct rotation amongst five possible pictures reported on the A4 paper (seven trials, see Figure 1 E).

Sum and Straighten Task. Participants had to mentally sum and straighten a series of three segments depicted on an A4 paper in order to obtain the actual length and then indicate the correct answer among four alternatives (seven trials; Figure 1 F).

Based on the cumulative nature of the Siegel and White model's as above described and following the criteria of Nori and Giusberti [56-57], we classified participants as *Landmark Style (LS)* Users if they provided at least 80% of correct answers (score = > 5) on the two *landmark* tasks less than five correct answers on both the route and survey tasks. Participants who gave at least 80 % of the correct answer in both the landmark and route tasks and less than five correct in the *survey* tasks were classified as *Route Style (RS)* Users. Finally, participants who provided at least 80 % of correct answers in the landmark, route and survey tasks were considered as *Survey Style* Users (SS). For two participants (one for each group), it was not possible to define the navigational style.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 30 April 2021 doi:10.20944/preprints202104.0790.v1

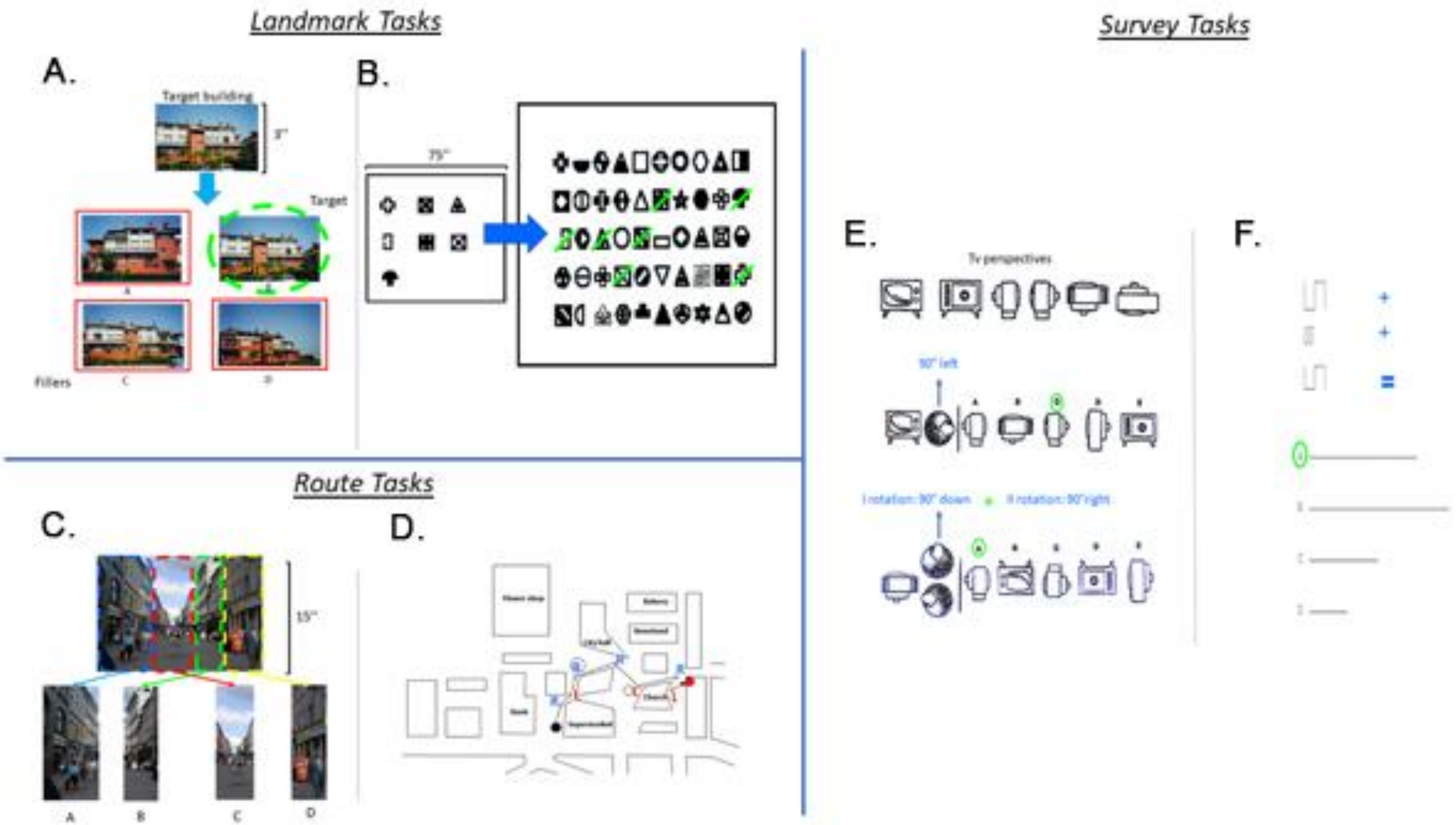

Figure 1. *An example of each type of tasks (landmark; route and survey).*

 doi:10.20944/preprints202104.0790.v1

3. Results

In order to evaluate the distribution of the three navigational styles in both groups (pilots and non-pilots), Cochran's Q test was performed. Regarding the pilots group, the variation amongst the three navigational styles (frequencies amongst the three navigational styles are reported in Table 1) was significant (Cochran's Q_2=88.91; p=.00). More specifically, the comparisons were significant between LS and RS (Cochran's Q_1=26.00; p=.00); LS and SS (Cochran's Q_1=59.00; p=.00) and RS and SS (Cochran's Q_1=33.00; p=.00).

Pilots Group		
Cognitive Style	***Frequencies***	***Percentages***
Landmark	*7*	*6.61 %*
Route	*33*	*31.13 %*
Survey	*66*	*62.26 %*

Table 1. *The frequencies of the three cognitive styles in the pilots group*

Regarding the non-pilots group, the variation amongst the three navigational styles (frequencies amongst the three navigational styles are reported in Table 2) was significant (Cochran's Q_2=60.25; p=.00). More specifically, the comparison between LS and RS was significant (Cochran's Q_1=32.00; p=.00) as well as between LS and SS (Cochran's Q_1=30.00; p=.00). The comparison between RS and SS was not significant (Cochran's Q_1=2.00; p=.16).

Non-Pilots Group		
Cognitive Style	***Frequencies***	***Percentages***
Landmark	*10*	*10.87 %*
Route	*42*	*45.65 %*
Survey	*40*	*43.48 %*

Table 2. The frequencies of the three cognitive styles in the non-pilots group

Three different Cochran's Q tests were performed, one for each navigational style to evaluate the distribution of the three navigational styles in both groups. Frequencies amongst the three navigational styles for pilots and non-pilots are reported in Table 3. Regarding the LS, no differences were found between pilots and non-pilots (Cochran's Q_1=3.00; p=.083) whereas, significant differences were found for both RS (Cochran's Q_1=9.00; p=.03) and SS (Cochran's Q_1=26.00; p=.00). Therefore, military pilots seem to show more complex navigational strategies than non-pilots.

Pilots vs Non-Pilots Groups		
Cognitive Style	***Pilots Frequencies***	***Non-Pilots Frequencies***
Landmark	*7*	***10***
Route	***33***	***42***
Survey	***66***	***40***

Table 3. The frequencies of the three cognitive styles in both pilots and non-pilots groups

Afterward, in order to evaluate the differences between pilots and non-pilots in each task of the SCST, we performed six separate one-way analyses of variance (ANOVA) with group (pilots vs. non-pilots) as independent variable and the accuracy score of each task of the SCST (Photo Task, Figure Task, Sequence Task, Map Description Task, Three Dimensional Rotation Task and Sum and Straighten Task) as dependent variables. No differences between groups were found in the Photo Task ($F_{1, 196}$= 1.51; p=.22; η_p^2= .008); Figure Task ($F_{1, 196}$= 0.23; p=.88; η_p^2 = .000); Sequence Task ($F_{1, 196}$= 2.40; p=.12; η_p^2= .012) and Sum and Straighten Task ($F_{1, 196}$= 2.40; p=.12; η_p^2= .012). Whereas we found that pilots outperformed non-pilots in the Map Description Task ($F_{1, 196}$= 14.37; p=.00; η_p^2= .068) and the Three Dimensional Rotation Task ($F_{1, 196}$= 11.56; p=.001; η_p^2= .056). See Figure 2.

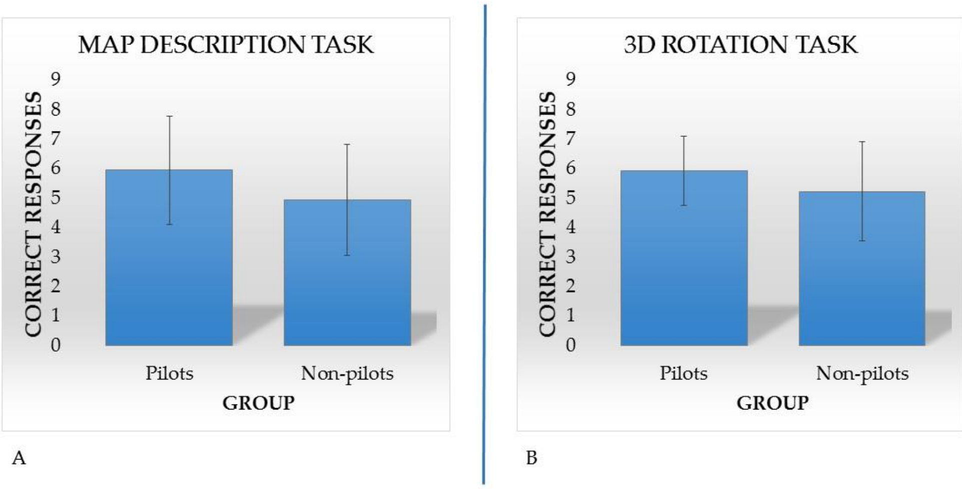

Figure 2. A. *Mean plot: In the x-axis, the two groups (pilots and non-pilots) are reported. The y-axis shows the participants' mean accuracy score on the Map Description Task of the Spatial Cognitive Style Test (SCST);* ***B:*** *Mean plot: In the x-axis, the two groups (pilots and non-pilots) are reported. The y-axis shows the participants' mean accuracy score on 3D Rotation Task of the Spatial Cognitive Style Test (SCST).*

Moreover, we performed six separate one-way analyses of variance (ANOVA) with the execution time of every task of the SCST as dependent variable and the group as independent variable. Pilots seem to be slower than non-pilots in the Photo Task ($F_{1, 196}$= 18.80; p=.00; η_p^2= .088), the Figure Task ($F_{1, 196}$= 12.95; p=.00; η_p^2= .062), the Sequence Task ($F_{1, 196}$= 12.73; p=.00; η_p^2= .061), and

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 30 April 2021 doi:10.20944/preprints202104.0790.v1

the Map Description Task ($F_{1,196}$= 8.69; p=.004; η_p^2= .042). No significant differences were found in the Three Dimensional Rotation Task ($F_{1,196}$= 2.95; p=.087; η_p^2= .015) and the Sum and Straighten Task ($F_{1,196}$= 3.04; p=.083; η_p^2= .015). See Figure 3.

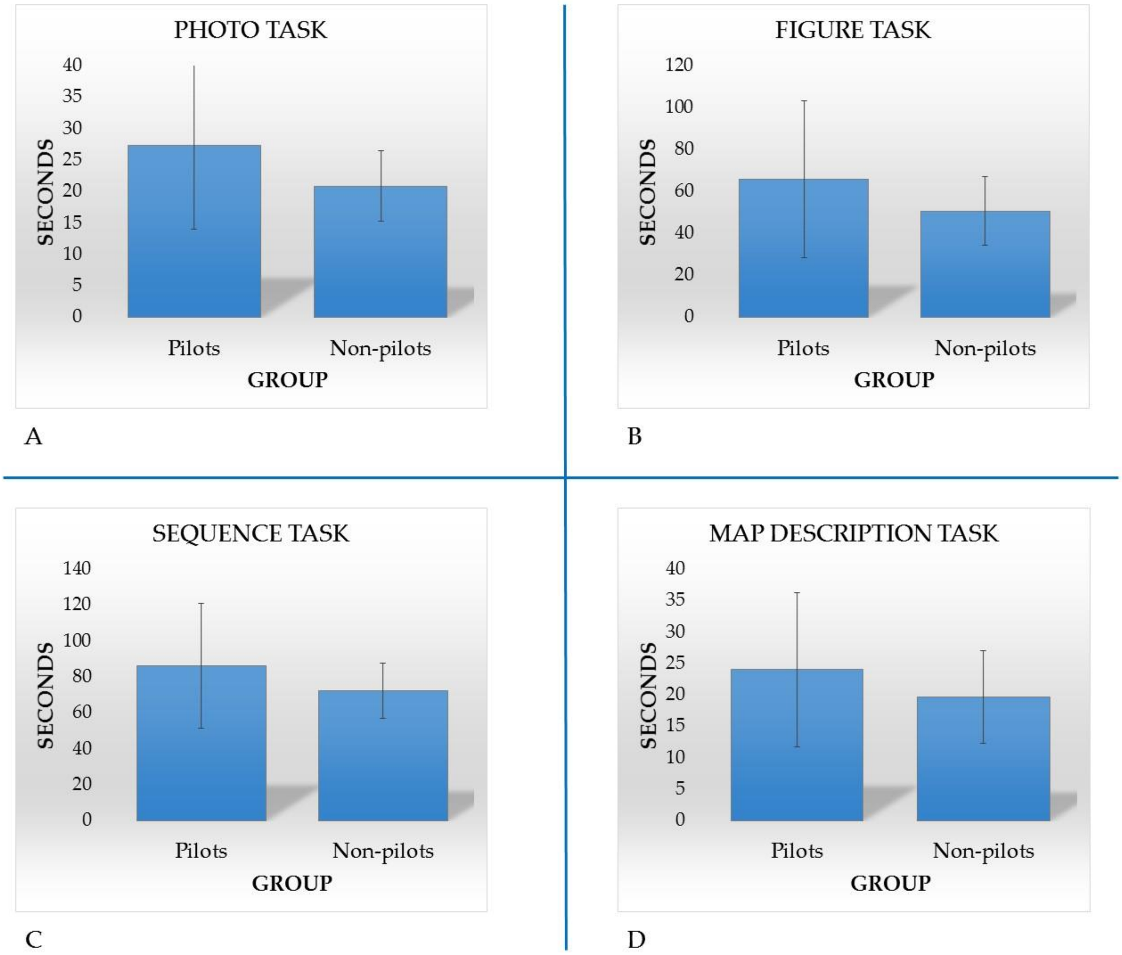

Figure 3. *Mean plot: In the x-axes, the two groups (pilots and non-pilots) are reported. The y-axes show the participants' mean execution time (sec) on the Photo Task (A), Figure Task (B), Sequence Task (C) and Map Description Task (D) of the Spatial Cognitive Style Test (SCST).*

In order to evaluate whether the pilots' expertise could influence their performance on the SCST, a correlation analysis was performed considering the flight hours and the accuracy score of each task of the SCST. No significant correlations were found. Descriptive statistics and Pearson's correlation amongst the different variables are reported in Table 4.

	Min	*Max*	*M*	*SD*	*1*	*2*	*3*	*4*	*5*	*6*	*7*
SCST - Photo Task (1)	*5.00*	*7.00*	*6.80*	*.42*	*1*	*.05*	*.08*	*.06*	*.03*	*.01*	*.09*

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 30 April 2021 doi:10.20944/preprints202104.0790.v1

SCST - Figure Task (2)	*4.00*	*7.00*	*6.56*	*.68*	*.05*	*1*	*.08*	*-.03*	*.07*	*.08*	*-.07*
SCST - Sequence Task (3)	*2.00*	*7.00*	*6.19*	*1.08*	*.08*	*.08*	*1*	*.04*	*.36*	*.10*	*.02*
SCST - Map Description Task (4)	*2.00*	*7.00*	*5.96*	*1.83*	*.06*	*-.03*	*.04*	*1*	*.17*	*.03*	*-.09*
SCST – 3D Rotation Task (5)	*2.00*	*7.00*	*5.93*	*1.17*	*.03*	*.07*	*.36*	*.17*	*1*	*.006*	*.01*
SCST - Sum and Straighten Task (6)	*.00*	*6.00*	*3.12*	*1.20*	*0.1*	*.08*	*.10*	*.03*	*.00*	*1*	*-.06*
Flight hours (7)	*15.00*	*6000.00*	*724.11*	*1205.02*	*.09*	*-.07*	*.02*	*-.09*	*.01*	*-.064*	*1*

Table 4. *Descriptive statistics and Pearson's correlations among accuracy scores of the SCST tasks and flight hours.*

Finally, in order to evaluate whether the pilots' expertise could influence their performance on the SCST in terms of execution time, Pearson's correlation analysis was performed considering the flight hours and the execution time of each task of the SCST. The analysis showed that the Map Description Task positively correlated with flight hours (r=.247; p=.011). No significant correlations were found amongst the other task of the SCST and flight hours. Descriptive statistics and Pearson's correlation amongst the different variables are reported in Table 5.

	Min	*Max*	*M*	*SD*	*1*	*2*	*3*	*4*	*5*	*6*	*7*
SCST - Photo Task (1)	*10.01*	*86.03*	*27.40*	*13.36*	*1*	*.28*	*.45*	*.19*	*.14*	*.14*	*-.02*
SCST - Figure Task (2)	*18.00*	*260.00*	*65.95*	*37.35*	*.28*	*1*	*.180*	*.13*	*.18*	*.10*	*-.07*
SCST - Sequence Task (3)	*34.00*	*284.57*	*86.24*	*34.59*	*.45*	*.18*	*1*	*.38*	*.37*	*.36*	*.04*
SCST - Map Description Task (4)	*5.66*	*64.00*	*24.01*	*12.30*	*.19*	*.13*	*.38*	*1*	*.32*	*.15*	***.24***

SCST – 3D Rotation Task (5)	*23.00*	*200.94*	*76.60*	*35.40*	*.14*	*.18*	*.37*	*.32*	*1*	*.34*	*-.15*
SCST - Sum and Straighten Task (6)	*27.51*	*411.56*	*95.52*	*56.41*	*.14*	*.10*	*.36*	*.15*	*.34*	*1*	*-.11*
Flight hours (7)	*15.00*	*6000.00*	*724.11*	*1205.02*	*-.02*	*-.07*	*.04*	*.24*	*-.15*	*-.11*	*1*

Table 5. *Descriptive statistics and Pearson's correlations among execution time scores of the SCST tasks and flight hours. The correlation of interest is reported in bold.*

4. Discussion

In the present study, we investigated whether military pilots showed more survey navigational strategies than non-pilots and whether flight hours may explain in part the use of higher navigational strategies in this special population. It is known in literature that spatial training may enhance significantly performances ([49] for a review) and this is true also with respect to years of work experience, Maguire and co-workers [58-59] showed that London taxi drivers had a larger hippocampus than other categories as a result of their environmental knowledge, which was explicitly required even to obtain a licence to drive a taxi. Our results showed that in the military pilots the distribution of the navigational styles is different from that of the control group with respect to route and survey style users. Generally speaking, in the non-pilot population the most of individuals use route navigational strategies to move through the environment, a few individuals are landmark users, and equally a few individuals are survey users to demonstrate that there are a few people with little or no navigational skills and a few with excellent navigational skills. On the other hand, the ability to move around in the environment for humans is a skill that is learned in the very first months of life and perfected with practice. It is one of those skills in which a neurodevelopmental disorder (developmental topographical disorientation) has been described that can affect healthy individuals who fail to develop adequate navigational strategies [60-61]. On the other hand, there are also individuals who have strong navigational skills, explorers, orienteers, forestry guides and undoubtedly also pilots who, although they do not practice ground navigation, need to use quickly all those cognitive processes that are at the basis of the ability to navigate successfully in order to fly. A military pilot needs to be fast and accurate when mentally rotate a target, he has to learn fast a spatial configuration, he has to have an accurate mental environmental representation [62] and in general to have cognitive resources useful to process spatial information. Interestingly, we also found that even if military pilots are better in these skills already at the time of selection to enter the academy, certain aspects of navigation are influenced by flight hours, e.g. pilots with more flight hours spent more time in Map Description task with respect others. So also in the case of pilots, the effects of the work they do affect their skills, which increase over time. Survey users have a map-like representation regardless of their position, which implies the use of an allocentric perspective in which the mental representation of the environment exists in spite of the individual's position. That means a better ability to reach a planned goal, to find novel paths and shortcuts when the familiar route is not accessible and to have metric knowledge. It is also known that the relationship with the environment is reciprocal because the mental representation is modified whenever an environmental change occurs. A peculiar case that has been studied is the mental reorganisation that an individual is forced to do when due to a natural disaster the environment is completely changed. In that case the individual is exposed to a kind of intensive navigational training that leads him to relearn the environment. This is the case, for example, described by Piccardi et al. [63], who find that individuals exposed to the L'Aquila earthquake without psychological disorders have an increase in topographic memory capability resulting from the need to relearn the configuration of the surrounding environment. These data are in line with the fact that although pilots are certainly already individuals with a propensity for spatial orientation, as flight hours increase, some crucial navigational skills improve, at least in terms of speed of execution. The presence in our sample of more survey style users support data of past studies in which military pilots self-reported to use cardinal points to orient themselves, to visualize a path not in first-person perspective but like a map and to think about distances in meters. Our results are also in line with those found by Glicksohn and Naor-Ziv [55] in which they observed the presence of more field independent individuals in military population with respect to other populations. Considering the single tasks of the SCST, we found that military pilots outperformed non-pilots in two tasks: the Map Description Task and the Three Dimensional Rotation Task. In both tasks pilots are more accurate than non-pilots. When the execution times are considered, pilots appear slower than non-pilots in the Photo Task, the Figure Task, the Sequence Task, and the Map Description Task. It is important to point out that execution times are taken but the subjects are never told to be fast, but to be accurate, this could be an explanation for the slowness of execution of some tasks in the group of pilots it is as if in the absence of an explicit order of speed they preferred greater accuracy of execution. In fact, when they are specifically told to be fast, their performance outperforms that of the general population. In fact, Verde et al. [53] found that pilots are much faster than non-pilots in two-dimensional rotations. Differently, in the present study, we found no difference with non-pilots in terms of speed in three-dimensional rotations, but the instructions provided in the two studies were different, whereas in Verde et al [53] pilots were explicitly told to be accurate and fast here they were only told to be accurate. The present result is also in line with the data emerging in Verde et al [29] with respect to directional judgements, where pilots are slower in providing directional judgements but are much more accurate even when judgements are counter aligned.

 doi:10.20944/preprints202104.0790.v1

Undoubtedly, maintaining orientation during flight requires rotating in three dimensions with higher workload than spatial orientation in ground navigation and it is surely a critical skill for a flight expert. A military pilot has to have *navigational awareness* that requires to establish the geometries between egocentric and allocentric systems that would explain their attitude in mentally represent the environment like a map without considering their own position. To reach such awareness, the mental rotation ability in addition to triangulation, image comparison and translation represent the four fundamental cognitive operations necessary during the pilots' flight [64]. Considering our data, we can state that the flight expertise and specific flight training practiced by pilots would not seem to completely influence the type of ground navigational style, pilots self-perceived themselves as people with a good sense of direction also in ground navigation context (see [28]) and indeed they performed better than non-pilots several tasks characterizing the survey users. Surely, a high spatial attitude characterizes this special population, and it is certainly thanks to this attitude that they were able to pass the selection and enter the Academy. To all intents and purposes, our data seem to confirm what had emerged in some of our previous studies that professional experience has a minimal effect on the skills already present in this population. So in military pilots case it would be a selection bias that groups together for the purpose of carrying out this profession already individuals with high visuo-spatial skills.

Author Contributions: "Conceptualization, P.V., R.N., L.P.; methodology, R.N., M.G., A.B., M.P..; formal analysis, M.P., R.N., M.G.; investigation, M.G., P.V., L.C, G.A. ; resources, P.V.; data curation, M.P., M.G., A.B., L.C., G.A.; writing—original draft preparation, M.G., L.P.; writing—review and editing: all authors; visualization, M.P., P.V..; supervision, L.P., R.N., P.V. All authors have read and agreed to the published version of the manuscript

Funding: This research received no external funding

Conflicts of Interest: The authors declare no conflict of interest

References

1. Siegel, A.W.; White, S.H. The development of spatial representations of large-scale environments. *Adv. Child Dev. Behav*, **1975**, *10*, 9–55.
2. Tversky, B. Cognitive maps, cognitive collages and spatial mental models. In: Frank AU, Campari I (eds) Spatial information theory: a theoretical basis for GIS, proceedings COSIT'93. *Lecture Notes in Computer Science*, **1993**, 716, 14–24
3. Montello, D.R. *A new framework for understanding the acquisition of spatial knowledge in large-scale environments.* Oxford University Press, NewYork, **1998**, pp 143–154
4. Nori, R.; Piccardi, L. Familiarity and spatial cognitive style: how important are they for spatial representation? In: Thomas JB (ed) *Spatial memory: visuospatial processes, cognitive performance and developmental effects.* Nova Science, New York, **2011**, pp. 103-124.
5. Lawton, C.A. Strategies for indoor wayfinding: The role of orientation. *J. Environ. Psy*cjol. **1996**, 16, 137-145.
6. Dogu, U.; Erkip, F. Spatial factors affecting wayfinding and orientation: a case study in a shopping mall. *Environ. Behav.*, **2000**, 32, 731-755.

7. Bocchi, A.; Giancola, M.; Piccardi, L.; Palmiero, M.; Nori, R.; D'Amico, S. How would you describe a familiar route or put in order the landmarks along it? It depends on your cognitive style! *Exp Brain Res.*, **2018**, 236, 3121-3129.
8. Boccia, M.; Piccardi, L.; Di Marco, M.; Pizzamiglio, L.; Guariglia, C. Does field independence predict visuo-spatial abilities underpinning human navigation? Behavioural evidence. *Exp. Brain Res*., **2016**, 234, 2799-807.
9. Boccia, M.; Piccardi, L.; D'Alessandro, A.; Nori, R.; Guariglia, C. Restructuring the navigational field: individual predisposition towards field independence predicts preferred navigational strategy. *Exp Brain Res*., **2017**, 235, 1741-48.
10. Boccia, M.; Vecchione, F.; Piccardi, L.; Guariglia, C. Effect of Cognitive Style on Learning andRetrieval of Navigational Environments. *Front. Pharmacol*., **2017**, 8:496.
11. Boccia, M.; Vecchione, F.; Di Vita, A.; D'Amico, S.; Guariglia, C.; Piccardi, L. Effect of Cognitive Style on Topographical Learning Across Life Span: Insights From Normal Development. *Child Dev*., **2019**, 90, 462-470.
12. Nazareth, A.; Huang, X.; Voyer, D.; Newcombe, N. A meta-analysis of sex differences in human navigation skills. *Psychon Bull Rev*. **2019,** 5,1503-1528.
13. Lawton, C.A. (2001) Gender and regional differences in spatial referents used in direction giving. *Sex Roles*, ***2001***, 44, 321–337
14. Lawton, C.A, Gender, spatial abilities and wayfinding. In: Chrisler J, McCreary D (eds) *Handbook of gender research in psychology*. Springer, New York, **2010**, pp 317–341
15. Piccardi, L.; Risetti, M.; Nori, R.; Tanzilli, A.; Bernardi, L.; Guariglia, C. Perspective changing in primary and secondary learning: A gender difference study. *Learn. Individ. Diff*., **2011**, 21,114-118.
16. Piccardi, L.; Bianchini, F.; Iasevoli, L.; Giannone, G.; Guariglia, C. Sex differences in a landmark environmental re-orientation task only during the learning phase. *Neurosc. Lett*., **2011**, 503, 181-5.
17. Bianchini, F.; Verde, P.; Colangeli, S.; Boccia, M.; Strollo, F.; Guariglia, C.; Bizzarro, G.; Piccardi, L. Effects of oral contraceptives and natural menstrual cycling on environmental learning. *BMC Womens Health*, **2018**, 18(1):179
18. Palmiero, M.; Nori, R.; Rogolino, C.; D'Amico, S.; Piccardi, L. Sex differences in visuospatial and navigational working memory: the role of mood induced by background music. *Exp Brain Research*, **2016**, 234, 2381-9.
19. Nori, R.; Piccardi, L.; Migliori, M.; Guidazzoli, A.; Frasca, F.; De Luca, D.; Giusberti, F. Sex differences in learning real and virtual environments. *Comput. Hum. Behav*., **2015**, *48: 72-77*.
20. Moffat, S.D.; Zonderman, A.B.; Resnick, S.M. Age differences in spatial memory in a virtual environment navigation task. *Neurobiol Aging*. **2001,** 22, 787-96.
21. Ramanoël, S.; York, E.; Le Petit, M., Lagrené, K.; Habas, C.; Arleo, A. Age-Related Differences in Functional and Structural Connectivity in the Spatial Navigation Brain Network. *Front Neural Circuits*. **2019**, 13,69.
22. Li, A.W.Y.; King, J. Spatial memory and navigation in ageing: A systematic review of MRI and fMRI studies in healthy participants. *Neurosci Biobehav Rev*. **2019,** 103, 33-49.
23. Muffato, V.; Hilton, C.; Meneghetti, C.; De Beni, R.; Wiener, J.M. Evidence for age-related deficits in object-location binding during place recognition. *Hippocampus*, **2019,** 29, 971-979.
24. Fernandez-Baizan, C.; Diaz-Caceres, E.; Arias, J.L.; Mendez, M. Egocentric and allocentric spatial memory in healthy aging: performance on real-world tasks. *Braz J Med Biol Res*. **2019**,52,e8041.
25. Piccardi, L.; Nori, R.; Palermo, L.; Guariglia, C. Age effect in generating mental images of building but not common objects. *Neurosc. Lett*., **2015**, 602: 79-83.
26. Guzmán, J.F.; Pablos, A.M.; Pablos, C. Perceptual-cognitive skills and performance in orienteering. *Percept Mot Skills*. **2008,** 107, 159-64.
27. Piccardi, L.; Palmiero, M.; Bocchi, A.; Boccia, M.; Guariglia, C. (2019) How does environmental knowledge allow us to come back home? *Exp Brain Res*. **2019**, 237, 1811-1820.
28. Verde, P.; Piccardi, L.; Bianchini, F.; Guariglia, C.; Carrozzo, P.; Morgagni, F.; Tomao, E. Gender has no effect on pilots' navigational memory. *AMHP*, **2015**, 86, 103-111.
29. Verde, P.; Angelino, G.; Piccolo, F.; Carrozzo, P.; Bottiglieri, A.; Lugli, L.; Piccardi, L.; Nori, R. Spatial orientation and directional judgments in pilots vs. nonpilots. *AMHP*, **2018**, 89,857–862.
30. Verde, P.; Angelino, G.; Piccolo, F.; Carrozzo, P.; Piccardi, L.; Nori, R. Engineers' abilities influence spatial perspective changing, *IJEE*, **2019**, 1,106-113.
31. Weisberg, S.M.; Newcombe, N.S.; Chatterjee, A. Everyday taxi drivers: Do better navigators have larger hippocampi? *Cortex*, **2019,** 115, 280-293.
32. Lopez, A.; Caffò, A.O.; Bosco, A. Topographical disorientation in aging. Familiarity with the environment does matter. *Neurol. Sci*., **2018**, 39, 1519–1528

33. Nori, R.; Piccardi, L.; Maialetti, A.; Goro, M.; Rossetti, A.; Argento, O.; Guariglia, C. No Gender Differences in Egocentric and Allocentric Environmental Transformation After Compensating for Male Advantage by Manipulating Familiarity. *Front Neurosci*. **2018**, 28, 12:204.
34. Pazzaglia, F.; Cornoldi, C.; De Beni, R. Differenze individuali nella rappresentazione dello spazio e nell'abilità di orientamento: presentazione di un questionario autovalutativo. *GIP*, **2000**, 27, 627-650.
35. Pazzaglia, F.; De Beni, R. Strategies of processing spatial information in survey and landmark centered individuals. *Eur J Cogn Psychol*, **2001**, 13, 493-508.
36. Shelton, A.L.; Gabrieli, J.D.E. Neural correlates of encoding space from route and survey perspectives. *J. Neurosci.*, **2002**, 22, 2711–2717.
37. Shelton A.L.; Marchette S.A.; Furman A.J. A mechanistic approach to individual differences in spatial learning. *Psychol. Learn. Motiv*., **2013**, 59, 223-258.
38. Bocchi, A.; Palmiero, M.; Boccia, M.; Di Vita, A.; Guariglia, C.; Piccardi, L. Travel planning ability in right brain-damaged patients: two case reports. *Front. Hum. Neurosci.*, **2020**, *14:117.*
39. Bocchi, A.; Palmiero, M.; Piccardi, L**.** Travel planning in men and women. Who is better? *Curr. Psychol*., **2021**, 1-8
40. Nori, R.; Piccardi, L. (2015) I believe to be good in orienteering…but is that true? *Cogn. Process*., ***2015***, 16, 301-7.
41. Boccia, M.; Rosella, M.; Vecchione, F.; Tanzilli, A.; Palermo, L.; D'Amico, S.; Guariglia, C.; Piccardi, L. Enhancing Allocentric spatial recall in pre-schoolers through navigational training programme. *Front Neurosci*. **2017**, 11, 574.
42. Frick, A. Spatial transformation abilities and their relation to later mathematics performance. *Psychol Res.* **2019**, 83, 1465-1484.
43. Forloines, M.R.; Reid, M.A.; Thompkins, A.M.; Robinson, J.L.; Katz, J.S. Neurofunctional correlates of geometry and feature use in a virtual environment. *J Exp Psychol Learn Mem Cogn*. **2019,** 45, 1347-1363.
44. Nori, R.; Palmiero, M.; Bocchi, A.; Giannini, A.M.; Piccardi, L. The specific role of spatial orientation skills in predicting driving behaviour. *Transport. Res. Part F*, **2020**, 71, 259–271.
45. Bocchi, A.; Palmiero, M.; Nori, R.; Verde, P.; Piccardi, L. Does spatial cognitive style affect how navigational strategy is planned? *Exp. Brain Res*., **2019**, 237, 2523-2533.
46. Boccia, M.; Guariglia, P.; Piccardi, L.; De Martino, G.; Giannini, A.M. The detail is more pleasant than the whole: Global and local prime affect esthetic appreciation of artworks showing whole-part ambiguity. *Att. Percept. Psychophys*., **2020**, 82, 3266-3272.
47. Kozhevnikov, M.; Kosslyn, S.M.; Shepard, J. Spatial versus object visualizers: a new characterization of visual cognitive style. *Mem. Cogn*., **2005**, 33, 710–726.
48. Kozhevnikov, M. Cognitive styles in the context of modern psychology: Toward an integrated framework of cognitive style. *Psychol. Bull*., **2007**, 133, 464–481.
49. Uttal, D.H.; Meadow, N.G.; Tipton, E.; Hand, L.L.; Alden, A.R.; Warren, C.; Newcombe, N.S. The malleability of spatial skills: A meta-analysis of training studies. *Psychol. Bull*., **2013**, 139, 352–402.
50. Kozlowski, L.T.; Bryant, K.J. Sense of direction, spatial orientation, and cognitive maps. *J. Exp. Psychol. Hum. Percept. Perform.* **1977**, 3, 590–598.
51. Sholl, M.J.; Kenny, R.; Della Porta, K.A. Allocentric-heading recall and its relation to self-reported sense of direction. *J. Exp. Psychol. Learn. Mem. Cogn*. **2006**, 32, 516–533.
52. Piccardi, L.; De Luca, M.; Nori, R.; Palermo, L.; Iachini, F.; Guariglia, C. (2016) Navigational Style Influences Eye Movement Pattern during Exploration and Learning of an Environmental Map. *Front Behav Neurosci.* ***2016***, 29; 10:140.
53. Verde, P.; Piccardi, L.; Bianchini, F.; Trivelloni, P.; Guariglia, C.; Tomao, E. No gender differences in performing a mental rotation task among pilots. *Aviat., Space Enviro. Med*., 2013, 84 (7): 726-729.
54. Sutton, J.E.; Buset, M.; Keller, M. Navigation Experience and Mental Representations of the Environment: Do Pilots Build Better Cognitive Maps? PLoSONE, **2014**, 9(3), e90058.
55. Glicksohn, J.; Naor-Ziv, R. (2016) Personalityprofiling of pilots: traits and cognitive style. *Int. J. Personal. Psychol*., **2016**, 2, 7-14
56. Nori, R.; Giusberti, F. Predicting cognitive styles from spatial abilities. *Am J Psychol*, **2006**, 119, 67–86
57. Nori, R.; Giusberti, F. Cognitive styles: errors in the directional judgments. *Percept*., **2003**, 32, 307–320
58. Maguire, E.A.; Gadian, D.G.; Johnsrude, I.S.; Good, C.D.; Ashburner, J., et al. Navigation-related structural change in the hippocampi of taxi drivers. *Proc Natl Acad Sci U S A* **2000**, 97, 4398–4403.
59. Maguire, E.A.; Woollett, K.; Spiers, H.J. London taxi drivers and bus drivers: A structural MRI and neuropsychologicalanalysis. *Hippocampus*, **2006**, 16, 1091– 1101.

60. Iaria, G.; Bogod, N.; Fox, C.J.; Barton, J.J. Developmental topographic disorientation: case one. *Neuropsychologia* **2009**, 47, 30–40.
61. Bianchini, F., Incoccia, C., Palermo, L., Piccardi, L., Zompanti, L., Sabatini, U. et al. Developmental topographical disorientation in a healthy subject. *Neuropsychologia*, **2010**, 48, 1563–1573.
62. Casner, S.M. The effect of GPS and moving map displays on navigational awareness while flying under VFR. *Int. J. Appl. Aviat. Stud.* **2005**, 5(1): 153–165.
63. Piccardi, L.; Palmiero, M.; Bocchi, A.; Giannini, A.M.; Boccia, M.; Baralla, F.; Cordellieri, P., D'Amico, S. Continuous Environmental Changes May Enhance Topographic Memory Skills. Evidence From L'Aquila Earthquake-Exposed Survivors. *Front HumNeurosci*. **2019**, 7,12:318.
64. Aretz, A. J. The Design of Electronic Map Displays. *Hum Factors*, 1991, 33, 85-101.
65. Verde, P.; Boccia, M.; Colangeli, S.; Barbetti, S.; Nori, R.; Ferlazzo, F., Piccolo, F.; Vitalone, R.; Lucertini, E.; Piccardi, L. Domain-Specific Interference Tests on Navigational Working Memory in Military Pilots. *Aerosp Med Hum Perform*, **2016**, 87, 528-33.