# Bicycle Messengers: A Study of Mental Representations of the Environment and Experience

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## Abstract

The present study aim to evaluate the effect of experience gained from navigation-dependent careers on spatial memory performance of bicycle messengers (N = 21), regular cyclists (N = 20) and non-cyclists (N = 32), females (N = X) and Males (N = X). Also, analyse the predictive value of time spent as a bicycle messenger in spatial navigation performance of this group. Participants were recruited with convenience and snowball sampling technique and categorized into the different groups based on their self-report of bicycle usage. Their spatial memory was assessed with the Corsi Block test and three covariates were considered in the investigation: Spatial Ability (measured with the Mental Rotation Task), Cycling Frequency and the age of the participants. No significant mean differences were found between the three groups after controlling for the effect of the covariates. Although the time spent as a bicycle messenger and performance in spatial memory showed a strong and positive relationship, the months spent as bicycle messenger did not have a significant predictive value on the variance of spatial memory scores in those individuals. The present study acknowledges that navigation ability is a complex term and continued efforts are needed to understand factors that influence people's navigation performance.

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# Introduction

Navigation is a typical everyday experience that allows individuals to process information from the environment and interact with its demands, which is vital for their adaptation and survival (Bannerman et al., 2014). Successful navigation has been described in the literature as the ability to learn from the environment, by identifying cue features and associating them with self-motion action (Head and Isom, 2010). Impairments in this cognitive function can greatly affect the individuals' independent living and overall quality of life. Therefore, significant investigation has occurred into the possible interventions for cognitive decline in this area that may result in recovery of these functions. Equivalent importance has been provided in determining protective factors that could prevent the dysfunction from happening.

## The theory behind Spatial Cognition

Early studies on the domain of spatial cognition offered a theoretical approach still relevant in contemporary studies. This approach puts forward the idea that animals and humans, by experiencing and processing the environment stimuli, build a mental representation of the environment. This notion was initially conceptualized as Cognitive Maps by Tolman (1948), when studying the ability of rats to find new paths that lead them to food, once placed in a variety of mazes. Further investigations done by O'Keefe and Nadel in 1978 (Bannerman et al., 2014) and later supported by Wolbers and Hegarthy (2010) suggest that the environment it's encoded within two modalities: with an egocentric reference frame, where the stimuli location is determined in reference with the navigator and it allows the learning of fixed routes, or with an allocentric reference frame, where the encoding of the information is based on the location of other objects in the environment, considering also the relationship between those objects. The authors suggest that the allocentric modality allows the building of a flexible mental representation of the environment, which is not self-centred and it is stored in long-term memory (Bannerman et al., 2014; Burgess et al., 2002). Lastly, animal studies have provided evidence of the existence of place cells (particular cells that increased their firing rate in the hippocampus of rats, once located in a specific part of their environment) supporting the hypothesis that the hippocampus is where these cognitive maps are located, maintained and managed, playing an important role in spatial navigation (O'Keefe & Dostrovsky, 1971; Burgess et al., 2002; Lithfous et al., 2013).

As mental representations of the environment cannot be measured directly, attempts to study spatial cognition have focused on processes like Spatial Memory. This has been defined as the process of storage of cognitive maps that have been acquired through navigation, (Lithfous et al., 2013). The authors explain that at early stages of the building process of cognitive maps, our spatial working memory uses landmark locations and their relationships with other objects which then are stored in our long-term memory. Spatial Memory it is frequently analysed by comparing individual differences in visuospatial working memory performance in tasks like the Corsi Block Tapping Task (Furley & Memmert, 2008). However, a variety of tasks can be used to measure cognitive maps resulted from exposure to an environment, Hegarty et. al (2006). Mental Rotation tasks, which measure the ability of the individual to manipulate the mental representation of the environment (Cheng, 2016) has been linked to Spatial Memory, in particular with spatial working memory tasks (Muffato, 2006). This suggests a link between the two underlying processes of spatial cognition.

**Influence of rich environments in Spatial Cognition**

Brain plasticity, commonly referred in the literature as Cognitive reserve (Stern, 2000), it is considered to build upon environmental enrichment, while studies show that under this environmental condition there is more re-mapping of connections in the hippocampus. This highlights a synaptic plasticity outcome with great implication on the cognitive recovery of functions in post-stroke mice in Wang et al. (2018) study. In humans, a rich environment condition involves experiences where the person engages with difficult tasks or encounter activities that represent a challenge such as occupation complexity. On this respect, it has been demonstrated that occupation complexity has a positive relationship with the cognitive functioning of the person, where the strength of the association is moderated by the age of the individual (Kramer et al., 2004). More relevant to spatial cognition, several authors have explored the relationship between exposure to navigation tasks and navigation performance at different ages.

Findings have shown that training for theses tasks positively affects navigation performance across all ages in different cognitive. Therefore, this results notices the protective factor of training towards cognitive decrements (Lodven et al., 2012; Wenger et al., 2012).

These findings have a significant implication in developing investigations on spatial memory, as age seems to be a factor in successful navigation. More recent evidence on the elderly reveals that by the age of 60, people start experiencing neuron loss and vestibular decline, that in turn expands to their hippocampus, affecting their perception of speed and direction in self-motion, and therefore resulting in performance impairments in Visuospatial memory tasks (Lester et al., 2017). Forecasting investigations proposed that by the year 2050 the number of people affected with Alzheimer's Disease will be four times higher than it was in 2006. This forecast of 106.2 million people affected (Brookmeyer et al., 2007) highlights the real need of research to identify risks and protective factors associated with cognitive impairments. Brain plasticity studies are of great relevance for public health as they frequently demonstrate the resilience nature of the brain as it copes with the adversity of age-related cognitive declines and atrophies.

**Navigation Dependent Careers and Spatial Navigation Performance**

As shown in the evidence reviewed so far, training has been demonstrated to hold an important role in spatial navigation performance, however, this positive relationship is not only evident when the individual is trained in a specific spatial task. Recent investigations proposed that great exposure to different spatial activities could also result in greater performance in spatial navigation. On this note, navigation-dependent careers have been identified recently as an important variable to study as they represent a daily demand for navigation abilities from the individual that could in turn differentiate their mental capabilities in spatial memory from others with a different career. For instance, studies conducted with dentistry students demonstrated greater spatial performance at later stages of the career, where greater exposure and training on spatial tasks in previous years seemed to enhance the development of spatial models of teeth structure (Hegarty et al, 2009).

Recent investigations focused on individuals with navigation-dependence occupation, like taxi drivers (Maguire et al., 2000; Maguire, Woollett & Spiers, 2006; Burgess et al., 2002) and pilots (Sutton et al., 2014; Keller & Sutton, 2018), suggest an experience-dependent plasticity of the brain. Changes in the volume of grey matter distribution in the hippocampus of the taxi drivers were associated with years of navigation experience, and the use of complex mental representations of the environment as demanded by the career profile (Maguire, Woollett & Spiers, 2006). In contrast, Keller and Sutton (2018) found no significant differences between pilots regarding flying hours and spatial cognition performance, but overall, the pilot group demonstrated better recall of routes and accurate map representations when compared with non-pilots. Moreover, another study was done on experienced basketball players (which frequently encounter activities that required visuospatial working memory) and the control group did not demonstrate any difference in Visuospatial Working Memory measured with the Corsi Block test (Furley & Memmert, 2008). It is apparent that the findings in current research are conflicting and furthermore, very few studies have investigated the relationship between navigation-dependence careers and performance in spatial abilities and spatial memory, where other navigation-dependence occupations like, for instance bicycle messengers have yet to be studied in relation to this topic.

Bicycle messengers would seem to be an ideal sample for these studies due to the fact that their occupation is centred on learning routes and building accurate representations of the environment (Kidder, 2009). The job as a bicycle messenger involves fast-paced delivery of a variety of type of packages to various locations in metropolitan cities. One can assume that the knowledge of the city of bicycle messengers can differ from the knowledge of bus drivers and taxi drivers, as bicycle messengers use alleyways, small passages, main roads and bike lanes as shortcuts when mapping the most efficient delivery route. This is done by recognizing the shortest distance between different landmarks in the city and estimating how long it would take to hand-deliver the package (Lockfoot, 2015). In contrast with the job of taxi drivers, that have only one route per “delivery”, bicycle messengers may have packages with different urgency status, and the list of delivery request it is constantly updated along the day. Therefore, one could consider that the mental representations of the environment for bicycle messengers are frequently updating as the list of deliveries also change throughout the day.

A previous investigation conducted by Romanillos and Austwick (2015) on bicycle messengers, illustrated the cycling flow of bicycle messengers and regular cyclists in the city and reported behavioural differences between the two groups. While bicycle messengers cycle relatively the same along the day, regular cyclist density was mainly observed on-peak hours (commuting hours). Interestingly, the first group showed to ride on the main streets of the city through traffic, rather than using the bike lane. Finally, Kidder (2009) on his social research on bicycle messengers in New York, highlights the relationship between time and knowledge of the city. Such expositions, however, have failed to address this relationship empirically.

As aerobic exercise is an essential element of Bicycle messenger's profession, and there is evidence of the effect of exercise in spatial memory and navigation learning, it is pertinent to introduce relevant literature that can illustrate the empirical knowledge that can illustrate the nature of this relationship.

**Aerobic exercise and Spatial Memory**

Exercise has shown to increase neurogenesis and synaptic plasticity in the hippocampus of rats, enhancing their learning and memory, and special improvements observed in spatial memory performance once impaired (Senna, et al., 2017). Likewise, the introduction of exercise programs in rats have revealed greater latency and accuracy performance in a task similar to the water maze from Morris et al. (1982) when compared to a sedentary group (Fordyce & Farrar, 1991), and it has been also positively associated with increments of cerebral blood flow in the dentate gyrus, (an area of the brain associated with spatial memory) as reported by Pereira et al. (2007).

The effect of exercise in human health demonstrates consistent results with animal studies. Reviews of cross-sectional and longitudinal studies that used exercise intervention programs, found that engaging in aerobic exercise affects brain volume and functional connectivity in areas associated with affection in the pre-frontal lobe and spatial memory in the temporal lobe (Colcombe, et al., 2006), but also behavioural outcomes showed the training group outperforming controls in visuospatial memory tasks (Stroth et al., 2009).

Authors have proposed that frequency of engagement in physical exercise is associated with motor function and visuospatial abilities in people diagnosed with schizophrenia and healthy adults (Svatkova et al., 2015). Furthermore, they highlighted that the integration of exercise in the daily routine has a positive association with memory functioning as it acts as a protective factor for the ageing process (Flöel et al., 2010). Moreover, people change their routines and frequency of exercise activity at different points of their life. Researchers Ku et al. (2012) have investigated how the frequency of exercise activity varies at different points in an individual's life and cognitive cognitive decline rates were found to be associated with physical activity changes over time, individuals that engage in less physical activity were consider to be more at risk of cognitive decrement at old age. Additionally, studies show that the earliest the person starts engaging in physical exercise, the less likely they were to develop age-related cognitive declines later in life (Middleto et al., 2010), these results are similar to those reported by, Hotting et al. (2012) who writes that exercising in mid-adulthood could contribute to the cognitive reserve of the person, allowing adaptation to changes at later stage.

Overall, cycling as an aerobic activity has being used previously in intervention programs for post-stroke patients, showing promising results in relation to improvements in executive functions and spatial memory performance in the intervention group (Quaney et al., 2009). This was reflected in speed-feedback therapy studies with a bicycle ergometer for elderly patients with cancer (Miki & Okamyra, 2014) and in combination with virtual reality in a study for patients with brain injury (Grealy et al., 1999). Nevertheless, Holzschneider et al. (2012) highlight the importance of exercise and training and their combined influence on improvements in spatial navigation performance in their study. The authors found in their study that groups under spatial training did improve spatial performance and more interesting, that the group with the highest level of cardiovascular activity and that received spatial training outperformed the other groups. This evidence leads one to assume that exercise boosts cognitive function, but perhaps it has a moderator influence in the relationship between training/ great exposure to navigation tasks and the performance on those tasks.

**Rational of the current study & aims and hypothesis**

Overall, a myriad of studies proposed that high levels of cognitive functions are associated with cognitive stimulating activities and positively influenced by occupation complexity (Kramer, Bherer, Colcombe, Dong & Greenough, 2004), whereas navigation centred occupations have been linked with high activity in areas of the brain associated with spatial navigation and greater concentration of grey matter in the posterior hippocampus of taxi drivers, bus drivers and pilots. Notwithstanding, these individuals with great spatial experience gain from the occupation also evidenced better performance in navigation-related tasks than matching controls (Keller & Sutton, 2018; Maguire et al., 2000; Maguire, Woollett & Spiers, 2006; Sutton et al., 2014). Despite this evidence, few studies have investigated the role of navigation-dependent activities like cycling on spatial navigation performance, and up to date few empirical research has narrow the attention in navigation centred career as bicycle messengers, where the nature of the job requires the navigation skills of the individual every day for many hours a day, and spatial memory performance to succeed in the job.

A more integrated sample where females are considered is needed, as there are inconsistencies regarding the navigation abilities across gender. For instance, Burggraaf et al., (2017) found no difference in visuospatial memory performance by gender, while Zarantonello et al., (2019) found that females were slower on their reaction time performance on visuospatial working memory tasks.

It is uncommon to find studies conducted on spatial cognition that control for the effects of age, exercise or spatial ability. Base on the literature reviewed, these are variables that could influence the variance between groups of individuals on spatial memory, as expressed by Muffato (2006) old people seem to develop less efficient cognitive representations of the environment when compared with young people, findings that have been reported in many investigations (Middleto et al., 2010; Ku et al., 2012; Burggraaf et al., 2017). Moreover, by measuring the participant's frequency of engaging in aerobic activities like cycling, the influence of exercise can be controlled when investigating the differences between groups with regard to spatial memory performance. Finally, by measuring the spatial abilities of participants through a mental rotation task, it is possible to account for individual differences in spatial abilities that could affect the outcome of spatial memory performance.

The main question to address in the present investigation is: Do individuals with a navigation centred career as bicycle messengers differ on spatial memory performance when compared with non-bicycle messengers?

Due to the daily navigation demand of the bicycle messenger occupation it is assume in the present investigation that bicycle messengers will evidence better performance in spatial memory than regular cyclists and non-cyclists, once controlled by age, spatial ability performance and cycling frequency.

Furthermore, expertise and training have been suggested to improve cognitive abilities in adults (Keller & Sutton, 2018; Wenger et al., 2012), where years of experience in a career that demands constant engaging in navigation activities results in greater mental representations of the city (Maguire et al., 2006; Kidder, 2009; Burgess et al., 2002). Thus, a second hypothesis proposes that performance in visuospatial memory tasks will vary by the time spent as a bicycle messenger.

# Methods

## Participants

The sample size proposed for the present investigation consisted of 128 participants calculated with G*power 3.1 Software based on a priori analysis for ANOVA. The final sample of the study included 73 participants, males (n=52) and females (n=21), age (m= 35.34, sd=9.5). Participants naturally belonged to three different cyclist groups based on their self-report of bicycle usage: the Regular Cyclist group (n=20); the Non-Cyclist group (n= 32) and the Bicycle messenger group (n=21). One person was excluded from the analysis as the participant's wish to drop out of the investigation.

The exclusion criteria were presented in the information sheet, available in Appendix Section B. None of the participants meet the exclusion criteria and they were all over 18 years old. Participants were recruited using a non-probabilistic convenience sampling.

## Measures/Materials

The present study used google for self-report measurement, please see it annexed in Appendix section E. Participants were asked about their navigation experience, their age and gender and some of the questions were conditional. The questionnaire was anonymous and it contained the information sheet and consent form at the start.

The assessment of Spatial Ability and Visuospatial memory were performed using Inquisit 5 in a MacBook Pro 2011 with macOS Sierra operating system and with a Huawei Matebook Xpro with Windows 10 operating system.

### Mental Rotation Task

Spatial Ability was measured using the Mental Rotation Task developed by Gavis and Kievit (2015) based on Shepherd & Metzler (1971) mental rotation task. The stimuli in the task consisted of two 3D cubes presented side by side, one of the cubes was rotated 0deg, 50deg, 100deg or 150deg (see Appendix F). The task of the participant was to decide whether the cubes were the same or mirror images by pressing the key "D" if consider the cube figures were different or pressing the "S" key if consider the cubes represented the same object. On half of the trials, the two 3D cubes were the same besides the rotation; the order of the trials was randomized by the program. Participants were instructed to respond as fast as they could but not ignoring their accuracy. The test involved 96 trials in total, with 12 practice trials where participants were offered feedback on their selected answer (correct or incorrect) and on trial #48, the participant had a break and continue with the test when feeling ready. For the present investigation, the main outcome of interest was the accuracy score from the experiment trials, which was provided in percentage scores, the maximum score was 100% accuracy. The Mental Rotation task for 3D blocks has shown good internal validity and reliability with Cronbach Alpha's between 0.83 and 0.87 (Cheng, 2016).

### Corsi Block Tapping Task

Visual-spatial memory performance was assessed using the Corsi Block Tapping Task – Forward, a version developed by Schellig (2011) Vienna test system version. The test involves a practice trial and an experiment trial. On the experiment trial, the participant is presented with 9 blocks in a blank screen that light up in colour blue in a pre-set sequence, and the individual's task was to click on the boxes by recalling the order previously presented. The end of the sequence was followed by a "BIP" sound that notified the participants about their turn to respond. The initial sequence length was of 3 blocks lit in order and trials continue up to 8 blocks in the maximum level. Participants had three opportunities to respond correctly per trial, once responded correctly to one sequence, the next sequence started. Responding at least one of the three sequences correctly was sufficient for the next trial to follow. The test finished when the participant responded incorrectly three times in a row or when finished the last trial (8 blocks) (available at Appendix G and H). The Corsi Block Test shows good validity and internal reliability with Cronbach Alphas between 0.81 and 0.89 (Kober et al., 2013).

## Pilot

Prior to the recruiting process on the first week of December, a pilot study was conducted with one adult in order to provide feedback regarding the clarity of the instruction for each task, self-report questionnaire, information sheet and informed consent. Also, to understand how long the experiment lasts, how the software works and to evaluate if the output data were analysable. The instructions were provided in English and in Spanish to guarantee the same communication in both languages and potentially apply the test to participants with not proficient English. Some of the issues raised during the pilot study included a duplicate question within the google form questionnaire and the definition and expected answer of "mirror images" in the Mental Rotation Test were also addressed.

**Procedure**

The present study was carefully designed following the NCI Ethic guidelines and it was further reviewed by the National College of Ireland Ethics Committee. Following the approval from the ethics committee, the recruitment process started in the month of December by advertising flyers in physical locations (at the NCI student union and the first-floor student board, at Donaghmede Library, and at workplace, also by sharing the flyers with friends and acquaintance for distribution), previous authorization required for each organization, see Appendix Section J.

Also, online apps as WhatsApp, Facebook and Instagram were used to share the recruitment information online. People were also recruited using a snowball sampling and the recruitment process lasted 6 weeks. The exclusion criteria were detailed on the flyer information and once the participants emailed the researcher, a time and a place scheduled, posters are annexed in the Appendix Section I. Bicycle messengers were approached by providing the flyers in their usual meeting points at Saint Stephens Green park.

The test was conducted on the study rooms in National College of Ireland and in rooms with similar conditions outside the college (i.e. Library rooms, training rooms in the workplace) with a desk, great illumination and quietness.

Following a brief introduction, participants sat in front of the laptop with the researcher sitting beside. The information sheet was presented and the researcher read the informed consent out loud making sure there were no questions regarding the participant's volunteer role before proceeding with the study.

Once the cognitive test started, the researcher sat distant from the participant, unable to see the screen in order to control for any influence on the participant's answer. For the Corsi Block Test, participants were provided with a set of Headphones, as the task has an audible trigger. The instructions of each of the tasks were provided in English or Spanish by the researcher but also they could read them on the screen (only in

English). During the practice trials and after the culmination of it, the researcher asked if the participant understood the task.

The presentation order of the tasks was systematically counterbalanced to prevent order effect as suggested by Pickering et al. (2001) if one participant was presented first with the Mental Rotation Task, the following participant was presented with the Corsi Block test first and so on.

Finally, once the tests were completed, a debrief sheet was offered to the participants with their ID and the researcher informed them about the way to contact herself or her supervisor if more information was required about the study.

**Design and Data Analysis**

The present study entailed a quantitative analysis, specifically, an observational investigation with a cross-sectional, between-groups design as the Spatial Memory and Spatial Ability was recorded at a specific point in time.

The Independent Variable (IV) for the first hypothesis included the categorical variable, Cyclist group with three levels: Bicycle Messenger, consisted of adults with a career as bicycle messengers; the Regular Cyclist involved adults with a career different from bicycle messengers, and that cycle for commuting or/and leisure at least twice a week, these inclusion criteria follows the guidelines of previous systematic analysis and similar studies that divided groups of people based on how frequent participants engaged in aerobic activities (McDonnell et al., 2011; Holzchneider et al., 2012; Bug & Head, 2011); the Non-Cyclist were adults that reported no use of the bicycle for commuting or leisure, or alternatively, used the bicycle less than 2 times weekly and were not bicycle messengers. The Dependent Variable (DV) for both hypotheses was Spatial Memory (operationally defined as the Block Span score or the maximum number of blocks recalled incorrect order, performed on the Corsi Block Test). On the first hypothesis, three variables were statistically controlled by consider them as covariates: the age of participants (continuous variable), Spatial Ability (operationally defined as the percentage accuracy score obtained with the Mental Rotation Test) and Cycling Frequency (operationally defined as the usage frequency of the bicycle, due to commuting, leisure or as part of the job on a weekly basis).

The statistical conducted for the first hypothesis was a one-way Analysis of Covariance or ANCOVA, aiming to evaluate the variance of scores in Spatial Memory between the cyclist groups by statistically controlling for the Age of the participants, Spatial Abilities and Cycling Frequency. In order to evaluate the relationship between each covariance and the Independent Variable Cycling Groups, three one-way ANOVA was also conducted prior to the ANCOVA.

The second hypothesis involved a linear regression analysis with Career Length, (defined as months spend as a bicycle messenger) as the predictor and Spatial Memory as criterion variables to evaluate the predictive value of the career length in the variability of scores in the criterion variable.

A Pearson-moment Correlation coefficient was conducted to evaluate the correlation between the continuous variables and screening of the data was conducted to evaluate the distribution of residuals in the normal probability plot and scatter plot, where outliers will be identified if situated between -3 and 3 standard deviations. On the second hypothesis, one person was excluded from the analysis once identified as an outlier, the case was excluded statistically with the select case option in SPSS adding the condition of select all cases from Career Length variable if < of 200 months, with this procedure only bicycle messengers were included in the analysis.

# Results

## Descriptive Statistics

The present investigation involved N = 73 participants, where 28.8% were females (N = 21) and 71.2% were males (N = 52). Furthermore, the groups were identified as Non-Cyclists (N = 32), Regular Cyclists (N = 20) and Bicycle Messengers (N = 21), see Table 5 for Gender frequency in each group in Appendix section A.

Table 1

Descriptive statistics of all continuous variables

| | Mean (95% CI) | SE Mean | Median | SD | Range |
|---|---|---|---|---|---|
| Age | 35.34 (33.12-37.56) | 1.11 | 34 | 9.51 | 20-60 |
| Spatial Memory | 5.29 (5.07-5.50) | .11 | 5 | .92 | 3-8 |
| Spatial Ability | .82 (.78-.86) | .18 | .88 | .15 | .35-1 |
| Career Length | 56.05 (32.81-79.29) | 11.14 | 36 | 51.05 | 4-228 |
| Cycling Frequency | 3.47 (2.74-4.2) | .37 | 3 | 3.13 | 0-7 |

*Note*. CI = Confidence Interval for mean differences; SE = Standard Error Mean; SD = Standard Deviation. N = 73 for Age, Spatial Memory and Spatial Ability; N = 21 for Career Length.

Table 2

Skewness and Kurtosis values of all continuous variables

| | Skewness | Kurtosis |
|---|---|---|
| Age | 1.02 | .7 |
| Spatial Memory | .49 | 1.03 |
| Spatial Ability | -1.18 | .64 |
| Career Length | 2.07 | 5.69 |
| Cycling Frequency | .05 | -1.87 |

Kolmogorov-Smirnov analysis was applied on continuous variables to evaluate the assumption of normality, and it result in significant values of $p<0.05$ for all variables but Career Length ($p = .054$). See Table 6 for detailed information in Appendix Section A. However, the Skewness and Kurtosis value are situated within the range of -3 and 3, which indicates acceptable values to consider the distribution as normal, detailed information can be find in Table 2 and the in Appendix Section A, Figures 5 to Figure 10 for Histograms displaying distribution of the variables.

**Inferential Statistics**

Previous to the ANCOVA analysis for the first hypothesis, the influence of the Independent Variable (Cycling Groups) on each of the covariates was evaluated by conducting three one-way ANOVAS, one for each covariate.

The fist one-way analysis of variance was conducted to explore the mean age differences between cyclist groups (Non-Cyclists, Regular-Cyclists and Bicycle Messengers). There was a statistically significant difference at the $p < .05$ in mean age for the three groups: $F (2,72) = 9.25$, $p < .001$. However, the effect size calculated with Eta Square was .21 suggesting that the actual differences between means of age was medium to small. Post-Hoc comparison using the Tukey HSD test indicated that the mean age for the Non-Cyclist group ($M = 40$, $SD = 10.37$) was significantly different from Regular Cyclists ($M = 33.5$, SD = 8.12) and from the Bicycle Messenger group (M = 30, SD = 5.3). The Regular Cyclist group did not differ significantly from the Bicycle Messenger group on regard of mean age, see Figure 1 for a bar graph representation of the mean differences on age between groups.

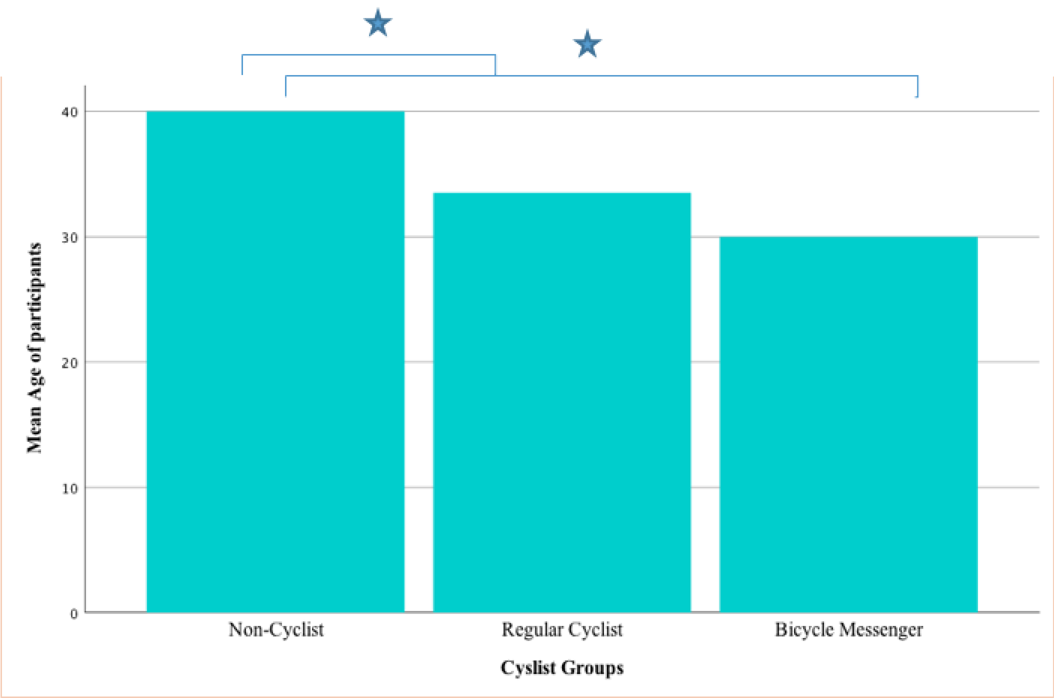


*Figure 1.* Difference on mean age between groups.

The second analysis of variance evaluated the group differences on Spatial Ability mean scores. Finding no statistically significant difference at the $p < .05$ in mean accuracy scores of Spatial Ability for the three groups: $F(2,72) = .31$, $p = .73$. An Eta Square of .009 indicates a very small effect size between the mean scores of the three groups. Figure 2 evidence the mean differences between groups.

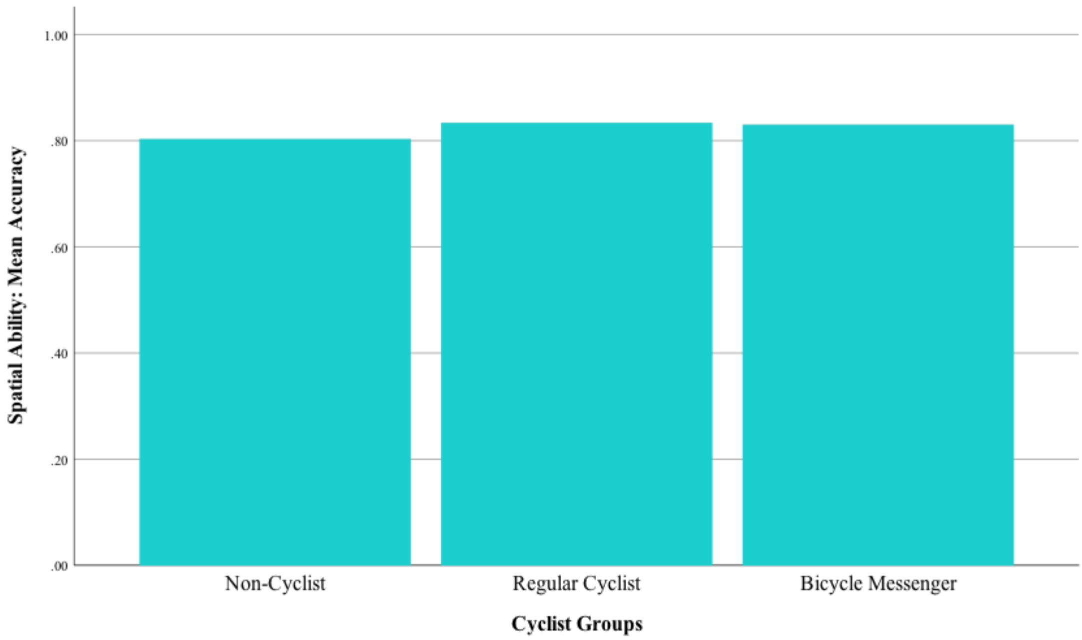


*Figure 2.* Difference on mean accuracy in Spatial Ability test between groups.

A third one-way ANOVA was conducted to evaluate mean differences on Cycling Frequency between the three cyclist groups. There was a statistically significant difference at the $p < .05$ in cycle frequency mean for the three groups: $F(2,72) = 221.34$, $p < .001$. The effect size calculated with Eta Square was .86 suggesting a big effect size. Post-Hoc comparison using the Tukey HSD test indicated that the cycling frequency mean for the Non-Cyclist group ($M = .25$, $SD = .44$) was significantly different from Regular Cyclists ($M = 5.25$, $SD = 1.86$) and from the Bicycle Messenger group ($M = 6.67$, $SD = 1.11$). The Regular Cyclist group also differ significantly from Bicycle Messengers on regard of cycling frequency mean, as it can be evidenced on Figure 3.

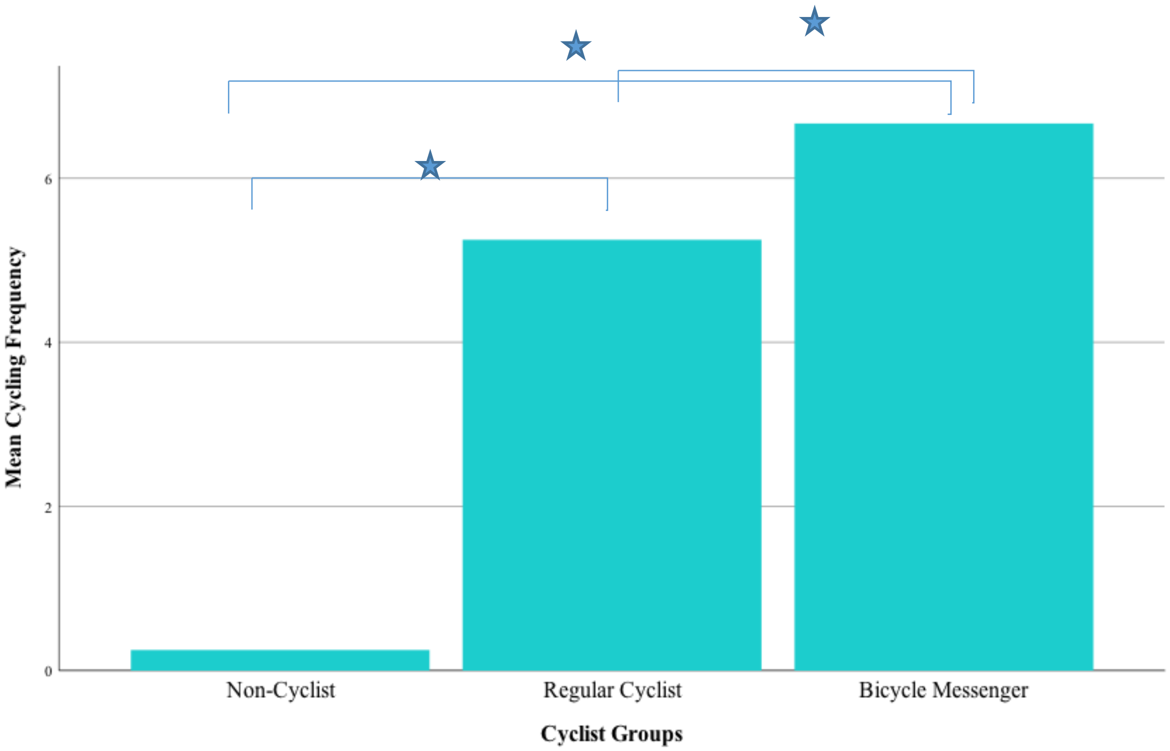


*Figure 3.* Difference on Cycling Frequency mean between groups.

As two of the covariates (Cycling Frequency and Age) seem to be affected by the cyclist groups, the results from the Analysis of Covariance should be interpreted with caution, as by controlling for the influence of the covariates may also remove some of the effect of the independent variable on the dependent variable, the model may not be that sensitive to identify differences between the groups.

A one-way between groups ANCOVA was conducted to test the null hypothesis that cycling groups are equal in regard to Spatial Memory scores while statistically controlling for Age, Spatial Ability and Cycling Frequency.

Preliminary checks were conducted to ensure no violation of the assumptions of normality, linearity, homogeneity of variances, homogeneity of regression slopes and reliable measurement of the covariates. First, a Pearson product-moment correlation coefficient was conducted to evaluate the correlation between the covariates, and a non statistically significant negative correlation was found between Age and Spatial Ability scores ($p = -.085$) and the strength of the correlation was weak; between Age and Cycling Frequency the correlation wasn't strong either, where a statistically significantly negative correlation was found ($p = .38$). Finally, the correlation between the covariates Spatial Ability and Cycling Frequency was also weak, showing a negative relationship between the two variables (p = 05) and the correlation was no statistically significant.

The assumption of linearity was assessed with Scatterplots, displaying the relationship between the covariates Age, Spatial Ability scores and Cycling Frequency and the dependent variable Spatial Memory in each group, see Figure 11 to Figure 21 in the Appendix section A. Moreover, the assumption of homogeneity of regression slopes was evaluated in order to aiming to study if the relationship between the covariate and the dependent variable in each group was the same. This assumption was statistically assessed by evaluating the significant interaction between the covariates and the independent variable Cyclist Group. The level of interaction between Age and Cycling Group was not significant (p = .602), neither was the relationship between Spatial Ability and Cycling Group (p = .334), which doesn’t represent a violation of the assumption of homogeneity of regression slopes. Finally, the assumption of equality of variance was evaluated with the Levene’s Test and the significant value was greater than .05 (p = .976), which means that the variability its equal across groups.

Once the ANCOVA vas conducted and after adjusting for Age, Spatial Ability Scores, and Cycling Frequency, there was no significant difference between the three Cyclists Groups on the Block Span scores for Spatial Memory (F (2,67) = 2.06, p = .14), partial eta squared = .06 which indicates that only 6% of the variance in Spatial Memory scores are explained by the cyclist group that Individual belongs to. Additionally, the relationship between the dependent variable Spatial Memory and the three covariates while controlling for the independent variable, cyclist group were not significant, with Age and Spatial Ability each predicting 4% of the variance in the dependent variable ($\eta 2$ = .04) and cycling frequency predicting 0.4% of the variance in Spatial Memory ($\eta 2$ = .004). See Table 3 for detailed information of the group difference mean scores on spatial memory (unadjusted mean) and mean when controlling for covariates.

Table 3

Group differences on Spatial Memory Scores (Block Span)

| Group | N | Unadjusted Mean | SD | Adjusted Mean | SE | F | $\eta^2$ |
|---|---|---|---|---|---|---|---|
| Non-Cyclists | 32 | 5.09 | .86 | 5.34 | .34 | 2.65 | .06 |
| Regular Cyclists | 20 | 5.10 | .85 | 4.97 | .25 | | |
| Bicycle Messengers | 21 | 5.76 | .94 | 5.51 | .36 | | |

*Note.* SD = Standard Deviation; SE = Standard Error; $\eta^2$ = eta square.

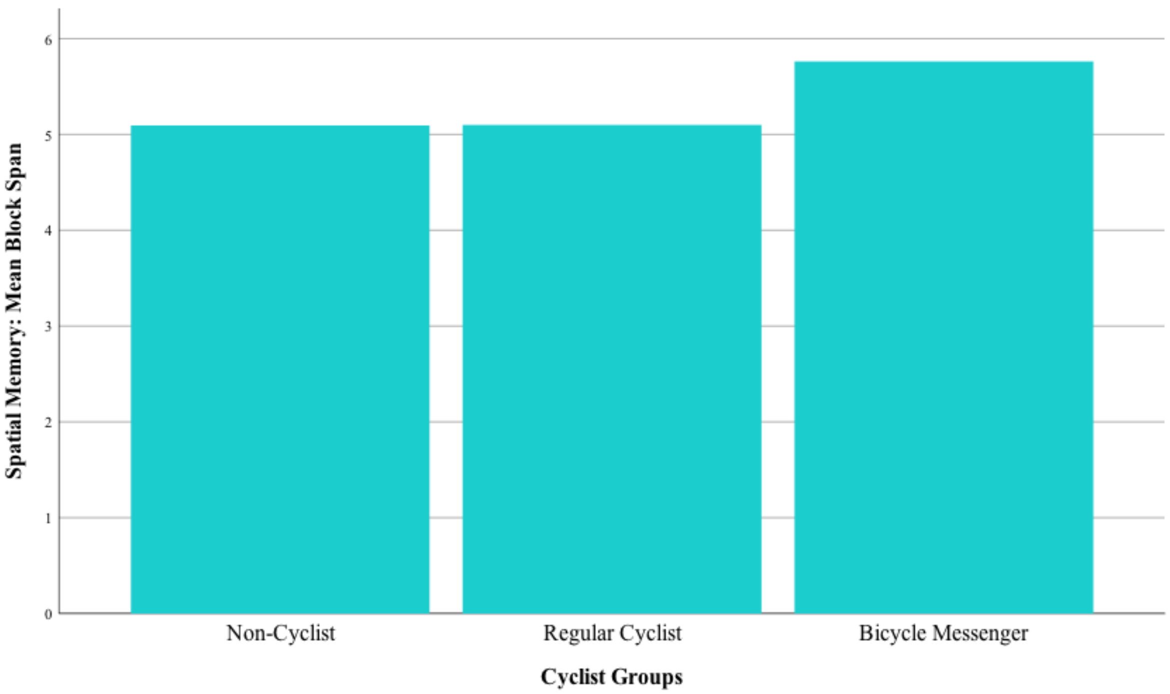


*Figure 4.* Difference on mean scores of Spatial Memory between groups.

For the second hypothesis, a linear regression was conducted to evaluate how well the career length of the bicycle messengers group predicts the variability in Spatial Memory Scores.

Preliminary analyses were conducted to ensure no violation of the assumptions of normality, linearity, multicollinearity and homoscedasticity. The sample size meet the criteria stablished by Stevens (1996, p. 72), as the predictor includes over 15 participants. Outliers were excluded from the analysis and normality, linearity, homoscedasticity and independence of residuals were evaluated with Normal

Probability Plot (P-P) and Scatterplot of the regression standardised residual, for more detail see Figure 22 and Figure 23 in the Appendix section A. As the model only included one predictor, the assumption of multicollinearity and singularity was not violated. A positive correlation was found between Career Length and Spatial Memory with medium strength (R = .33), for a full disclosure of the correlation between the Predictor and Criterion see Table 7 in the Appendix section A.

The predictor variable Career Length explained 11% of the variance in the criterion variable Spatial Memory ($F (1, 18) = 2.18$, $p = .16$), with an $R^2$ of .11. Participant's predicted Spatial Memory is equal to 5.3 + .01 Block Span when Career Length is measured in months. Participant's Spatial Memory increases .01 for each month working as a bicycle messenger. Overall, the model didn't predict the variance of Spatial Memory scores at a statistically significant level ($p = .16$)

Table 4

Linear regression model predicting Spatial Memory scores

| | $R^2$ | Adj $R^2$ | β | B | SE |
|---|---|---|---|---|---|
| **Model** | .11 | .06 | | | |
| Career Length | | | .33 | .01 | .01 |

Note. $R^2$ = R-squared; Ajd $R^2$ = Adjusted R-squared; β = standardized beta value; B = unstandardized beta value; SE = Standard errors of B; Statistical significance: *p < .05; **p < .01; ***p < .001

## Discussion

The present investigation aimed to evaluate the influence of experience grained from navigation-dependence careers on the spatial memory performance of bicycle messengers compares with regular cyclists and non-cyclists in order to understand how accurately this individual build and recall cognitive maps.

Contrary to expectations, the results of this study indicate no significant differences between bicycle messengers, regular cyclists and non-cyclists, once the age of the participants, their cycling frequency and spatial abilities where kept constant. Small differences were evident in the mean scores of spatial memory between the groups, where bicycle messengers showed greater scores in Spatial Memory compared with the other two groups, however, it is important to acknowledge that the magnitude of these differences was very small and the results rather suggest that this differences may be due to chance, where the null hypothesis of no differences is more likely.

These results differed from the outcome of the taxi driver study (Maguire et al., 2000; Maguire, Woollett & Spiers, 2006; Burgess et al., 2015) and the pilots study (Sutton et al., 2014; Keller & Sutton, 2018) who found that individuals whose career is navigation-dependent are better at building and recalling cognitive maps than the control group. The results suggest that bicycle messengers have similar recall of the spatial representations of the environment when compare with individuals who don't share the same navigation-dependent career, therefore it could be assumed that irrespective of the navigation demand from the job, bicycle messenger's abilities in relation to building and recalling of cognitive maps do not differ from other individuals with a different career. This is in accordance with early observations from Furley and Memmert (2008) with basketball players, that found no significant differences in mean scores between the groups of study and matching controls.

Further analysis of the results in Maguire et al. (2000; Maguire, Woollett & Spiers, 2006) study on taxi drivers proposed that taxi drivers may have a better memory than non-taxi drivers only in old cognitive maps, but not better recall for new representations of the environment. Considering that the Corsi Block tests demands participants to update the new location of the blocks per trial as expressed by Burggraaf et al.

(2017), a possible explanation for the present investigation's results might be that bicycle messengers are no better than non-bicycle messengers in recalling new mental representations. This provides premise for further investigations in relation to differences between bicycle messengers and non-bicycle messengers on the recall of old cognitive maps.

Results from the present study may indicate that participants in the present investigation obtain their navigation experience from differences sources: bicycle messengers and regular cyclists by cycling frequently in the city, and non-cyclists by navigating in their environment through walking or driving. In the Non-cyclists group, 65% drive at least twice a week for their commuting.

These findings may be limited by the interaction of the covariates (age and cycling frequency) and the cyclist groups. There was a large variance in age between the groups, where the non-cyclist group showed an average age difference of 7.5 years with the regular cyclists and around 10 years of average age difference with bicycle messengers, cyclist being the youngest group. The influence of age in cognitive function has been repeatedly highlighted by many researchers (Ku et al., 2012; Middleto et al., 2010), and previous investigation have noticed that performance in the Corsi Block task showed to be especially sensitive to the age of the individuals (Burggraaf et al. (2017). Therefore, differences between groups on mean age could be expected to influence the relationship between the Independent Variable (Cyclist Groups) and Spatial Memory scores. In addition to this, the covariate Cycling Frequency, significantly differ between groups, as expected because two groups were cyclists. By controlling for the effect of the covariates in the model, it is possible that the influence of the Independent Variable over the Dependent Variable could be obscure, compromising the interpretation of the statistical analysis.

The findings did not support the second hypothesis that stated that time spent as a bicycle messenger will predict the variance in spatial memory scores in bicycle messengers. While there was a positive relationship between this time in the job and scoring higher in the Spatial Memory test as suggested by previous studies (Maguire, Woollett & Spiers, 2006; Kidder, 2009; Burgess, Maguire & O'Keefe, 2015), this relationship was not significant. Moreover, the predictive level of Career Length over Spatial Memory variance of scores was not statistically significant either, which contrast with previous analysis on the relationship between time spent on the navigation-dependent career and navigation performance. Yet, this result is congruent with previous reports on flying hours and spatial cognition performance (Keller & Sutton, 2018) and contrasting with the results of Maguire, Woollett and Spiers (2006). Due to the discrepancies of the findings reported in previous studies, no conclusion can be driven on this regard in the present investigation, further analysis is needed to address the relationship of time spent in a navigation-dependent career and performance in different cognitive tasks related to navigation. Finally, it was not possible to evaluate differences between gender due to the lack of female participation in the study, especially in the bicycle messenger group, where only one female participant volunteer to take part.

Further research should consider recruiting participants of the same age for each group, to avoid discrepancy between the groups regarding the age that could affect the outcome of the analysis, and bigger sample size in order to increase the power of the study to identify possible mean score differences between groups. Perhaps studies outside of Ireland would be of benefit, as more bicycle messengers work in bigger cities that Dublin. For instance, in New York city there are hundreds of bicycle messengers working for different companies within that city (Kidder, 2009). Regarding the levels of aerobic exercise (measured as cycling frequency), further investigations may include other types of aerobic activities, like running or swimming into their studies. In addition to this, a widely used measurement of cardiovascular fitness like The Maximal Oxygen Update can be implemented as an alternative to self-report measures of physical activity (Holzschneider et al.,2012). Moreover, in other writings within this area measures of variables like level of education, leisure activities that the individual engages, music skills and career as their influence in cognitive functions have been suggested to be representative (Kramer et al., 2004).

A benefit from using the Corsi block test is the variety of outcome data that the tool offers. Future investigation should make use of this extra information that extends on the interpretation of spatial memory performance. For instance, it has been suggested by Burggraaf et al. (2017) that if the number of errors and type of errors made during the test is collected, this information could inform about the strategy used by the participant when recalling the order sequence of the objects. Lastly, a more effective way of studying the cognitive maps of bicycle messenger could be with a longitudinal design, also including a control group of regular cyclists. With this design measures of navigation, performance could be more sensitive to appreciate differences across time within the same individual, that is not evident with a cross-sectional design. For instance, one possible relationship of study could be if years in the job as a bicycle messenger affect their spatial memory among other spatial abilities at different ages, therefore, a person that has worked as a bicycle messenger for 5 years since the age of 18, might perform differently than a bicycle messenger with the same years of experience but later involvement in the career. Another possible analysis can be if there are peaks of spatial memory performance at certain points in time within the career, or if the performance gradually improves with the time on the job.

This is one of the first studies documenting the relationship of navigation-dependent careers such as bicycle messengers, in the build and recall of cognitive maps. Further investigation is needed to expand on how this career influences an individual's spatial abilities. This paper's contribution acknowledges that navigation abilities are not a neither/or variable that is only acquired by engaging in specific activities such as those utilised in navigation-dependent careers. Rather, it seems to be a more complex term and continued efforts are needed to understand factors that influence people's navigation performance like the way people navigate in their environment, strategies implemented to remember a route, the type of career they engage among others.

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# Appendix

**Appendix A.** Figures and Tables

Table 5

Gender and Driving Frequencies per group

| | Females | Males | Driving for commuting (Percentage) | N |
|---|---|---|---|---|
| Non-Cyclists | 12 | 20 | 65.6% | 35 |
| Regular Cyclists | 8 | 12 | 20% | 20 |
| Bicycle Messengers | 1 | 20 | 9.5% | 21 |

Table 6

Test of Normality: Kolmogorov-Smirnov

| | Statistic | df | Sig. |
|---|---|---|---|
| Age | .14 | 73 | .000 |
| Spatial Memory | .25 | 73 | .000 |
| Spatial Ability | .2 | 73 | .000 |
| Career Length | .19 | 21 | .001 |
| Cycling Frequency | .23 | 73 | .000 |

*Note.* CI= Confidence Interval for mean differences; SE= Standard Error Mean; SD= Standard Deviation.

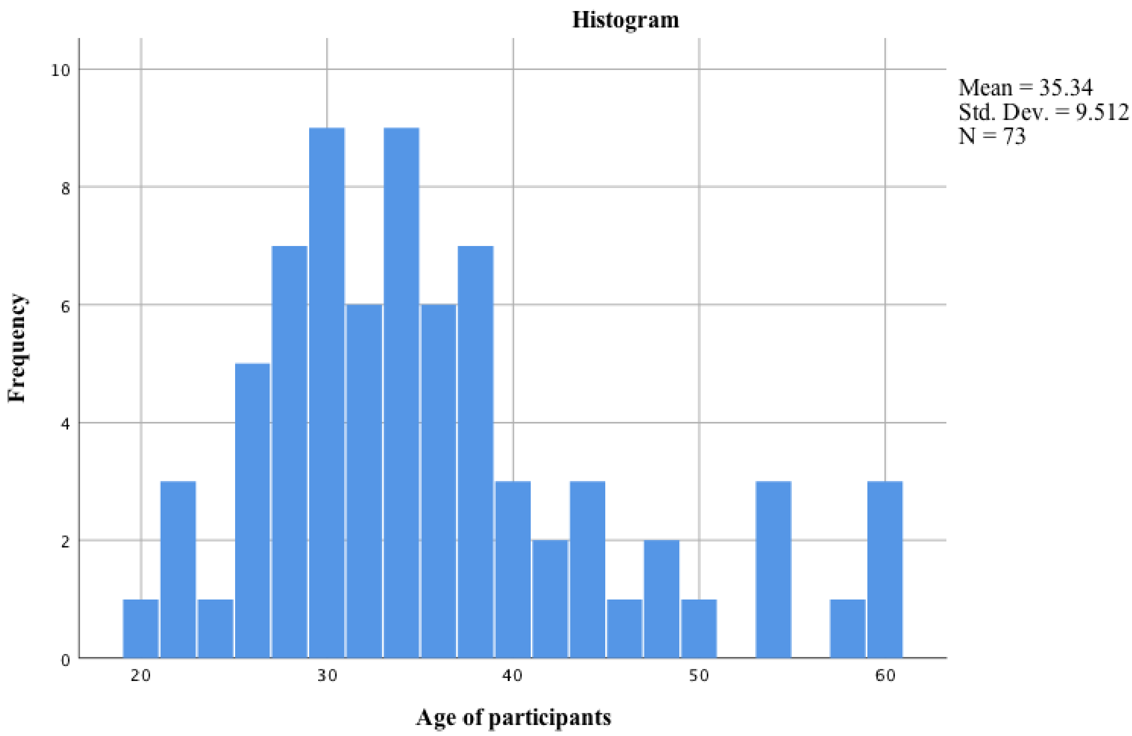



*Figure 5*. Frequency distribution of predictor variable Age.

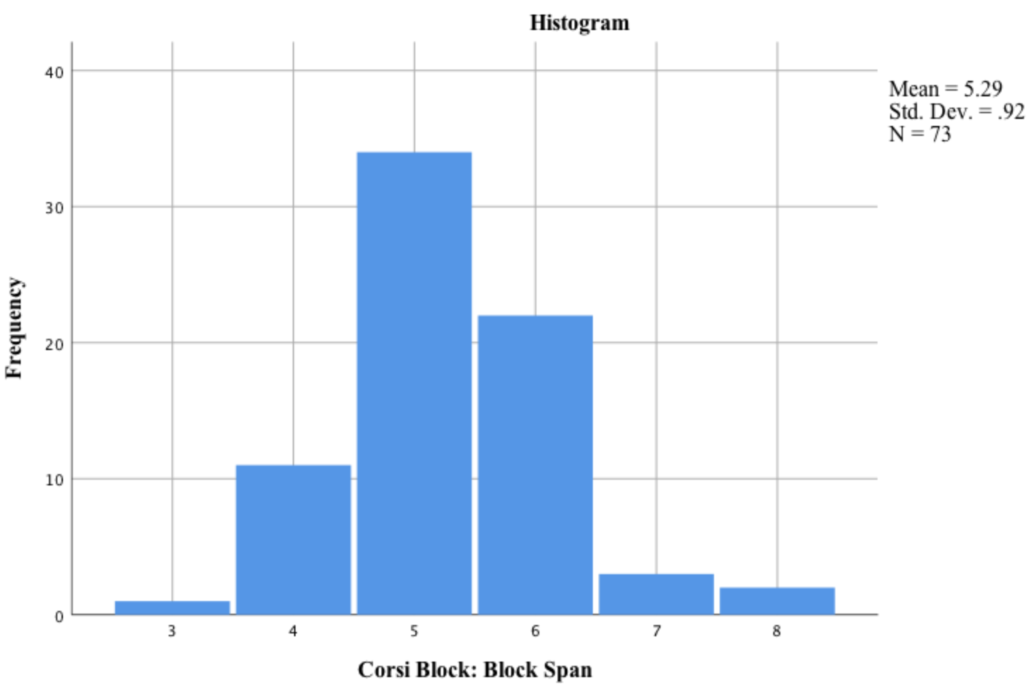



*Figure 6*. Frequency distribution of variable Block Span.

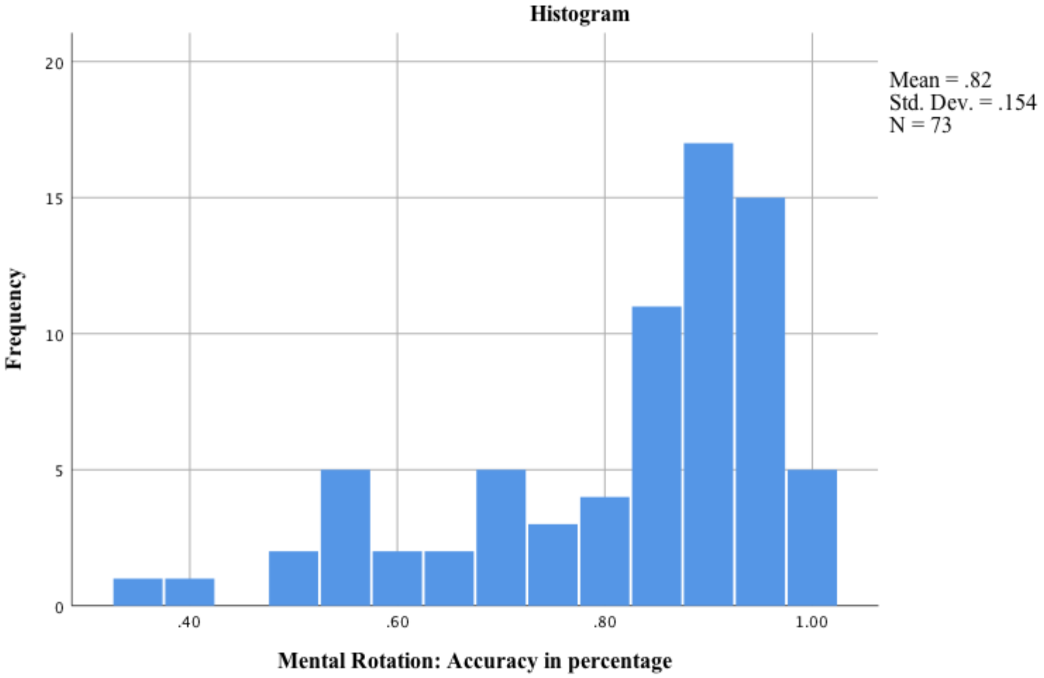



*Figure 7.* Frequency distribution of variable Mental Rotation.

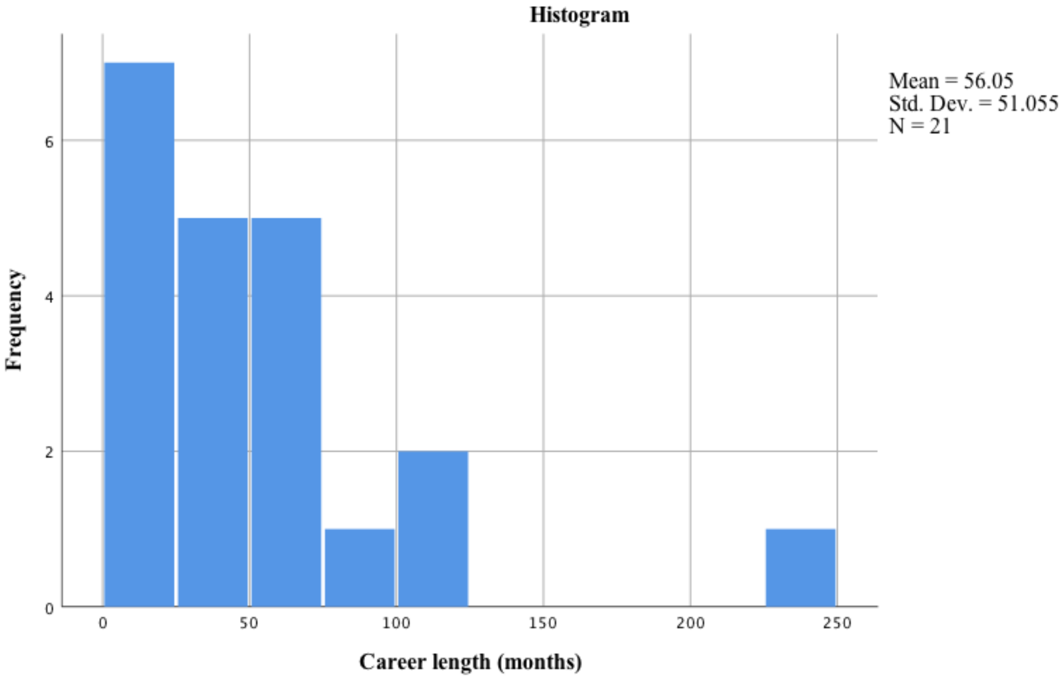



*Figure 8.* Frequency distribution of variable Career Length.

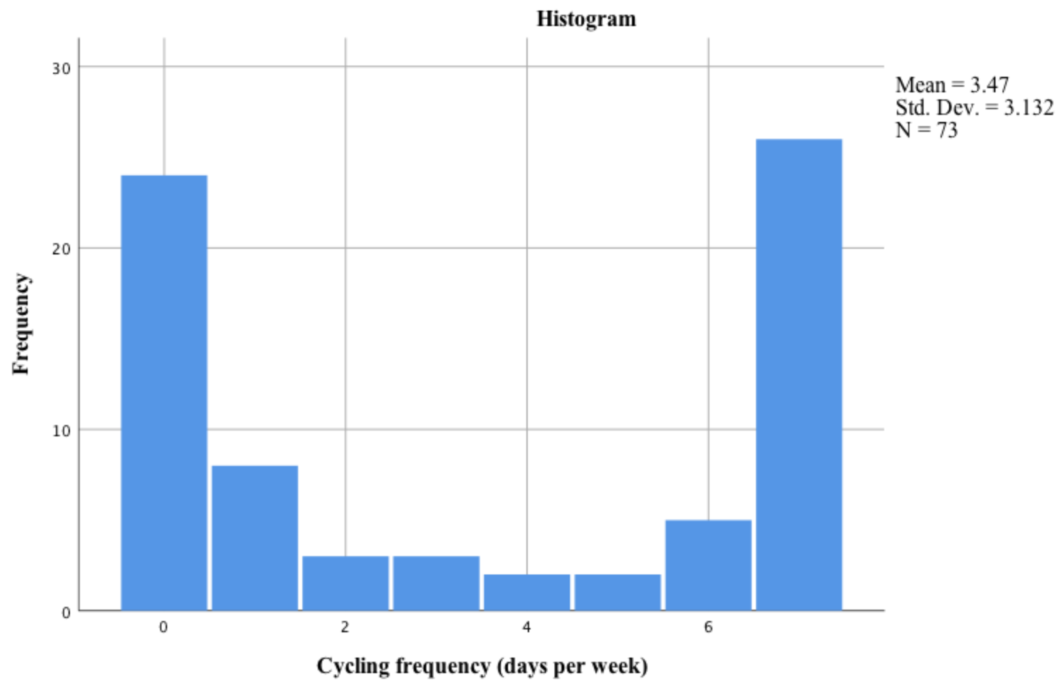



*Figure 9.* Frequency distribution of predictor variable Cycling frequency.

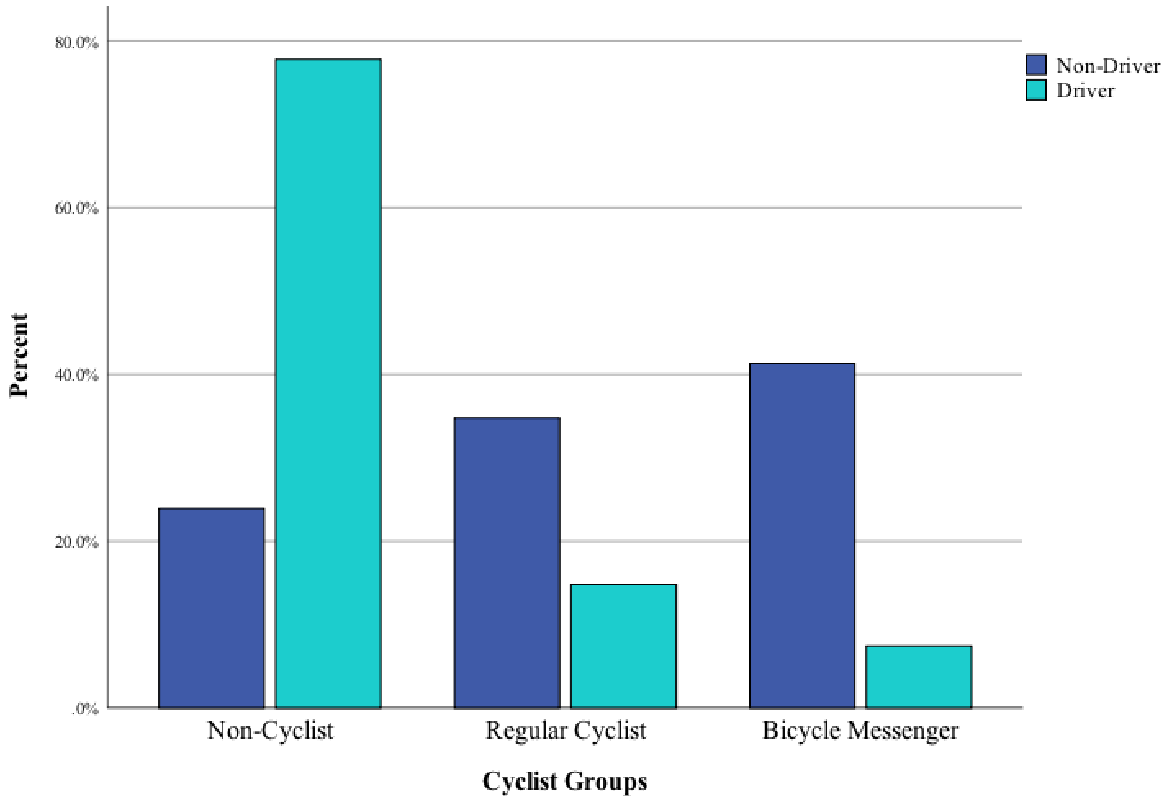



*Figure 10.* Frequency distribution (in percentage) of driving experience between groups

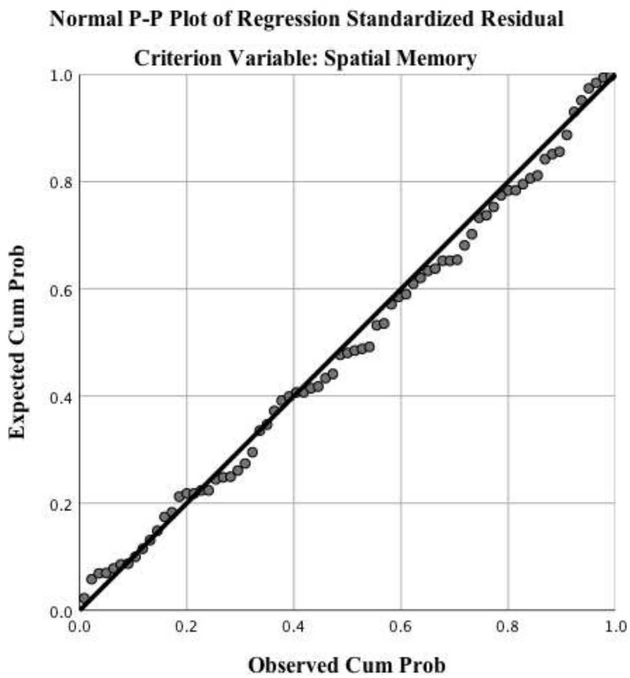



*Figure 11*. Normal probability plot of the regression standardized residual of the variable Spatial Memory.

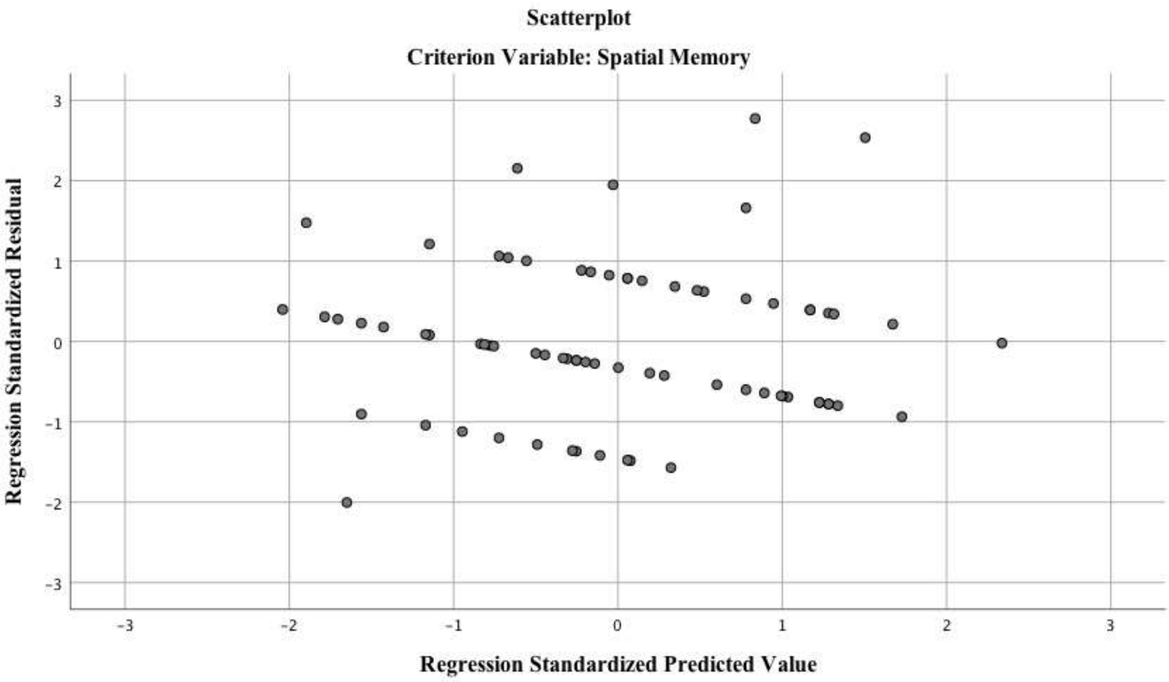



*Figure 12*. Scatterplot of the regression standardize residual for the variable Spatial Memory.

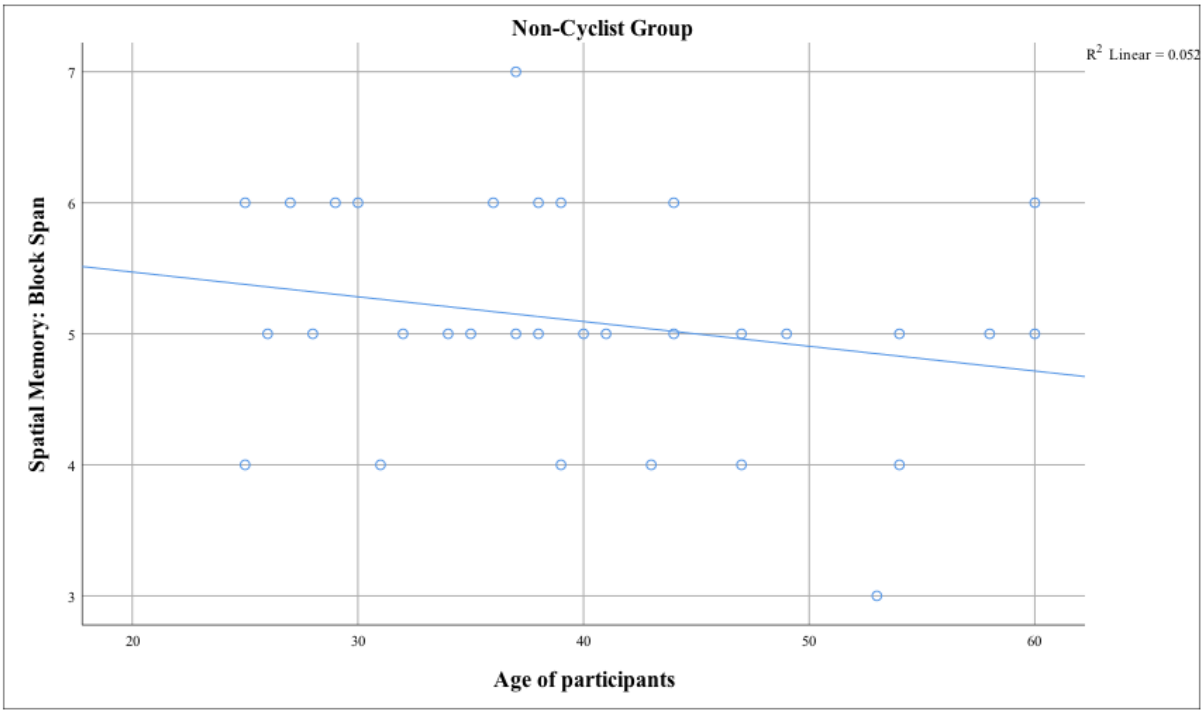



*Figure 13.* Scatterplot of the covariate Age and the dependent variable Spatial Memory in the Non-Cyclist Group.

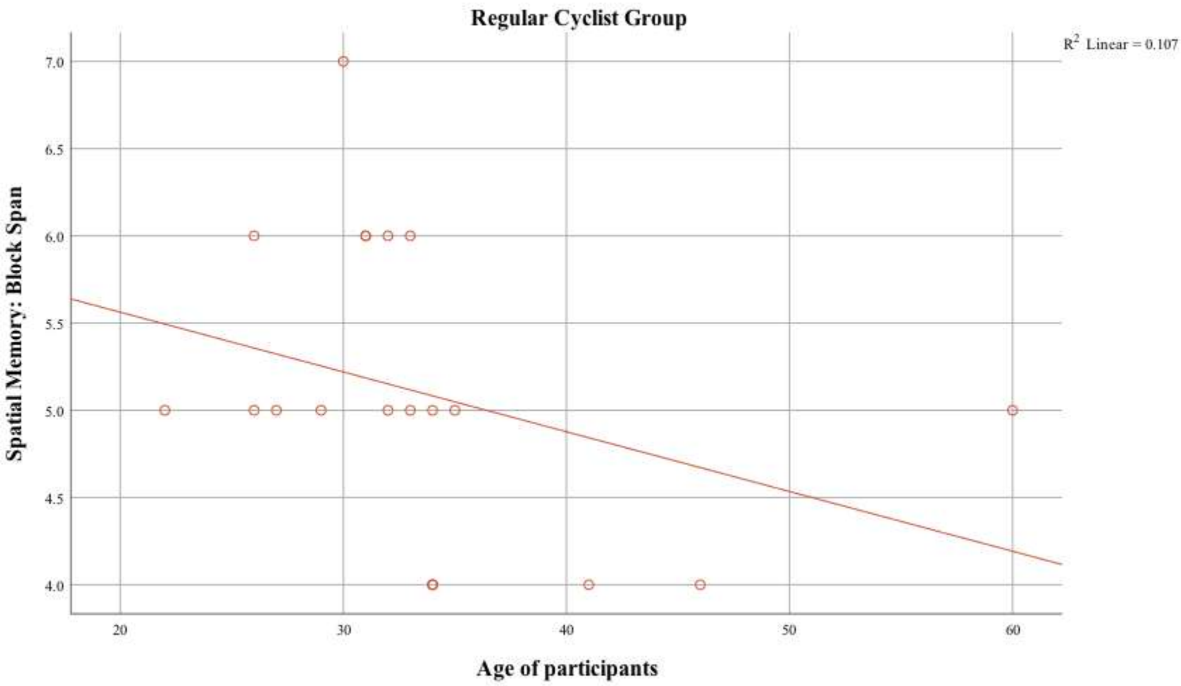



*Figure 14.* Scatterplot of the covariate Age and the dependent variable Spatial Memory in the Cyclist Group.

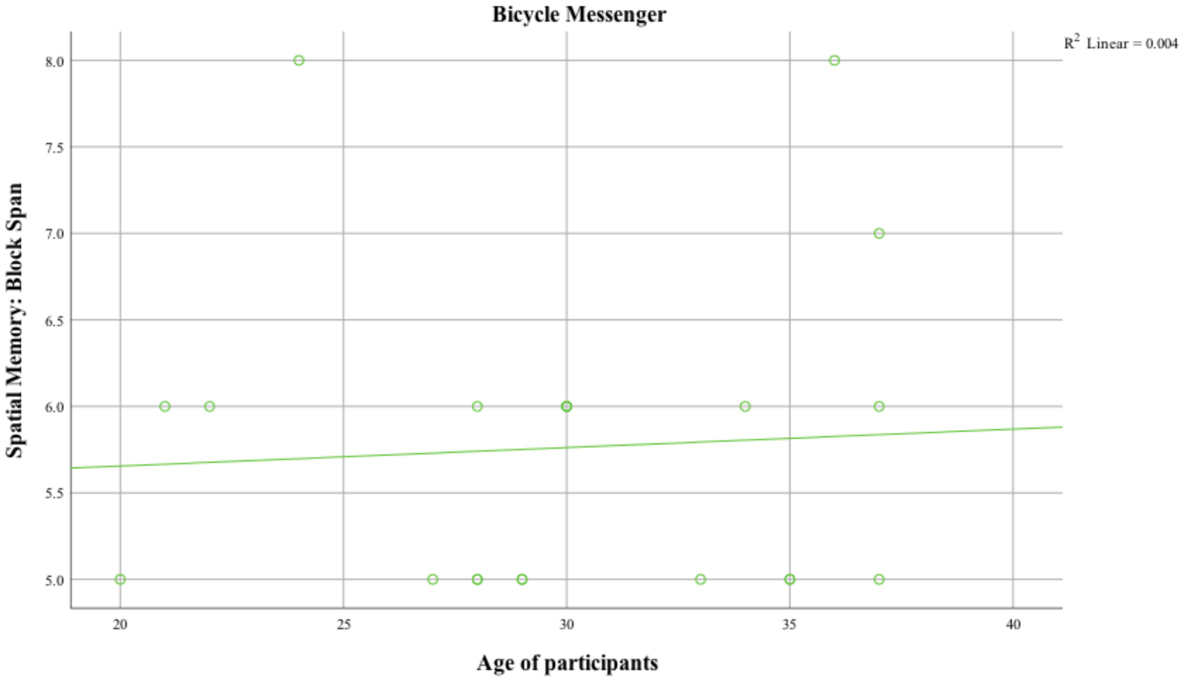



*Figure 15*. Scatterplot of the covariate Age and the dependent variable Spatial Memory in the Bicycle Messenger Group.

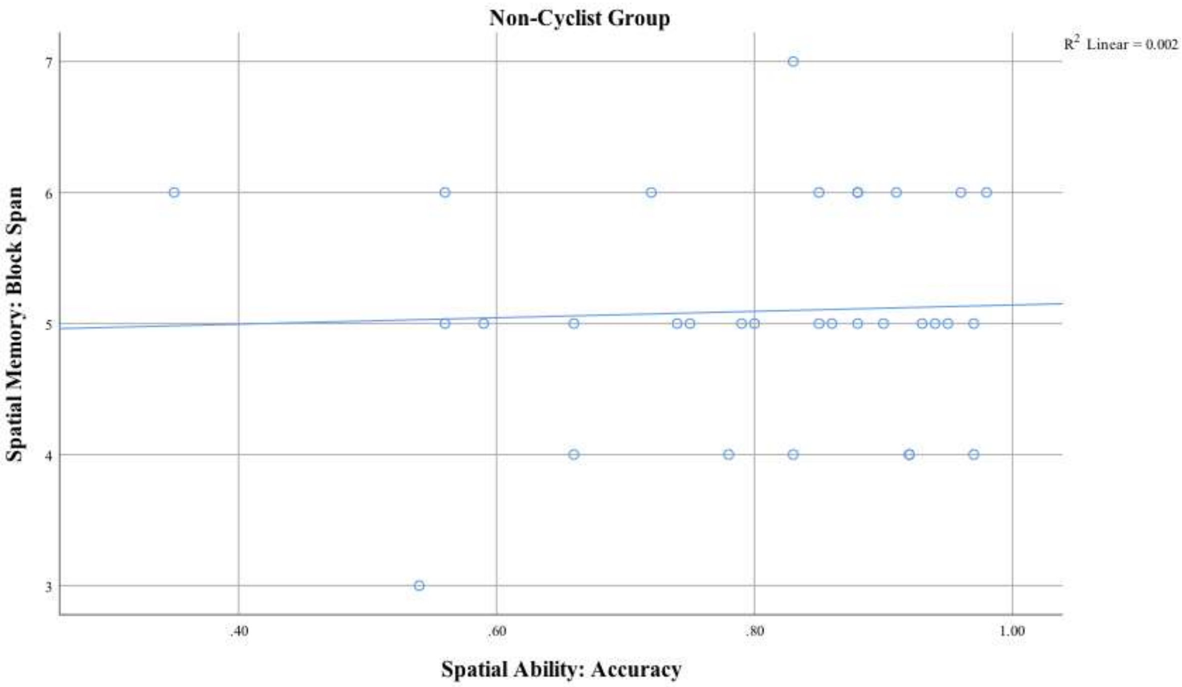



*Figure 16*. Scatterplot of the covariate Spatial Ability and the dependent variable Spatial Memory in the Non-Cyclist.

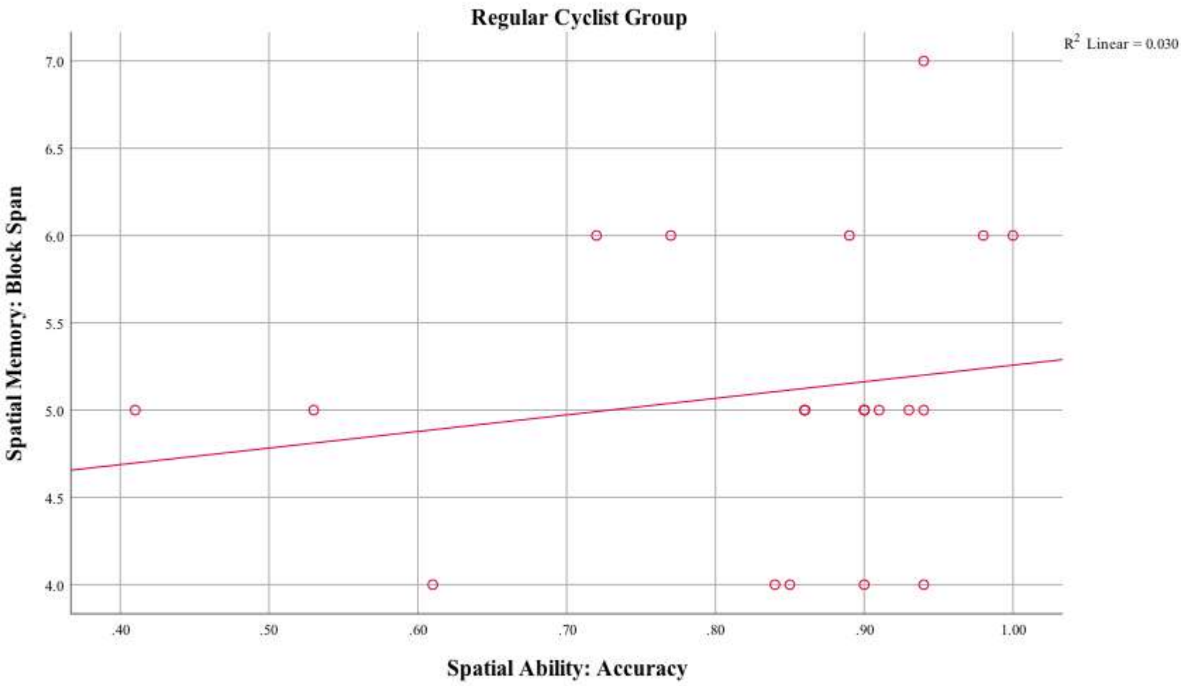



*Figure 17*. Scatterplot of the covariate Spatial Ability and the dependent variable Spatial Memory in the Regular Cyclist Group.


*Figure 18*. Scatterplot of the covariate Spatial Ability and the dependent variable Spatial Memory in the Bicycle Messenger Group.

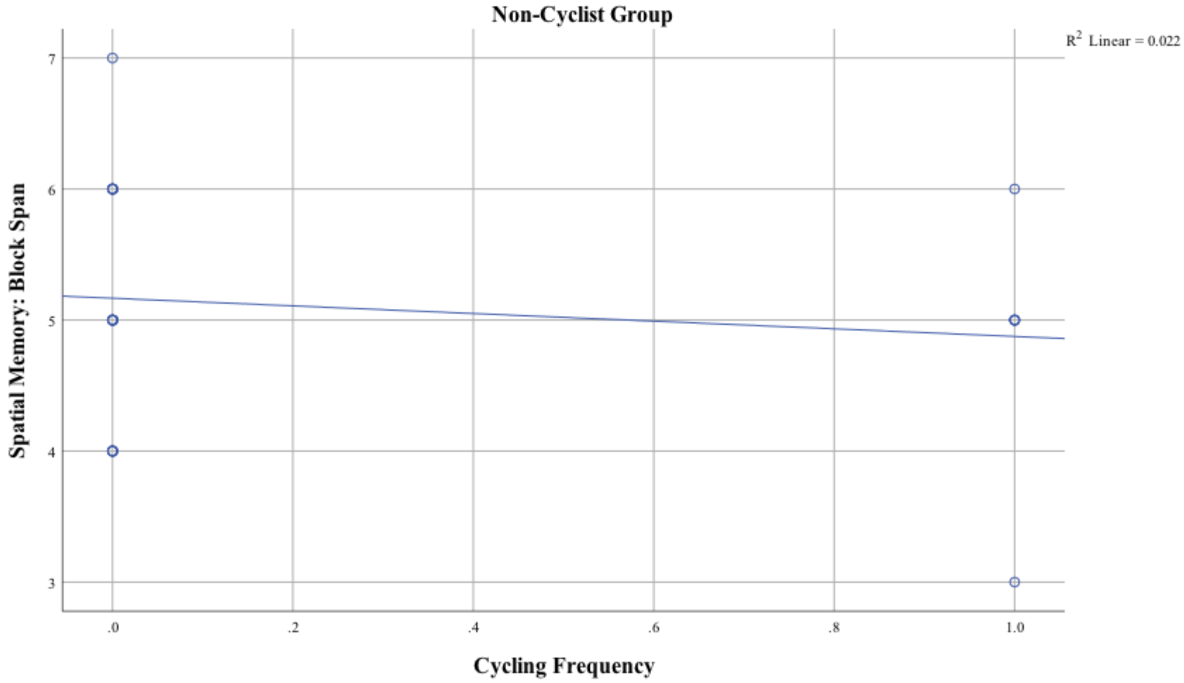



*Figure 19*. Scatterplot of the covariate Cycling Frequency and the dependent variable Spatial Memory in the Non-Cyclist Group.

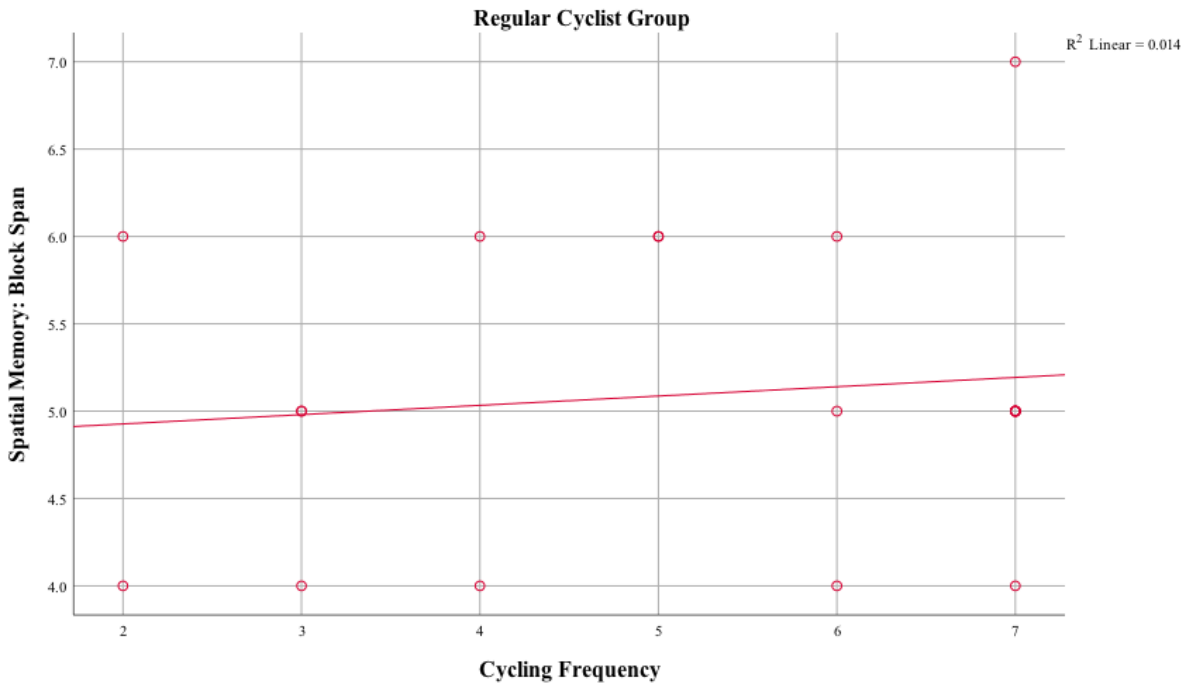



*Figure 20*. Scatterplot of the covariate Cycling Frequency and the dependent variable Spatial Memory in the Regular Cyclist Group.

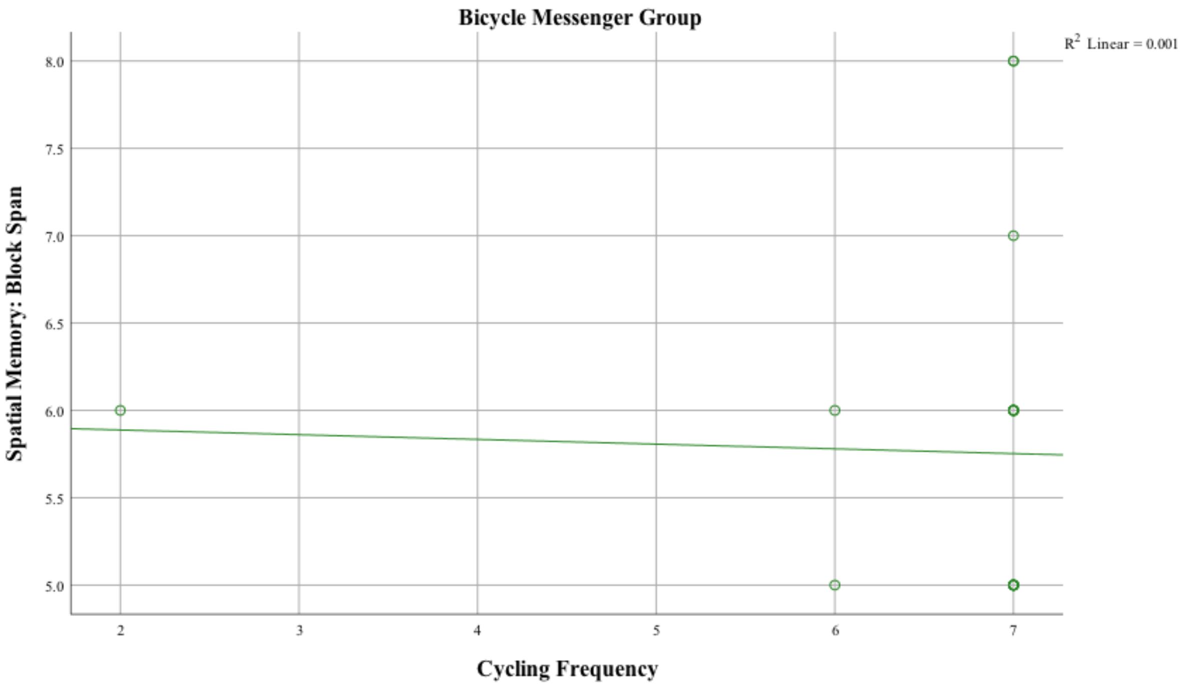



*Figure 21*. Scatterplot of the covariate Cycling Frequency and the dependent variable Spatial Memory in the Regular Cyclist Group.

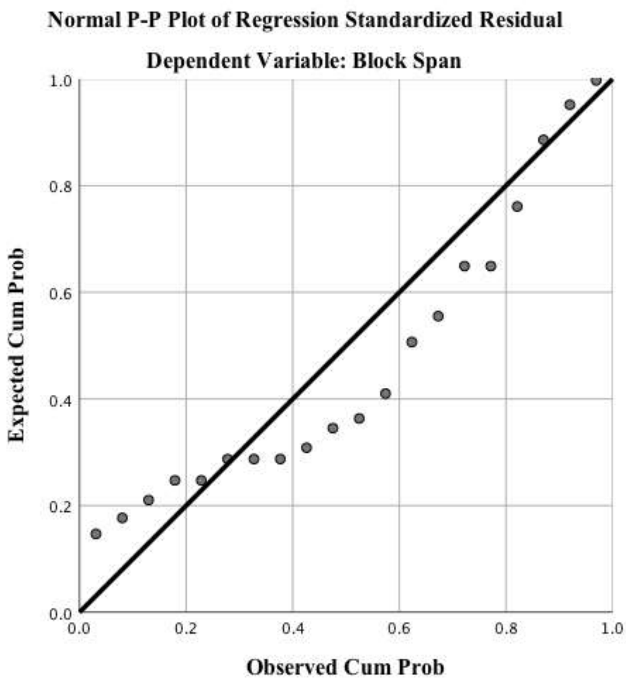



*Figure 22*. Normal P-P Plot of Regression Standardized Residual for the Criterion Variable Spatial Memory.

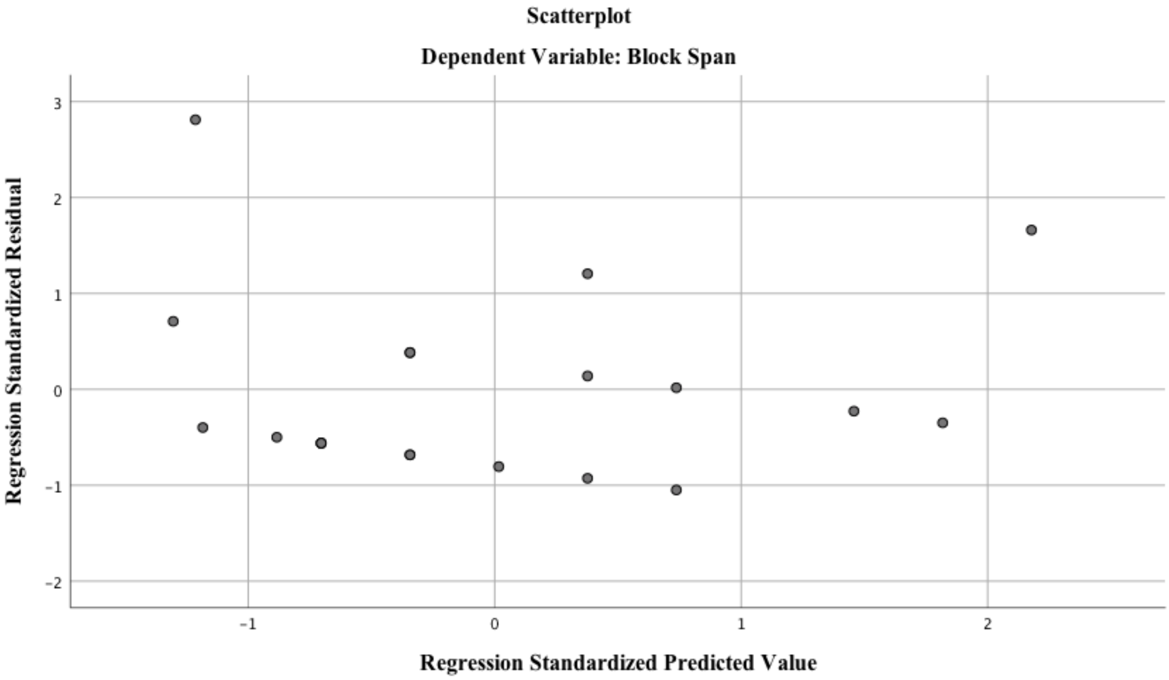



*Figure 23.* Normal P-P Plot of Regression Standardized Residual of the Criterion Variable Spatial Memory

Table 7

Correlations between all continuous variables in the Regression Model.

| **Variables** | 1 | 2 |
|---|---|---|
| 1. Spatial Memory | 1 | |
| 2. Career Length | .33 | 1 |

Note. Statistical significance: *$p$ < .05

**Appendix B.** Information Sheet

**Study Title**
The effect of navigation experience on visuo-spatial memory performance

**Invitation to participate**

I really appreciate your interest in my study and for carefully reading this Information sheet, please ask questions if you need to.

My name is Andrea, I'm a psychology student at National College of Ireland (NCI). I'm currently doing a research project that looks to examine the effect of personal experience on memory, and you have been kindly invited to participate in the present investigation.

Spatial memory is considered one of our most adaptive behaviour, also key for our survival. Interestingly, many of our daily tasks involve navigation abilities, so the aim of the present investigation is to evaluate if those experiences have an effect in spatial memory performance when tested. Please be aware that your participation in the study will be entirely voluntary.

The research will take approximately 20min to complete. Please be sure you are entitled to participate in the study by meeting the following criteria:

-Adults over 18 years old.

-You most not suffer of any intellectual or learning disability, or being diagnosed with brain damage or any neuropsychological disorder.

**What will happen?**

An Informed Consent will be given to you that provides information regarding your rights as participants and what to expect from the researcher and the study. Then, you will be handed a small questionnaire to answer.

After all this is done, I will introduce you to the Memory tasks, the “Corsi Block test” and the “Mental Rotation Task”. The tasks wouldn’t take long to complete, no more than 20 min, but the time frame will depend on you, as there is no time limit to complete it.

Then, a debrief sheet will be provided to you and if you have any questions please ask.

**Your rights**

You have the right to withdraw from the study at any point, without penalty. If you decide to withdraw after the data is collected (after the experiment is done), please email me or my supervisor so I can remove your data from the study. Emails will be provided on the debrief sheet and is also in the recruiting poster at display.

**Benefits and Risks**

You will gain brief knowledge about what is known of spatial memory in psychology and you will have the opportunity to be informed about the results of the present study on its completion, if you like. Your contributions to this study could help expand the knowledge there is on the area and lead to further investigation. No reimbursement will be given for participating.

There are no physical or psychological risk to be aware of. You may be challenged by an increase of difficulty in the task, please don't hesitate to report any feeling of discomfort or distress. A debrief sheet will be provided at completion of the study.

**Confidentiality and Anonymity**

The researcher will assume sole responsibility for the data, no other person will have access to the information you provide. The data collection will be anonymous in nature. The statistical information you provide during the investigation will be linked to an ID code, so not even the researcher will be able to associate the information with the person that generate it.

If you have any questions, please send me an email at x16126211@student.ncirl.ie or to my supervisor Dr. Fearghal O'Brien to fearghal.obrien@ncirl.ie.

Thank you,

Andrea Fernandes

**Appendix C.** Debrief Form

The effect of navigation experience on visuo-spatial memory performance

Thank you for participating in the study, I hope it was a grateful experience. Spatial memory performance was examined in order to evaluate if personal experience has an effect on it.

The following contact points are provided in order to give you appropriate support in case of feeling distress or discomfort after the cognitive test administration or if you require more information about the study.

Researcher email: Andrea Fernandes x16126211@student.ncirl.ie

Supervisor email: Dr. Fearghal O'Brien fearghal.obrien@ncirl.ie

**Appendix D**. Consent Form

Participant Consent Form

The effect of navigation experience on visuo-spatial memory performance

By signing this consent form I confirm that I've read the information sheet provided, that I understand the nature and implications of the study and my role as a volunteer. I acknowledge my right to withdraw from the study at any point without penalty and that once that my data once stored will be anonymous. Finally, I understand that I'm entitled to contact the researcher and researcher's supervisor if require clarification or further information and that I have access to supportive organizations in case of experiencing any distress feeling due to the study.

- I'm over 18 years old
- I recognize that my participation is entirely voluntary
- I'm familiar with my right to withdraw from the study

Question *

- I consent
- I do not consent

**Appendix E.** Google form

Questionnaire

2. Gender *

*Mark only one oval.*

- Male
- Female
- Prefer not to say

3. Age *

________________________________

4. How many times a week do you drive for your commute? *

To go to work/school/college/home

*Mark only one oval.*

- Never
- Once a week
- Twice a week
- Three days a week
- Four days a week
- Five days a week
- Six days a week
- Every day

5. How many times a week do you cycle for your commute? *

To go to work/school/college/home

*Mark only one oval.*

- Never
- Once a week
- Twice a week
- Three days a week
- Four days a week
- Five days a week
- Six days a week
- Every day

6. How many times a week do you cycle for leisure? *

Sport/Recreation/Touring

*Mark only one oval.*

- Never
- Once a week
- Twice a week
- Three days a week
- Four days a week
- Six days a week
- Every day

7. Are you currently working as a bicycle messenger? *

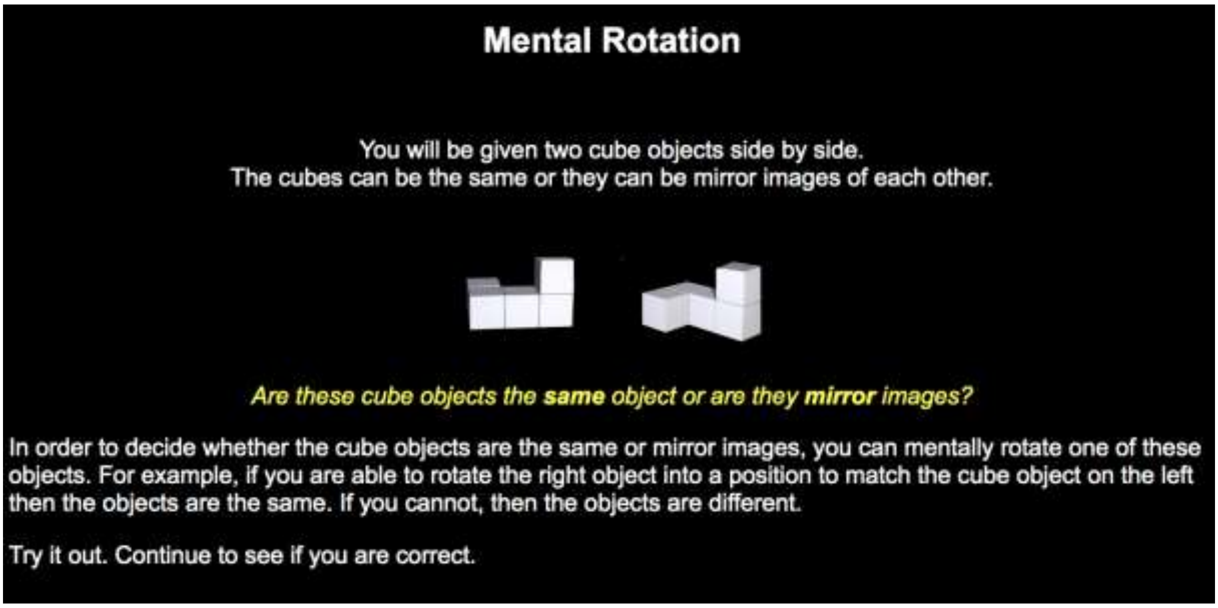
*Mark only one oval.*

- Yes *Skip to question 8*
- No

8. How long have you worked as a bicycle messenger? *

Please write your answer in years. If less than a year, write the amount of months followed by the word "months"

**Appendix F**. Instructions for the Mental Rotation Task.




“If you think the objects are the same, please press the key “S” in the keyboard. If you think the objects are different, please press the key “D” in the keyboard. Please respond as fast as you can without making too many errors”.

Instructions in Spanish:

“Verás en la pantalla dos objetos cúbicos uno al lado del otro. Pueden ser imagenes iguales o imagenes espejo/opuestas. Para decidir si los objetos son iguales or distintos, puedes mentalmente rotar uno de ellos. Por ejemplo, si logras mentalmente rotar el objeto de la derecha hasta que coincida con la posición del objeto de la izquiera, significa que ambos son la misma imagen. Sino, son imagenes espejo/opuestas”.

“Si consideras que la dos imagenes son iguales, por favor presiona la tecla “S” en el teclado. Si consideras que las imagenes son diferentes, por favor presiona la tecla “D” en el teclado. Por favor responde lo más rápido posible sin cometer muchos errores”.

**Appendix G**. Instructions for the Corsi Block Test.

**Welcome to the Corsi Block-Tapping Task!**

**You are about to take part in a test that measures your ability to remember a sequence of locations on the screen.**

**You will see nine blocks on the screen. On each trial, several bocks will light up in blue one at a time. Your job is to remember their exact sequence.**

**As soon as the sequence is finished, a beep is played and you must repeat the sequence by clicking on the blocks IN THE SAME ORDER THEY WERE PRESENTED.**

**When you are done, click the button labeled NEXT. If you made a mistake, click the button labeled CORRECTION to start over.**

**We will begin with a practice session of two trials to familiarize you with the set-up. During practice, you will receive feedback. If you made a mistake, you will simply repeat the trial.**

**"Continue" when you are ready to begin with the practice session.**

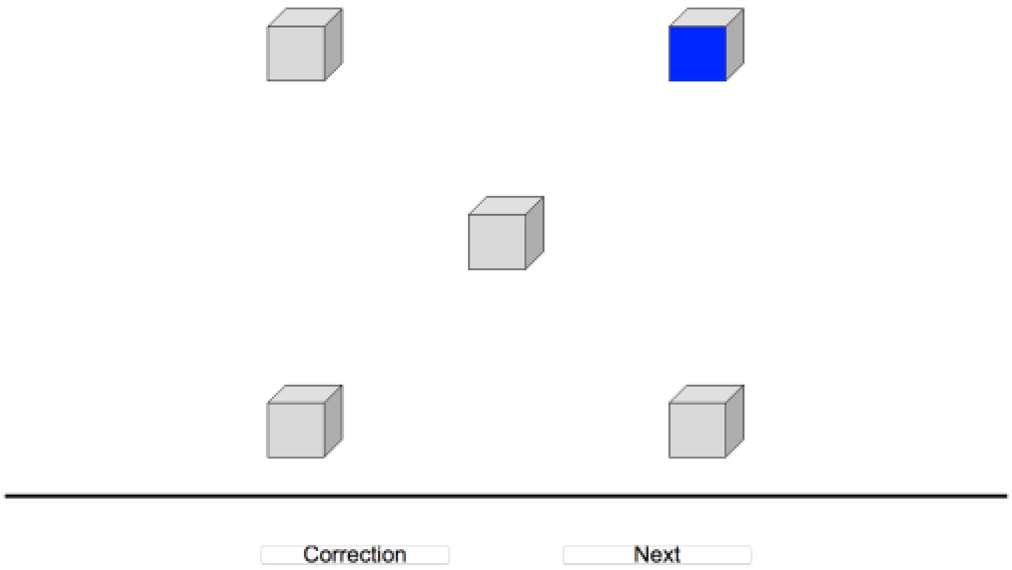
Instructions in Spanish:

"Se presentarán 9 bloques en la pantalla. Una vez por turno, varios bloques se iluminarán en azul, uno a la vez. Tu tarea es recordar la secuencia exacta en que los bloques se iluminaron en azul. Una vez la sequencia termine, escucharás un BIP y es tu turno para repetir la secuencia que memorizaste, debes darle click a los bloques en el orden exacto en el cual se presentaron. Cuando termines, por favor haz click en NEXT. Si cometes un error, haz click en el botón que dice CORRECTION para comenzar la secuencia nuevamente.

Comenzaremos con una sesión de práctica de dos turnos para que puedas familiarizarte con el procedimiento. Durante la práctica el sistema te indicará si la respuesta fue correcta o incorrecta. Si te enquivocas, tan solo repetirás el turno.

Por favor haz click en CONTINUE cuando estes listo para comenzar la sesión de práctica".

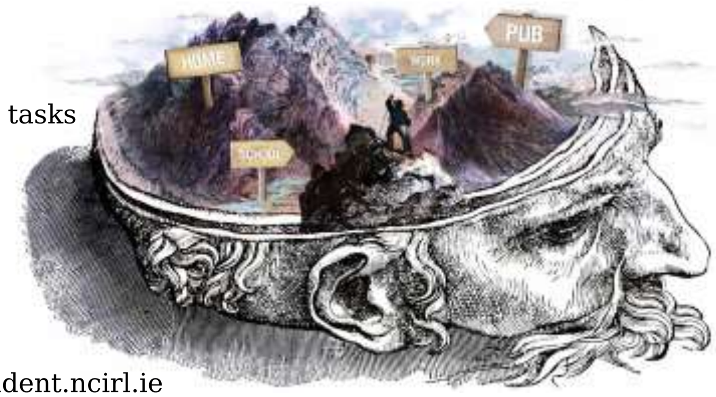
**Appendix H.** Practice trial Corsi Block Test.




**Appendix I.** Advertisement Poster

# A Study of Memory

I'm a student at NCI investigating spatial memory and personal experience




### What does it involve?

Your memory will be tested within 20min with two computer tasks

### Who can take part?

Anybody over 18 years old

### How to participate?

Email Andrea at x16126211@student.ncirl.ie

x16126211@student.ncirl.ie
x16126211@student.ncirl.ie
x16126211@student.ncirl.ie
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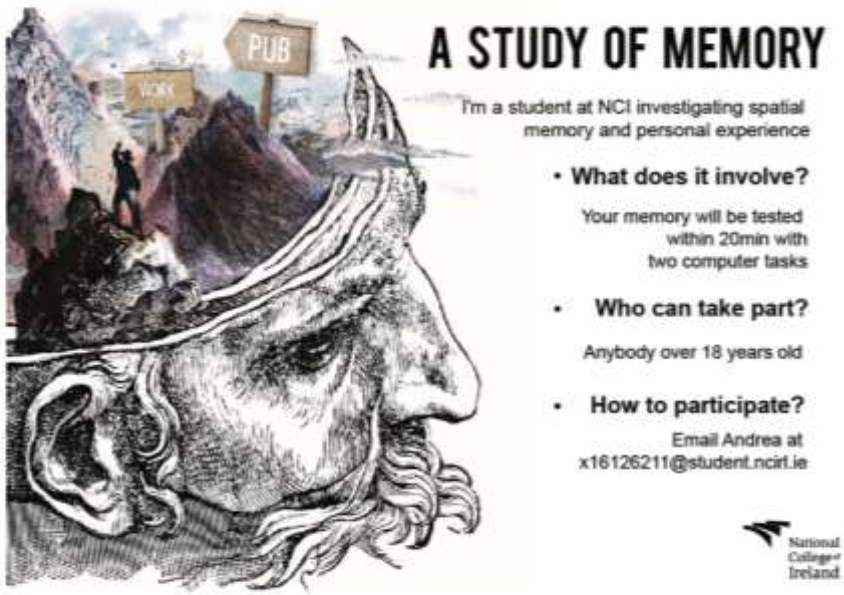
x16126211@student.ncirl.ie




**Appendix J.** Letter of agreements from host institutions

**Re: Psychology Research**

shane boyce <boycey_shane@hotmail.com>
Lun 30/09/2019 06:51 PM
**Para:** Andrea Fernandez Fernandez <ferferandre@hotmail.com>

Hi Andrea,
Thank you for getting in contact with me. The subject of your thesis seems very interesting and I would be more than happy to help in any way that I can. The next event that I will be hosting is on Friday November 1st in Funked Up bike shop if that could help your situation.

Look forward to your reply.

Kind regards,
Boycey.

Sent from Outlook

---

**From:** Andrea Fernandez Fernandez <ferferandre@hotmail.com>
**Sent:** Sunday 29 September 2019 13:13:02
**To:** boycey_shane@hotmail.com <boycey_shane@hotmail.com>
**Subject:** Psychology Research

Dear Boyce,

My name is Andrea Fernandes, I'm a 4th year Psychologist Student at National College of Ireland. As part of our studies, we are required to do a thesis.

The aim of the investigation is to examine the effect of navigation experience in spatial memory performance tasks in adults.

I would appreciate if I could be part of one of the usual events your Dublin Cycle Messengers group runs around November time, in order to inform participants about the study and provide contact details in case of interest.

Please let me know if you have any questions and if you are ok with my request.

Warm Regards,
Andrea Fernandes

Donaghmede Library,

My name is Andrea, I'm a psychology student at National College of Ireland (NCI). As part of our studies we are required to do a thesis. The aim of the research project is to examine the effect of navigation experience in spatial memory performance tasks in adult population.
I would appreciate if I could leave a flyer and information sheet on the notice board or assigned section for leaflets, for people to read and contact to me in case of interest to participate in the study.

By signing this consent form you confirm your happiness for myself to provide the information in the agreed section of the library.

Kind Regards,
Andrea Fernandes

CHARLOTTE FABIAN
LIBRARIAN
Name



Charlotte Fa

Signature

## Re: Psychology Research

Dublin BikePolo <dublinbikepolo@gmail.com>
Dom 29/09/2019 09:16 PM
**Para:** Andrea Fernandez Fernandez <ferferandre@hotmail.com>

Hi Andrea,

Thanks for the email! That sounds really interesting and we would love to help out. Please let us know when you have more details.

Chat soon,

**Fiona Markey**
Association Secretary
DBP

Check us out:
@dublinbikepolo DublinBikePolo

On Sun, Sep 29, 2019 at 1:08 PM Andrea Fernandez Fernandez <ferferandre@hotmail.com> wrote:

> Dear Dublin Bike Polo team,
>
> My name is Andrea Fernandes, I'm a 4th year Psychologist Student at National College of Ireland. As part of our studies, we are required to do a thesis.
>
> The aim of the investigation is to examine the effect of navigation experience in spatial memory performance tasks in adults.
>
> I would appreciate if I could be part of one of the usual events your group runs around November time, in order to inform participants about the study and provide contact details in case of interest.
>
> Please let me know if you have any questions and if you are ok with my request.
>
> Warm Regards,
> Andrea Fernandes

KONE Ireland,

My name is Andrea, I'm a psychology student at National College of Ireland (NCI). As part of our studies we are required to do a thesis. The aim of the research project is to examine the effect of navigation experience in spatial memory performance tasks in adult population.
I would appreciate if I could leave a flyer and information sheet on the notice board or assigned section for leaflets, for people to read and contact me in case of interest to participate in the study.

By signing this consent form you confirm your happiness for myself to circulare the information about the research.

Kind Regards,
Andrea Fernandes

JOE McGRATH
-----------------------------------
Name

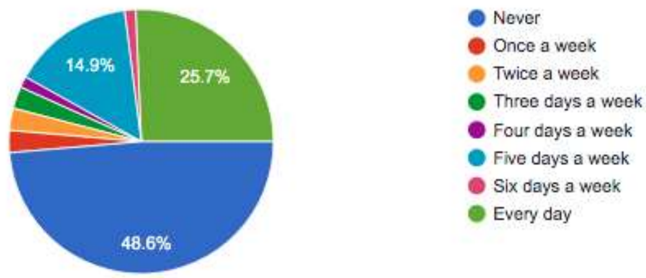
-----------------------------------
Signature

**Appendix K.** Data Evidence

| | ID | Gender | Age | Bicycle_Messenger | Career_Lenght | Corsi_Block | Mental_Rotation | Cyclist_Non cyclist | IV_Groups | Frequency_Cycling | Regular_Cyclist |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1050 | 1 | 26 | 0 | . | 5 | .80 | 0 | 0 | 0 | 0 |
| 2 | 1207 | 1 | 34 | 0 | . | 5 | .88 | 0 | 0 | 0 | 0 |
| 3 | 2244 | 1 | 28 | 0 | . | 5 | .86 | 0 | 0 | 1 | 0 |
| 4 | 2498 | 0 | 49 | 0 | . | 5 | .93 | 0 | 0 | 1 | 0 |
| 5 | 2556 | 0 | 60 | 0 | . | 5 | .90 | 0 | 0 | 1 | 0 |
| 6 | 2925 | 0 | 44 | 0 | . | 5 | .94 | 0 | 0 | 1 | 0 |
| 7 | 3119 | 1 | 25 | 0 | . | 6 | .72 | 0 | 0 | 0 | 0 |
| 8 | 3210 | 0 | 54 | 0 | . | 5 | .59 | 0 | 0 | 0 | 0 |
| 9 | 3477 | 0 | 41 | 0 | . | 5 | .97 | 0 | 0 | 0 | 0 |
| 10 | 4295 | 1 | 39 | 0 | . | 4 | .83 | 0 | 0 | 0 | 0 |
| 11 | 4357 | 0 | 43 | 0 | . | 4 | .97 | 0 | 0 | 0 | 0 |
| 12 | 4391 | 0 | 53 | 0 | . | 3 | .54 | 0 | 0 | 1 | 0 |
| 13 | 4989 | 0 | 27 | 0 | . | 6 | .88 | 0 | 0 | 0 | 0 |
| 14 | 5121 | 0 | 35 | 0 | . | 5 | .74 | 0 | 0 | 0 | 0 |
| 15 | 5557 | 1 | 40 | 0 | . | 5 | .75 | 0 | 0 | 0 | 0 |
| 16 | 5784 | 1 | 25 | 0 | . | 4 | .66 | 0 | 0 | 0 | 0 |
| 17 | 5897 | 0 | 38 | 0 | . | 6 | .88 | 0 | 0 | 0 | 0 |
| 18 | 5981 | 0 | 37 | 0 | . | 5 | .95 | 0 | 0 | 1 | 0 |
| 19 | 6334 | 0 | 44 | 0 | . | 6 | .96 | 0 | 0 | 1 | 0 |
| 20 | 6922 | 0 | 32 | 0 | . | 5 | .56 | 0 | 0 | 0 | 0 |
| 21 | 7567 | 0 | 37 | 0 | . | 7 | .83 | 0 | 0 | 0 | 0 |
| 22 | 7600 | 0 | 47 | 0 | . | 5 | .79 | 0 | 0 | 0 | 0 |
| 23 | 7660 | 0 | 38 | 0 | . | 5 | .85 | 0 | 0 | 1 | 0 |
| 24 | 7770 | 0 | 30 | 0 | . | 6 | .98 | 0 | 0 | 0 | 0 |

How many times a week do you cycle for your commute?

74 responses




How many times a week do you cycle for leisure?

74 responses