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如何找路？覓路測試環境、路線知識、心理地理空間能力與覓路表現的關係

How to find your way? Relationship between wayfinding testing environments, route knowledge, psychological geospatial abilities and wayfinding performance

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如何找路？覓路測試環境、路線知識、
心理地理空間能力與覓路表現的關係

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Relationship between wayfinding testing environments, route knowledge, psychological geospatial abilities and wayfinding performance

本論文係周峻民君（學號 R02228022）在國立臺灣大學地理環境資源學系、所完成之碩士學位論文，於民國 106 年 7 月 18 日承下列考試委員審查通過及口試及格，特此證明。

口試委員：______________________（簽名）
（指導教授）

郭柏呈

謝誌

耶和華是我的牧者，我必不致缺乏。他使我躺臥在青草地上，領我在可安歇的水邊。他使我的靈魂甦醒，為自己的名引導我走義路。我雖然行過死蔭的幽谷，也不怕遭害，因為你與我同在；你的杖，你的竿，都安慰我。

（詩篇 23:1-4）

四年前，決定要當地理老師而考進地理所，開始一段人生中迎接新挑戰的時期。感謝上帝，愛我、引導我，不論在修習教育學程、地理專業課程，或學術研究上，都有上帝安排的幫助與美意。

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四年研究生涯中曾一起打拼的伙伴，佳融、明清、品潔、崇安、稚倫、怡人、慶燁、羚翔、蕙君、婷玉、淑君，跟你們常常的討論，可以讓我不斷思考我的研究的改進方向，萌發更好的想法。研究室的助理們，玉臨、淑敏、昊妤、原華、昶安、鈺婷、偉嘉，讓研究室成為一個又溫暖又歡樂的工作場所。感謝父母，給我自由發展、探索自我的空間。感謝團契的弟兄們，常常的關心與代禱，讓我力上加力。

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摘要

空間認知對人類是重要的素養之一。空間認知使我們可以辨認路標、找出空間樣態，以及進行空間的決策。在過去研究中，覓路被廣為使用來評估空間認知能力。在覓路過程中，人類必須記住目的地、必須掌握路徑位置，並且確認周圍環境來決定正確方向，然後不斷朝向目的地前進。因此，心理地理空間能力以及環境知識在覓路過程中扮演重要的角色。此外，一種新的覓路測驗介面，虛擬環境，因為其花費成本比起真實環境找路測驗來的低，而被許多研究所採用。然而，目前沒有研究測試兩種介面上的覓路行為是否一致。

利用 Google 地圖 API，我們創造了一種新的虛擬環境介面：Google 街景。在本研究中，將同時測試真實環境與街景介面下的覓路行為。除此以外，研究者也操弄不同的環境知識描述（覓路線索），以測試環境知識對覓路行為的影響。覓路線索有三類：方向描述、地圖描述，以及伴走描述。在伴走線索描述中，實驗者陪伴受試者走過一次覓路路徑，稍後受試者自己反向走過一次路徑。利用便利取樣，三種覓路線索組別各有 15 位受試者。受試者根據所屬組別給予覓路線索，並完成真實環境以及街景環境的覓路。接著完成一系列的線上測驗組合，包括覓路策略、心理旋轉、工作記憶、方向感，以及地理空間思考能力的量表。

結果顯示，真實環境以及街景環境中的覓路行為是一致的，表示街景上找路也可以達到足夠的生態效度。不同的覓路線索對覓路表現也有不同的影響。伴走線索組的受試者，比起地圖線索或方向線索的受試者，花更少的時間。這個發現與認知拼貼(Tversky, 1993)的假設一致。在認知拼貼中，空間知識並非像是地圖一樣，而比較像是零碎的空間資訊的集合，這些資訊可以有空間、文字、或聲音等不同形式。在伴走線索組中，伴走過程中的不同形式的資訊，有助於更快速並更正確找到目的地。此外，覓路線索與心理地理空間能也有交互作用。地圖線索組的受試者，其覓路表現會與地理空間思考能力、心理旋轉以及視覺空間工作記憶有相關。伴走線索組的受試者，覓路表現則與心理旋轉及方向感有相關。顯示人們會因為對應不同的

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覓路環境知識，而使用不同的心理地理空間能力。當給予地圖線索，讀圖能力、旋轉能力及空間記憶能力是重要的。相對的，若給予伴走線索，則方向感的好壞會決定覓路表現。

關鍵詞：空間認知、覓路、Google 街景、心理地理空間能力、視覺空間工作記憶、方向感

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Abstract

Spatial cognition is an essential literacy for human beings. It enables people to recognize landmarks, identify spatial patterns, and make spatial decisions. To evaluate spatial cognitive abilities, wayfinding has been widely adopted in previous studies. In the process of wayfinding, one has to keep destination in memory, to keep track of path, to decide whether or not make turns by monitoring surrounding environments, and to head to the destination. Therefore, psychological geospatial abilities and knowledge about the environment are of concern in wayfinding process. Moreover, a new wayfinding testing environment, i.e. virtual environment, gains popularity because of it saves time and money than real-world environment does when collecting data. However, no studies have tested whether the wayfinding behaviors in the virtual environments are parallel to those in real-world settings.

Taking advantage of the Google Maps API, a new virtual environment interface, the Google Street View, was adopted in this study. Wayfinding behaviors in both real-world and google street view settings were compared simultaneously in our study. Three different types of knowledge of environment, i.e. wayfinding cues, were manipulated. Direction cue, map cue and walk cue (participants were accompanied walking through the wayfinding route) were varied across different groups of participants to test the cue effect. A total of 45 participants were recruited through convenient sampling and were

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randomly assigned to either of the 3 groups. Participants were given different types of wayfinding cue according to their group and they completed wayfinding test in the sequence of real-world setting and then street view setting. Finally, an online test battery which consisted of wayfinding strategies, mental rotation, working memory, sense of direction, and geospatial thinking abilities scales was given.

The results showed that behavioral patterns were similar between real-world and street view settings, suggesting that street view interface had ecological validity as real-world environment did. Types of wayfinding cues had differential effect on wayfinding performance. Participants in the walk cue group spend less time than those in map cue group or direction cue group did. These findings are consistent with the cognitive collage hypothesis (Tversky, 1993), in which spatial knowledge are represented as a fragmented collection of bits in spatial, textual, or acoustic forms rather than a detailed map. In the walk cue group, different formats of information during accompanied walking through the wayfinding route are beneficial to find the correct destination.

Interaction between wayfinding route cue types and psychological geospatial abilities was observed in this study. Wayfinding performance in map cue group was correlated with geospatial thinking abilities, mental rotation ability, and the capacity of visuospatial working memory. On the other hand, wayfinding performance in walk cue group was correlated with mental rotation ability and sense of direction. The results

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indicated that participants exercised different psychological geospatial abilities according to their knowledge about the wayfinding environments. When map cue is given, map reading skills (geospatial thinking abilities and mental rotation) and capacity of visuospatial information are required. When walk cue is given, sense of direction is related to wayfinding performance.

Keywords: spatial cognition, wayfinding, google street view, psychological geospatial abilities, visuo-spatial working memory, sense of direction

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Chapter 1. Introduction

1.1 Background and Motivation

The scenario described below happens on a daily basis that you might be familiar with. In your places, whether they are office building complexes or campus areas, you find someone holding a map, looking around, rotating the map in order to locate themselves on the map. After spending a few moments trying and sweating, he or she would come to you and ask for directions. Now it's your turn to make a decision. Whether you are going to give him/her detailed verbal directions of the route to the destination? Or you will draw a route map for them? And still another option is that you would choose to lead him/her to the destination.

The above scenario depicts the importance and complexity of wayfinding, which means the process of traveling from the starting point to the destination (Golledge, 1999a). In our daily lives, we all have to make movement between two or more places, whether they are in familiar or in unfamiliar environments. Getting lost in an unfamiliar environment during wayfinding would result in additional cost of time and money, and sometimes even at the cost of life.

Wayfinding is an important daily practice for all humans, but successful wayfinding is by no means an easy task. Before wayfinding, the starting point and the destination must be decided in advance. Sometimes, however, the destination is not clear or specific.

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For example, the destination might be just a name of a restaurant without address, which means the wayfinding route between the starting point and the destination could not be predefined. Wayfinders therefore would require navigational aids, e.g. maps or GPS devices, to assist in deciding wayfinding route. Second, during wayfinding process, wayfinders have to monitor the environment and the location of themselves to ensure they are on the decided route. Once getting lost, wayfinders have to relocate themselves by checking on the navigational aids or asking help from others. Finally, correction recognition of the destination is the last while the most important step in wayfinding. Mistakes in any of the elements of wayfinding process would make successful arrival to the destination impossible.

Given the significance of wayfinding, it is not surprising that multiple disciplines address their research in wayfinding. For example, psychologists have investigated the spatial cognition of wayfinding. Psychological studies have either focused on the developmental stages of spatial cognition, or on the mental representations of textual and graphical form of spatial information, or on the mental processing capacities. Environmental scientists, on the other hand, have been interested in the relationship between environmental characteristics and wayfinding performance. They have provided different types of geographical features and quantitative measures of the complexity of street shapes, which have been potentially related to wayfinding. Also pedestrian flows

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have been studied to better design building structures.

With the advancement of technology, wayfinding testing environments have changed a lot. Virtual environment (VE) techniques allow images of real-world or computer graphics to project on computer screens. Although virtual environment studies have higher efficiency of time and better experimental controls than outdoor real-life experiments of wayfinding, the ecological validity of virtual environment studies is not yet tested. Thus whether the results from the virtual environment studies are applicable to real-world wayfinding behavior remains unknown.

1.2 Objectives and Research Questions

Wayfinding is never an easy task for many people. In the process of wayfinding, factors such as environmental characteristics, prior knowledge about the traffic network, and cognitive properties of wayfinders all take part in. That is why wayfinding is a popular and practical issue and attracts academic research interest from various study fields.

In order to understand why and how wayfinders may succeed or fail in finding the destination, we tried to investigate wayfinding from a broader perspective. Previous studies have taken one perspective between the psychological or environmental approach. To achieve a more comprehensive understanding of complex wayfinding behavior, it is necessary to integrate both psychological and environmental factors in one study.

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Therefore, the first study objective aims to systematically test the role of psychological and environmental factors and the interactions between the two factors.

The second study objective is related to the first objective and addresses a more practical issue: how to give directions to wayfinders that ask for directions. Giving directions is perhaps not as easy as you might think. There are several types of direction guides, such as verbal instructions and map drawing. Previous studies, however, have never distinguish the effects of different direction guides. In this study, different types of information of the same wayfinding route were tested and suggestions of how to give directions were made.

The third study objective concerns about different wayfinding testing environments. Computer interface or virtual environment has gained its popularity in wayfinding research because of low cost of time and money comparing to real-world environment. Although virtual environment has many advantages, whether human subjects behave in the virtual environment as the same pattern as they do in real-world environment has not yet tested. We would like to bridge the gap between different testing environments and develop a potential online training course of improving wayfinding performance.

Based on the research objectives stated above, here are the core questions of wayfinding that will be investigated in this study.

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First, are the wayfinding studies on different interfaces comparable? Could the study results on computer interface extend to real-world wayfinding behavior?

Second, what is the underlying cognitive knowledge of wayfinders? To be specific, how do psychological geospatial abilities interact with knowledge of the environment?

Third, would the strategies adopted by individuals during wayfinding process make differences? How to we give wayfinders more effective cues according his/her own preferable strategies?

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Chapter 2. Literature review

2.1 Spatial cognition

2.1.1 The development of spatial cognition

What is space and how do human shape the spatial concept? Researchers once take the anthropological and philosophical approach to study. Egenhofer and Mark (1995) take advantage of naturalistic observation and literature review and 12 elements or presumptions of human spatial cognition are identified. Among the 12 elements, some key observations do have important application in daily life. For example, because humankind thinks the earth is flat, it is troublesome for them to understand the shortest distance from New York to Tokyo is through the North Pole. The follow-up study by Downs and DeSouza (2006) suggest that the flat earth myth might come from the habit that humans much often use flat map. As for element no. 7, it provides the evidence that human may change their knowledge about a geographical feature. For example, New York could be perceived either as a point or an area, depending on the context.

The classical work by Lynch (1960) have identified geographical space into 3 categories: zero-dimension, one-dimension and two-dimension. Zero-dimension space includes nodes and landmarks; One-dimension space includes routes and borders; Two-dimension space includes areas. Empirical studies prove that humankind also have the same structured spatial cognition (Hirtle & Jonides, 1985). When it comes to the spatial

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structure studies, landmarks are the main focus. Sorrows and Hirtle (1999) suggest a theory of landmarks, which divides landmarks into 3 categories. The fist category is called the visual landmarks, which are visually salient. The second category is structural landmarks. They might not be visually distinctive but are crucial in wayfinding. And the third category is cognitive landmarks, which have unique meanings. The theory of landmarks is supported by the studies by Winter and Raubal (2004). Empirical evidence indicates that a high ratio of subjects prefer the building with highest visual and semantical salience as a landmark to signal a right turn in a complex street scene.(Egenhofer & Mark, 1995; Freksa, Habel, & Wender, 1998; Hirtle, 2011)

2.1.2 The acquisition of spatial knowledge

Mark, Freksa, Hirtle, Lloyd, and Tversky (1999) posit three ways to acquire spatial knowledge. The first is through actual exploration. Humans are able to acquire spatial information by different modalities, such as vision, hearing, or touching, etc. But the process of exacting geographical knowledge from locomotion is indirect (Montello, 1997). With sensorimotor exploration in the environment, not only geographical features such as turns, landmarks, intersections, and distances but travel time, travel effort and aesthetic evaluation of one place are built.

Alternative media such texts, pictures, and charts is the second way to gain spatial knowledge. Subjects ae able to construct a mental model from text information of a place

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and the contents are similar to those constructed by studying maps of the same scene (Taylor & Tversky, 1992). The retention time of spatial text memory is, however, shorter than that of spatial pictorial memory (Federico & Franklin, 1997).

The third way to gain spatial knowledge is through virtual environment (VE). Navigation through VE mimics experience of movement through space but may not provide full sensory experience to the traveler. Though perceptual interactions with the environment are often lacking, VE simulations and current GISs are closer to an in interactive version of map use.

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2.2 Visual-spatial Working memory

The study of memory has been an important and popular research issue in psychology, neuroscience etc. In 1968, Atkinson and Shiffrin (1968) propose a well-known memory model, the multistore model of memory (Figure 1). This model follows the idea of "information processing", that is, human memory system is like a computer with an input, process and output. In the multistore model of memory, environmental stimuli enter human through modalities such as vision and hearing. Sensory information then enters short-term memory through a resource-limited attention window. Information is transferred into long-term memory only when it is rehearsed. Else, information will be lost due to information decay or displacement by subsequent stimuli.

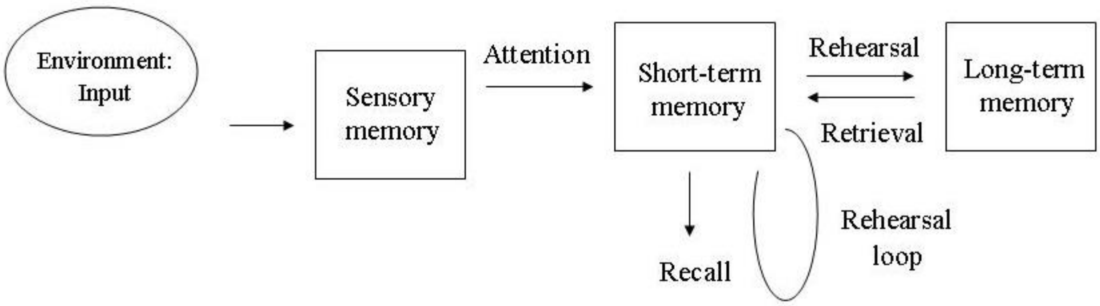

Figure 1 The multistore model of memory (Atkinson & Shiffrin, 1968).
Adapted from McLeod (2007)

In the model of Atkinson and Shiffrin (1968), short-term memory acts like a passive storage with limited capacity and storage time. It is, however, oversimplified and later studies have elaborated the concept of STM to working memory.

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Baddeley and Hitch (1974) propose the working memory model. In this model, STM is replaced by working memory, which has several subsystems (Figure 2). Instead of only one single storage of information, there are different subsystems for different types of modalities. Phonological loop deals with verbal or spoken material while visuo-spatial scratchpad deals with information in visual or spatial forms. Above the 2 subsystems, central executive regulates the information flow into the subsystems and allocates the attention resources between the two subsystem.

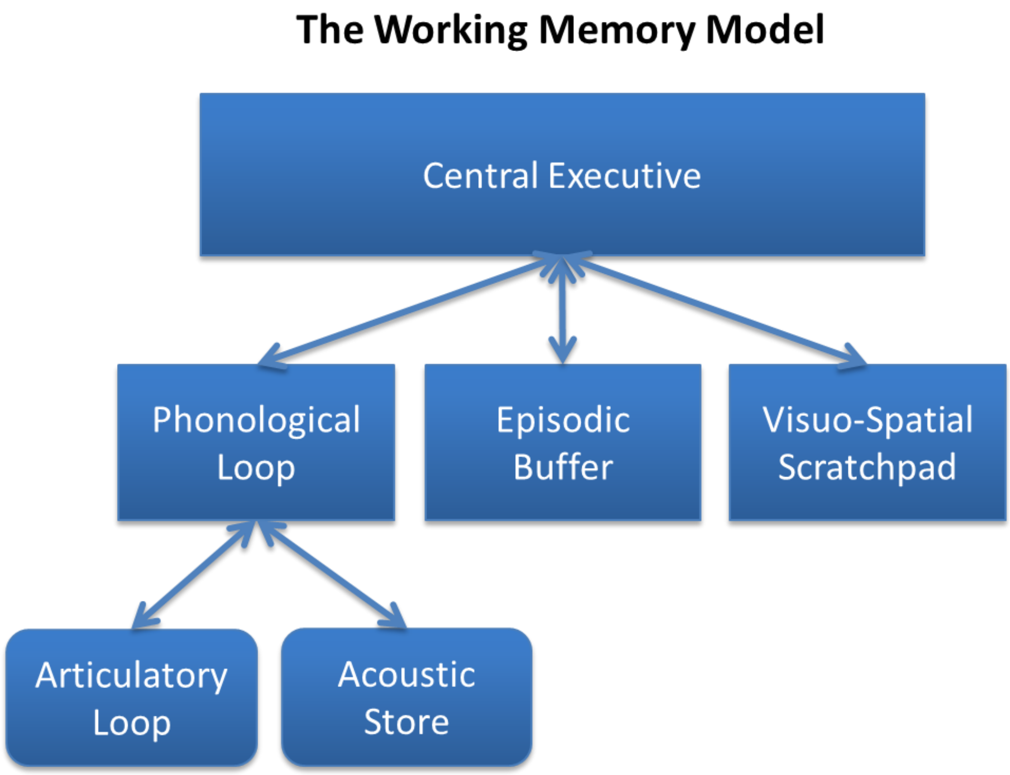

Figure 2 The Working memory model by Baddeley and Hitch (1974)

Source: Cheese360, URL:

https://commons.wikimedia.org/wiki/File:Baddeley_and_Hitch%27s_Working_Memory_Model.png

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Several studies have been testing the properties of the structure of human spatial cognition and its role in wayfinding. As Montello and Freundschuh (2005) suggest, wayfinding involves selection, maintenance, filtering and updating representations in our memory to make correct decisions. The key player in wayfinding is spatial working memory. However, there is very few, if any, studies dedicate to test the role of spatial working memory in wayfinding. Hence we attempted to test whether spatial working memory and wayfinding performance were correlated. Two representative psychological tasks, mental rotation and monkey ladder, were adopted to measure the spatial working memory.

Hund and Gill (2014) test interaction between the wayfinding direction cue types (route or survey) and the memory demand (memorized cues or piecemeal cues) in indoor environments. When participants are asked to memorize the direction cues, cue types do not make a difference. When participants are given piecemeal cues, route cues group spend less time and made fewer errors than the survey cues group do.

The role of visual-spatial working memory (VSWM) in the process of wayfinding has been investigated by several studies. Bosco, Longoni, and Vecchi (2004) have participants study a simplified map of a scenic spot in Rome and later receive a test battery of 8 spatial knowledge tests including landmark knowledge, survey knowledge, and route knowledge of the studied map. Another 4 VSWM tasks are given and statistical analysis

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shows a strong relationship between the spatial knowledge and VSWM.

Meilinger, Knauff, and Bulthoff (2008) examine the role of working memory in wayfinding using a dual task paradigm. Participants learn two routes through a virtual environment of a city while completing visual, spatial, or verbal secondary tasks or no secondary task. At test, participants are asked to retrace the routes to find goal locations. Performance is hindered with verbal and spatial secondary tasks, but not with the visual secondary task, indicating that both verbal and spatial working memory are required for wayfinding.

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2.3 Wayfinding

2.3.1 Definitions of Wayfinding

Space is around us and thus spatial cognition is an essential literacy for human beings. It enables people to recognize landmarks, identify spatial pattern, and make spatial decisions. Purposeful navigation between places is perhaps the most prominent real world application of spatial cognition. Wayfinding, i.e. navigation in environment space, is directed to distant destinations or distant space, respectively. Golledge (1999a) defines wayfinding as "the process of determining and following a path or route between an origin and destination." And the crucial aspect of wayfinding is that paths to the destination(s) are not always available from direct perception at the origin of travel. Three levels of spatial knowledge have been distinguished by Golledge (1999a) in his studies. At the first level, people gain the spatial knowledge about a point in space (e.g., a landmark, a destination). At the second level, people know about a sequence of points (i.e., a path to a destination, often referred to as route knowledge). And at the third level, people have the knowledge about an area (i.e., knowledge about the spatial relation of at least two points, often referred to as survey knowledge). Since then, route and survey knowledge have been the research focus of wayfinding studies. The properties of landmarks, path, and area have been of great interest.

Montello and Freundschuh (2005) defines navigation as consisting of two

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components, locomotion and wayfinding. Locomotion refers to navigation behavior in response to current sensory-motor input of the immediate surrounding and includes tasks such as steering, obstacle avoidance, and the approach of a visible object in vista space. The term wayfinding subsumes a number of navigation tasks that share certain common features: they require decision making and/or planning processes, involve some representation of the environment and aim at reaching destinations beyond the current sensory horizon. Typical wayfinding tasks are, for example, search, exploration, and route planning. Therefore, the process of way-finding, which is about navigating from one point to a destination along road networks, requires integration of different cognitive ability. Specifically, one has to keep destination in memory, keep track of path, decide direction by checking surrounding environment, and head to the destination. Human perception and memory play an important part in wayfinding.

Downs and Stea (1973) suggest that successful wayfinding consist of four steps. The first step is orientation. Wayfinders identify "where am I in the surrounding and related to nearby landmarks and destination." Second step is route selection. Wayfinders choose a route that will lead to the destination. Third step is route control. Wayfinders constantly monitor and control the wayfinding route and make confirmation that individual is following the selected route. The forth step is recognizing destination. Wayfinders have the ability to recognize that they have reached the destination

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From the literature reviewed above, we could give a common definition of wayfinding: destination guided motion (Brunyé, Mahoney, Gardony, & Taylor, 2010) due to the union of spatial and environmental cognition to allow people to make a series of decisions using cognitive abilities to find your way through the build or natural environment, with or without the use of external device such as maps or GPS systems (Fewings, 2001; Golledge, 1999b).

2.3.2 Spatial Knowledge in Wayfinding

2.3.2.1 Landmark, route and survey knowledge and map reading

Hirtle, Richter, Srinivas, and Firth (2010) have identified 3 main problems in wayfinding. The first is matching problem. Wayfinders must know their position and azimuthal directions and they have to match where they are on the map. Thus it is also called the "where am I" problem. The second problem is concerning about the spatial complexity. In the study of Tenbrink and Winter (2009), subjects are assigned to perform a route planning task. They have to give enough information about the route, e.g. where to make turns, distance between 2 landmarks, to enable others to follow. The complexity of their routes is calculated and compared with online map route planning results. The results show that subjects tend to give less information of a simple route while giving detailed information of a complex route. The third problem is expectation or knowledge about a place. When the knowledge background of wayfinders varies, the expectations of

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road networks will differ. Thus when wayfinders are in a stranger place and their knowledge doesn't apply, wayfinding performance would be impaired.

2.3.3 Wayfinding testing environment

Wayfinding performance has been tested in various environment settings, including paper-and-pencil tests, virtual environment settings, and real-world indoor or outdoor environments. Paper-and-pencil tests have the advantage of economic execution. Real-world field tests are often time-consuming and money-demanding while the ecological validity outperforms other testing settings. Virtual environment settings might be a compromise between the above two, but additional technological costs have to be covered. Taking advantage of Google street view, we were able to establish a virtual environment with even real street views. Wayfinding test on Google street view enables researchers to collect a large sample at the same time at minimum cost while keeping reliable ecological validity.

2.3.3.1 Real-world Outdoor environment

Comparing to indoor testing environment, wayfinding studies in real-world outdoor environment are very few, if any. With the constraint of time and money, the number of experiment participants is limited. When it comes to safety concern, real-world large scale field study is difficult for investigators to set up. It is, however, clear that the ecological

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validity of real-world environment testing is guaranteed. Since wayfinding is a problem in daily practice, the closer the study setting to real world situation, the better ecological validity would be.

Boumenir, George, Rebillard, Valentin, and Dresp-Langley (2010) conduct experiments in a large, park-like cemetery area. This study area features a complex network of different size of path and plenty of landmarks such as chapel, fountains, road name signs and information panels. Twenty-four participants, none of whom are familiar with the study area, are recruited and equally divided into 3 groups. The amount of spatial information given about the wayfinding route before field test is manipulated across 3 groups. The results show that virtual guided condition, in which participants form incorrect distance perception, results in worst performance.

Nori, Grandicelli, and Giusberti (2009) measure wayfinding performance in a botanical garden of moderately dense wooded area. Forty participants are accompanied walking from starting point to the destination and then are asked to followed the route in the opposite direction without any assistance. Though the wayfinding route distance is short (about 360m), route reversal and large number of turns (14 turns are required) make the route difficult. The results suggest that participants with higher visuo-spatial working memory (WSWM) make fewer errors, pause less frequently and finish the route in a shorter time than those with lower VSWM do.

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Only two studies have investigated real-world outdoor wayfinding in road network environment. Meilinger and Knauff (2008) test the impact of different types of spatial knowledge on wayfinding in urban road network. Twelve participants are given verbal direction (route knowledge) and route map (survey knowledge) respectively to either short route or long route condition. After wayfinding test, several posttests are given to exam how route and survey knowledge are represented in memory. Their study reports null relationship between spatial knowledge and wayfinding. Performance of verbal direction and route map condition do not differ in wayfinding performance and post spatial knowledge test scores. Meilinger and Knauff (2008) postulate that participants use the strategy to translate the map into verbal detections and that small sample size might attribute to the results.

Employing the dual-task paradigm, Garden, Cornoldi, and Logie (2002) study the differential influence of the two subcomponents of working memory, which are verbal working memory and visuo-spatial working memory, on wayfinding performance. The study site is a road network in a medieval European town featuring short, narrow, curvilinear streets and various cues such as road sign and different buildings. Thirty participants are led by the experimenter through the wayfinding route and then are asked to follow the route exactly in the same way. Twenty of the participants are assigned to experimental group and are required to perform a secondary concurrent task, either an

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articulatory suppression task or a spatial tapping task respectively for 2 different routes. The results show that only participants who report using a survey representation during wayfinding suffer a concurrent visuo-spatial dual task loss. On other hand, participants that are less likely to build survey representation are more affected by a concurrent verbal dual task loss. This study suggests that in real-world environment, different wayfinding strategies adopted by individuals might play an important role in the nature of their mental representations.

Taking advantage of military college graduation requirement, Malinowski and Gillespie (2001) have 978 sophomore students perform orienteering in a woodland terrain. The study site is a hilly forest area with some clearings and elevation difference between the lowest and highest points is about 90 m. Within this area, eight 6 km orienting lanes are established and in each orienting lane ten points were positioned. Participants receive an intensive 3-day training program on map reading, compass usage, terrain visualization and distance estimation. On the final day, participants are required to use a map, a compass, and a brief terrain visualization cue to find each of the ten points in a 4-hour period. The results indicate that, like previous small scale laboratory studies, wayfinding performance is related to gender, math ability, and map-use skills.

In addition to wayfinding performance of adult participants, a few researchers have been interested in developmental factors of wayfinding in children. Liben, Myers,

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Christensen, and Bower (2013) recruit 40 children of 9-10 years of age. The study site is a moderate dormitory quadrangle in which 8 flags are placed by the experimenter. Children are asked to mark the position on flags on the map. The study reports that children with better map skills such rotating and alignment and with better spatial abilities performe better in the outdoor mapping task.

Fenner, Heathcote, and Jerrams-Smith (2000) recruit two age groups of children, 5 and6 years old and 9 and10 years old, with 10 participants in each group. The study site is in a college campus and the wayfinding route is located between several buildings. Each child is first walked beside the experimenter along the wayfinding route and then asked to traverse the route in both forward and backward directions. After the wayfinding test, several tests concerning visuo-spatial ability and verbal ability are given and the relationship between wayfinding performance and posttest scores is examined. The results indicate that children with high visuo-spatial ability make fewer errors during wayfinding than those with low visuo-spatial ability and this holds only for young children.

The studies reviewed above all had their wayfinding settings in real-world outdoor environment. These studies share some methodological features in common. First, most of the wayfinding routes are located in college campus or parks for security concern with only 2 exceptions in urban narrow road network in which safety is guaranteed. Second,

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due to the cost of time and money, the sample size is limited to several tens of participants. Small sample size might results in the problem of restricted range of data when correlation between wayfinding performance and other task scores are calculated (Baldwin & Reagan, 2009; Boumenir et al., 2010; Heth, Cornell, & Flood, 2002; Murias, Kwok, Castillejo, Liu, & Iaria, 2016). Finally, spatial knowledge manipulation in wayfinding test could be categorized into 2 conditions: route following and map study. In the former category, participants have to follow the predefined route (Boumenir et al., 2010; Fenner et al., 2000; Garden et al., 2002; Meilinger & Knauff, 2008; Nori et al., 2009). In the latter, maps are given to participants but retrieved before wayfinding test (Boumenir et al., 2010; Meilinger & Knauff, 2008). It is worth noticing that none of the categories fits into the wayfinding taxonomy structure of Wiener, Büchner, and Hölscher (2009).

2.3.3.2 Virtual environment: Google Street View

Online electronic maps, such as Google Maps and Bing maps, have presented maps users from a bird's-eye view featuring zoomable map scales. In 2004, Google Street View (GSV) has brought map users into street-level view(Vincent, 2007). The emergence of GSV is significant in several ways. First, when viewing perspective changes from aerial to ground-level, much more spatial details about the buildings and environments are revealed. Users are able to navigate in the streets from an egocentric representation of the world, which greatly resembles our daily live perspective. Second, GSV provides a virtual

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record of an area and enables users to explore the neighborhood online.

The launch or Google Street View also brings an insight for academic studies. Advantages of GSV include time efficiency, low monetary cost, safety for researchers and participants, and historical images of the same location. Google Street View offers efficient alternative method to survey a broad or dispersed area comparing to in-person audits.

Studies about public health in built environment have been taking advantages of Google Street View the most. Several studies have investigated the built environments for different age groups. Some have investigated the built environments for general adults (Ben-Joseph, Lee, Cromley, Laden, & Troped, 2013; Clarke, Ailshire, Melendez, Bader, & Morenoff, 2010; Griew et al., 2013; Kelly, Wilson, Baker, Miller, & Schootman, 2013; Rundle, Bader, Richards, Neckerman, & Teitler, 2011), some for Senior adults (Chudyk, Winters, Gorman, McKay, & Ashe, 2014), and still some for Children health (Odgers, Caspi, Bates, Sampson, & Moffitt, 2012). Besides, rather than in-person audits along the streets, the investigations of built cycling environments are made available through GSV (Gullón et al., 2015; Mertens et al., 2017; Vanwolleghem, Van Dyck, Ducheyne, De Bourdeaudhuij, & Cardon, 2014). With GSV, studies at the parcel resolution of social survey are plausible (Ben-Joseph et al., 2013; Kepper et al., 2017).

Google Street View offers an alternative to questionnaire method to studies that care

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about pedestrians. For example, studies of pedestrian counts(Yin, Cheng, Wang, & Shao, 2015), walkability(Yin & Wang, 2016), pedestrian injury(Hanson, Noland, & Brown, 2013; Mooney et al., 2016) are doable through GSV images.

Other studies about street appearance through Google Street View are common. Some have surveys street tree or vegetation from a large scale (Deus, Silva, Catry, Rocha, & Moreira, 2015; Richards & Edwards, 2017). Some have surveyed information/advertisement on streets to understand the effects on local residents, e.g. alcohol consumption and promotion(Clews et al., 2016), obesity (Feuillet et al., 2016), and physical health or mental health of streets (Wu et al., 2014). And some have used GSV to evaluate the seismic affection on buildings (Basset-Salom & Guardiola-Víllora, 2014; Borrelli, Antronico, Gullà, & Sorriso-Valvo, 2014).

Another impressive function of Google Street View is its regular update of street images. It enables investigators to trace back to earlier times of the street images to make comparisons over different time of the environments possible through online survey (Weiss, 2014). Although some argue that images of spatially nearby locations may not be contemporaneous (Curtis, Curtis, Mapes, Szell, & Cinderich, 2013)

Google Street View also benefits geographical education. A recent study show that teachers have students analyze parcel-by-parcel images around a neighborhood near Detroit through GSV. By employing spatial analysis rather than collecting data in the field,

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students are capable to gain deeper understanding of a rhetoric descriptions in the book *Portrait of a Revolution* (Bentley, McCutcheon, Cromley, & Hanink, 2016).

From the studies reviewed above, there is no denying that Google Street View is beneficial on surveying the environments in street scale, and it turns out to be a valid method in the fields of public health, street built environments and geographical education. There is, however, very few studies employing GSV in the field of wayfinding.

To date, the number of wayfinding studies using Google Street View is rare. Fazekas, Gáspár, Biró, and Kovács (2014) collect the truck drivers' braking locations and check the surrounding braking environments on Google Street View. They find a systematic relationship between drivers' braking locations and street built environments. Baltaretu, Krahmer, and Maes (2015) take advantages of GSV to know whether references to paths and landmarks in wayfinding routes are influenced by environmental complexity.

Comparing to self-generated computer graphic virtual environment, Google Street View is adopted in our studies. There are three reasons. First, GSV provides real-life street images and hence preserves more details. Second, by providing real-life navigation environment, the real-life navigation behavioral pattern of our participants would be observed. Third, comparing to computer graphic virtual environment, GSV costs less time and money. By using the Google Street View API, Google Street View is free of charge, and some customizations is plausible.

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Although studies using Google Street View have shown potential and benefits, there are unresolved problems. Whether participants show similar behavioral patterns in virtual environments, e.g. GSV, as those in real-world environments is unknown. Therefore, whether the conclusions made in virtual environment studies could be applicable to real-world situations remains in uncertainty. This question will be investigated in this study.

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Chapter 3. Research Method

3.1 Research design

In this study, 3 key questions are to be investigated. Each question had its research method and statistical analysis stated below.

The first question: Are the wayfinding results on different interfaces comparable? Are the study results on computer interface parallel to real-world wayfinding behavior?

To answer this question, a within-subject experimental design was adopted. The within-subject variable was "wayfinding testing environment." Each participant in our study would receive wayfinding testing in two different environments, which were real-world environment and virtual environment (Google Street View) environment. To parallel the results of virtual environment condition to those of real-world condition, "criterion-related validity" was used here.

Criterion-related validity is an important concept in psychological testing, which demonstrates the accuracy of a measure or procedure by comparing it with another measure or procedure (criterion) which has been previously proved to be valid (American Psychological Association, 1999). For example, a new IQ test would claim its validity by comparing the results to that of Wechsler Adult Intelligence Scale (WAIC), which is the most broadly used IQ test in the world.

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In this study, the performance in real-world testing environment was our criteria. A statistical correlation analysis of wayfinding performances between virtual environment and real-world would reveal an answer to the first question.

The second question: Would different types of knowledge of the same wayfinding route affect the wayfinding performance of the participants?

A between-subject design was used to address question 2. The between-subject variable was "wayfinding route cue types (cue types)." In this study, there were three different kinds of descriptions (cues) of the same wayfinding route, which were verbal descriptions, map descriptions and exposure descriptions. Participants were randomly assigned to either of the 3 cue types. Randomization procedure were reported to have the benefit of mitigating the confounding variables, which affect the results due to factors other than the manipulated variables (Conlon & Anderson, 1990; Fisher, 1937). Therefore, the causal relationship between cue types and wayfinding performance would be able to establish. A between-subject analysis of variance (ANOVA) on the performances could show whether there was a differential effect of the 3 different kinds of wayfinding route cue types. Post hoc comparison procedure would help reveal the patterns or relationships between 3 cue types.

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The third question: how do psychological geospatial abilities and knowledge of the environment interact on the wayfinding performance?

Wayfinding process involved both psychological geospatial factors and environmental cognition. Environmental cognition in wayfinding was defined by the wayfinding route cue types in this study. Psychological geospatial factors included working memory, mental rotation, sense of direction and geospatial abilities. Psychological geospatial factors were explored through online survey method. How the two factors described above interact on the wayfinding performance was investigated. Statistical correlational analysis between the wayfinding performance and the surveyed variables would help determine influential factors during wayfinding (see 3.3 Design and materials for detailed descriptions of each test).

3.2 Participants

Convenience sampling was adopted in this study. From previous wayfinding studies (Fenner et al., 2000; Liben et al., 2013; Meilinger & Knauff, 2008), a number of 45 participants was decided in our study. Our participants were recruited from internet bulletin board, with the restrictions that participants must be unfamiliar with the real-world (NTU campus) or street view (Taichung Rail Station) wayfinding study sites. Unfamiliarity was ensured by a screening test of subject recruitment (Figure 3). Those whose response was “very unfamiliar” or “unfamiliar” were admitted to participate in this

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study.

資格檢核1：你對台大校園的熟悉程度為何？ *

- 非常不熟悉
- 不熟悉
- 有點不熟悉
- 普通
- 有點熟悉
- 熟悉
- 非常熟悉

資格檢核2：你對台中火車站周邊的熟悉程度為何？ *

- 非常不熟悉
- 不熟悉
- 有點不熟悉
- 普通
- 有點熟悉
- 熟悉
- 非常熟悉

Figure 3 Screening test for participants recruitment

There were 15 participants for each cue type. Block randomization was use in assigning participants to each cue type, i.e. the first 3 participants recruited were randomly assigned to each cue type, followed by next 3 ones randomly assigned, etc.

The age range of our participants was between 21 and 44 (*Mean (M)* = 28, standard deviation (*SD)* = 6). The total number of male is 19. All participants have the education level of college or above. They were paid NTD 250 for an approximately 90 mins experiment session.

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3.3 Design and materials

From section "3.1 Research design", the design of this study followed a two-factor mixed experimental design and a survey method (Figure 4). The between-subject variable was wayfinding route cue types and the within-subject variable was wayfinding testing environment. Wayfinding route cue types were varied across 3 different groups of participants. Each participant received 2 different wayfinding testing environments, i.e. real-world environment and Google Street View. The sequence of wayfinding testing environment was fixed. The real-world setting always came before Google Street View setting. The reason why the sequence of wayfinding testing environments were not counterbalanced was that participants were interviewed by the experimenter for the strategies adopted right after wayfinding test in either environmental setting. To attain naïve participants in real-world setting and to avoid carryover effect from Google Street View setting, wayfinding in real-world setting always preceded that in GSV setting.

All groups of participants underwent 3 experimental phases. The first phase was wayfinding testing in the real-world environment. The second phase was wayfinding testing in Google Street View interface. The last phase was an online test battery, which consisting of wayfinding strategy test, psychological abilities and geographical skills tests (see Table 1 for material used in each phases)

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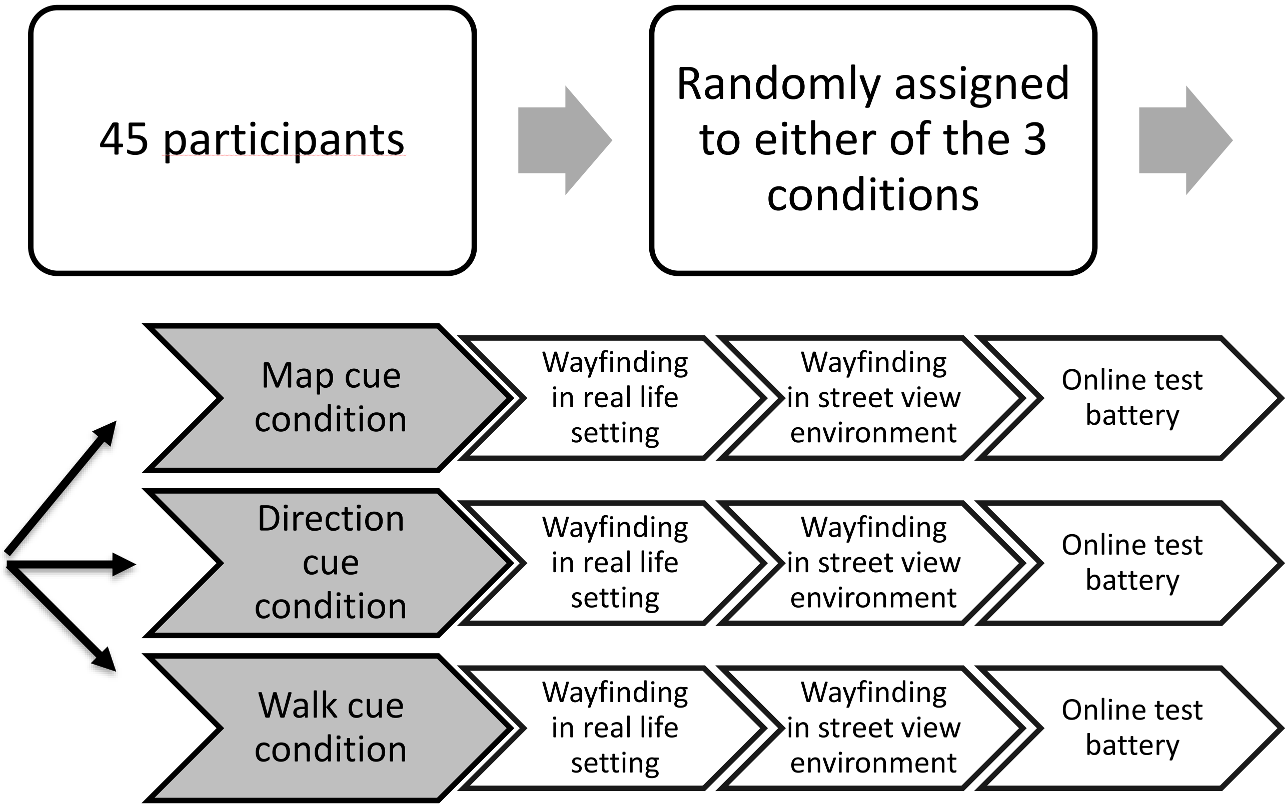

Figure 4 Schematic diagram of a two-factor mixed experiment design.
The between-subject variable is wayfinding cue types and the within-subject variable is wayfinding testing environment.

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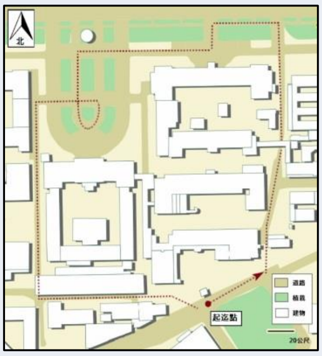
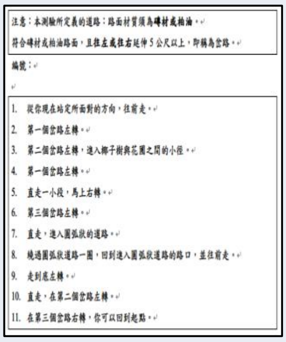
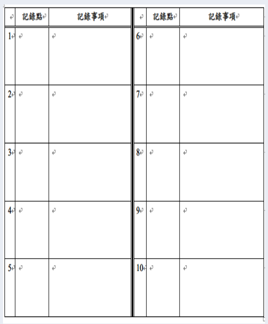
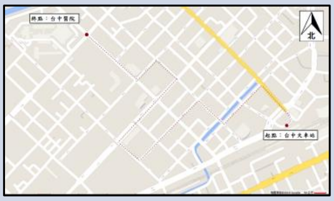
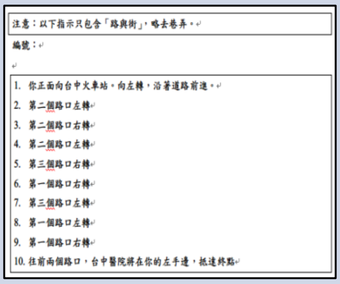
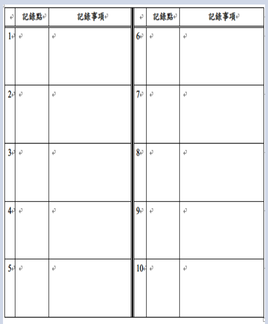
Table 1 Materials used in 3 wayfinding cue types during 3 phases

	Three wayfinding route cue types		
	Map cue	Direction cue	Walk cue[1]
<u>Phase1</u> real-world setting		 注意：本測驗所定義的道路：路面材質須為磚材或柏油。 符合磚材或柏油路面，且往左或往右延伸 5 公尺以上，即稱為岔路。 編號： 1. 從你現在站定所面對的方向，往前走。 2. 第一個岔路左轉。 3. 第二個岔路左轉，進入椰子樹與花園之間的小徑。 4. 第一個岔路左轉。 5. 直走一小段，馬上右轉。 6. 第三個岔路左轉。 7. 直走，進入圓弧狀的道路。 8. 繞過圓弧狀道路一圈，回到進入圓弧狀道路的路口，並往前走。 9. 走到底左轉。 10. 直走，在第二個岔路左轉。 11. 在第三個岔路右轉，你可以回到起點。	
<u>Phase2</u> Street view setting		 注意：以下指示只包含「路與街」，略去巷弄。 編號： 1. 你正面向台中火車站。向左轉，沿著道路前進。 2. 第二個路口左轉 3. 第二個路口右轉 4. 第二個路口左轉 5. 第三個路口右轉 6. 第一個路口右轉 7. 第三個路口左轉 8. 第一個路口左轉 9. 第一個路口右轉 10. 往前兩個路口，台中醫院將在你的左手邊，抵達終點	
<u>Phase3</u> online test battery	wayfinding strategy questionnaire Santa Barbara Sense of Direction Scale (SBSOD) [2] Geospatial Thinking Ability Test (GSTAT) [2] Mental Rotations task[3] Visuo-spatial working memory task[3] Digit Span task[3]		

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[1] In walk cue, participants were accompanied walking through the wayfinding route. A record sheet was given for them to take notes of any information helpful for later navigation on their own.

[2] geospatial skills test

[3] psychological abilities tasks

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3.3.1 First phase: Wayfinding testing in real-world environment

In the real-world wayfinding testing phase, the wayfinding route was 830 m, taking about 10 min to complete at a moderate pace. The participants in map-cue condition received a partial map of National Taiwan University (NTU) campus, which was clipped from the NTU official electronical map (http://map.ntu.edu.tw/mobile.html#mappage). The clipped map was modified to take out the names of all landmarks and only to include the north arrow, the scale bar, and the legend. The wayfinding route was indicated by red dotted line (Figure 5).

The route included 6 left turns, 2 right turns and an oval-shaped curve path. The road pavement was made of asphalt or tiles and no road signs along the route, which differed from regular traffic road networks. Participants were informed in advance about the definition of road network.

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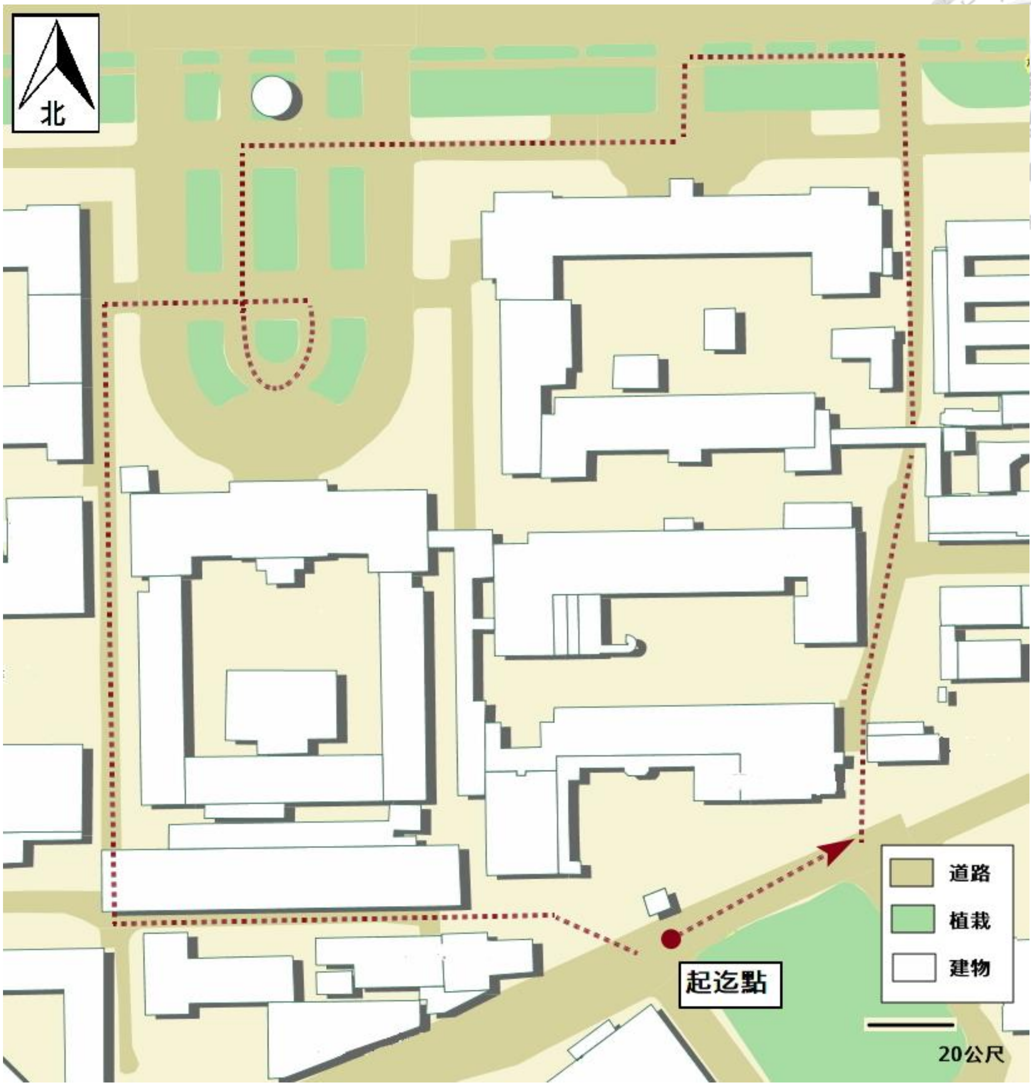

Figure 5 Partial NTU campus map that participants in map-cue condition receive

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The participants in the direction-cue condition were given a list of 11 verbal directions from the starting point to the destination. To make a parallel with the map cue, direction cues were written in the skeletal description (Denis, 1997). The information of making turns at a specific road junction was provided while the names of landmarks were omitted. And to clarify the wayfinding route, a written definition of road and junction was noted (Figure 6).

注意：本測驗所定義的道路：路面材質須為磚材或柏油。↵
符合磚材或柏油路面，且往左或往右延伸 5 公尺以上，即稱為岔路。↵

編號：↵

↵

1. 從你現在站定所面對的方向，往前走。↵
2. 第一個岔路左轉。↵
3. 第二個岔路左轉，進入椰子樹與花圃之間的小徑。↵
4. 第一個岔路左轉。↵
5. 直走一小段，馬上右轉。↵
6. 第三個岔路左轉。↵
7. 直走，進入圓弧狀的道路。↵
8. 繞過圓弧狀道路一圈，回到進入圓弧狀道路的路口，並往前走。↵
9. 走到底左轉。↵
10. 直走，在第二個岔路左轉。↵
11. 在第三個岔路右轉，你可以回到起點。↵

Figure 6 List of direction instruction in the direction-cue condition

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The third wayfinding route cue condition was walk cue. Participants in this condition were accompanied walking by the experimenter. Before walking, participants were given a record sheet to freely take notes of information that would help them travel the route by themselves in a reverse direction. The record sheet was made of a table with 10 cells to note the points of interest and related information. Participants were explicitly told that they could use the record sheet at will and points of interest were not limited to only 10 (Figure 7).

	記錄點	記錄事項		記錄點	記錄事項
1			6		
2			7		
3			8		
4			9		
5			10		

Figure 7 The record sheet provided in the walk cue condition.

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3.3.2 Second phase: Wayfinding testing in Google Street View

After finishing the wayfinding test in NTU campus, participants took wayfinding test on Google Street View interface, which was displayed on a 22-inch computer screen with Chrome browser. Participants were instructed to be seated upright so that the distance between eyes and screen kept at about 60 cm. A video clip of 1 min 38sec was played to introduce the interface of the GSV and show the participants how to navigate on GSV by keyboard. The navigation skills included moving forward or backward, rotating the viewing direction, zooming to see the streetscapes, and making turns (Figure 8).

Figure 8 Sample screen image of the Google Street View introduction video clip. This frame showed the participants how to make to right turn.

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Participants had one minute to practice the navigation skills on Google street view interface. Taking advantage of the Google Street View API, street view displayed was modified to remove the road name watermarks and mini navigational map (Figure 9). What's more important, the navigational tracks of each participant were recorded by point with a time and location stamp. With the tracks and it stamps, it was plausible to execute a comprehensive analysis of the navigation behavior of each participant, which might bring a great potential of later wayfinding analysis.

Figure 9 Sample screen image of Google Street View.
Note that road names and mini navigational map are taken out.

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In the map-cue group, a map was clipped form Google map but under modification of removing road names, landmarks, and small alleys. North arrow and scale were preserved. In the second phase, the wayfinding route was on regular traffic network. The starting point (Tai-Chung Rail Station) and destination (Tai-Chung Hospital) were marked and wayfinding route was indicated by red dotted line (Figure 10). The reason why Tai-Chung was picked up was that the road network near Tai-Chung rail station was of the grid pattern and Tai-Chung was far away from Taipei, where participants were recruited. Participants were told that at the beginning of the task they would be located facing the Tai-Chung Rail Station. The route was about 1800m in length and included 6 left turns and 4 right turns, which were about the same number of turns as that in the first phase.

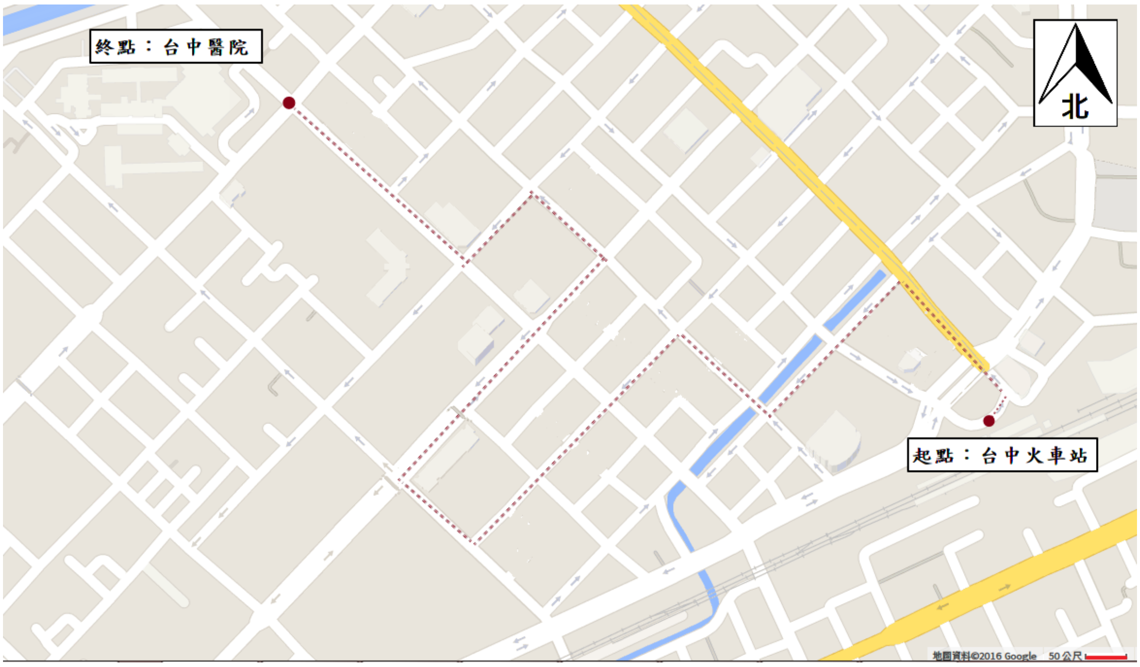

Figure 10 Wayfinding route map in map-cue condition

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In the direction-cue condition, a list of 10 verbal directions was given in the skeletal description form. Participants were instructed to ignore the small alleys in the Google Street View and concentrate on large streets and roads (Figure 11).

注意：以下指示只包含「路與街」，略去巷弄。

編號：

1. 你正面向台中火車站。向左轉，沿著道路前進。
2. 第二個路口左轉
3. 第二個路口右轉
4. 第二個路口左轉
5. 第三個路口右轉
6. 第一個路口右轉
7. 第三個路口左轉
8. 第一個路口左轉
9. 第一個路口右轉
10. 往前兩個路口，台中醫院將在你的左手邊，抵達終點

Figure 11 List of direction instruction in the direction-cue condition

In the walk-cue condition, participants watched a five-minute video clip that showed the navigation process from the starting point to the destination. This video clip was at a slower than normal pace in order to give participants more time to process the information in the clip (https://youtu.be/zo_cISLAxq4). Record sheet was given for participants to take notes of useful information to help them to navigate later on their own, while note-taking was not a compulsory action.

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3.3.3 Third phase: online test battery

In the third phase, a test battery consisted of a wayfinding strategy questionnaire, 3 psychological tasks, 2 geospatial ability scales, and a demographic survey was administrated online.

(1) Wayfinding Strategy Questionnaire

Wayfinding Strategy Questionnaire is an online 5-point Likert scale questionnaire developed by Lawton and Kallai (2002) (Figure 12). The questionnaire measures 2 different wayfinding strategies, the route strategy and the orientation strategy. When wayfinders rely on the landmark-based route information during wayfinding, the route strategy is preferred. When wayfinders are reported that they orient to global reference point (e.g. cardinal directions or North), the orientation strategy is preferred.

The questionnaire was translated into Chinese and contained 17 items. The first 11 items measured orientation strategy and remaining 6 items measured route strategy (see Appendix A for full questionnaire). Summation across belonging items was the score for each strategy. An extra item was added by the experimenter to investigate the way of commute.

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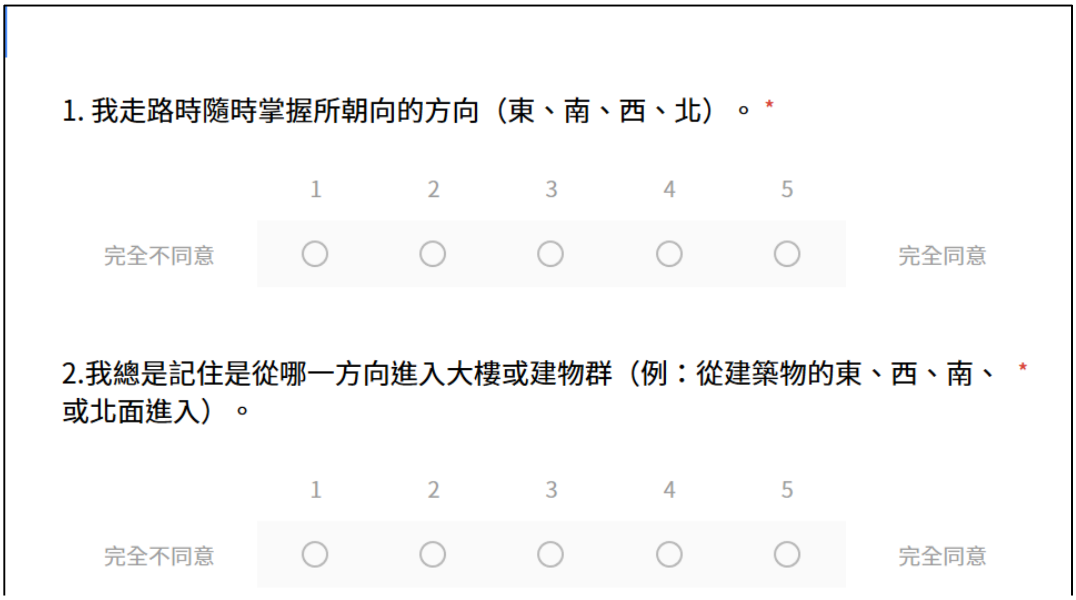

Figure 12 sample screen image of the questionnaire of wayfinding strategies

The following 3 psychological tasks were administrated online at http://www.cambridgebrainsciences.com/. This site was given its name after a team of neuroscientists at Cambridge University, UK. It offered a platform of 12 flash type online games which aimed to assess the neurocognitive functions such as reasoning, memory, and planning. All 12 flash-game task were accessible to the public, while some tasks required signing in in the first place.

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(2) Rotations task

Two boxes appeared on the screen with green and red squares filled in. Within 1 min 30 sec, participants were required to make a judgment of whether the two panels would be identical once mentally rotate either one panel (Figure 13). Item scores were given per each judgement.

Figure 13 Sample screen image of rotations task

Item scores were given according to the number of squares in the box. When correct responses were made, participants gained the point, otherwise lose it. If two successive correct responses were made, number of squares would increase by one. Mental rotation abilities were linked to performance in perspective taking and navigation. In particular, mental rotation skills have been found to significantly correlate with route learning; Individuals who performed better at mental rotation tasks were more able to find the most direct route out of a wooded terrain (Silverman et al., 2000).

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(3) Monkey Ladder task (visuo-spatial working memory, VSWM)

Boxes would appear at different locations on the screen, each having a number. Participants had to remember the numbers on each box. After a short period of time, the number would disappear. Participants were required to click on the boxes in numerical sequence (Figure 14). If correct responses were made, participants would have one more box to remember, otherwise one less box. After 3 errors were made, the test end. The test scores were the number of boxes at the last correct trial. Inoue and Matsuzawa (2007) found that a well-trained chimpanzee could maintain as high as 9 boxes in spatial working memory. That's exactly the reason why this task was called "Monkey ladder". Their research suggested that spatial working memory might play an essential role in human spatial cognition.

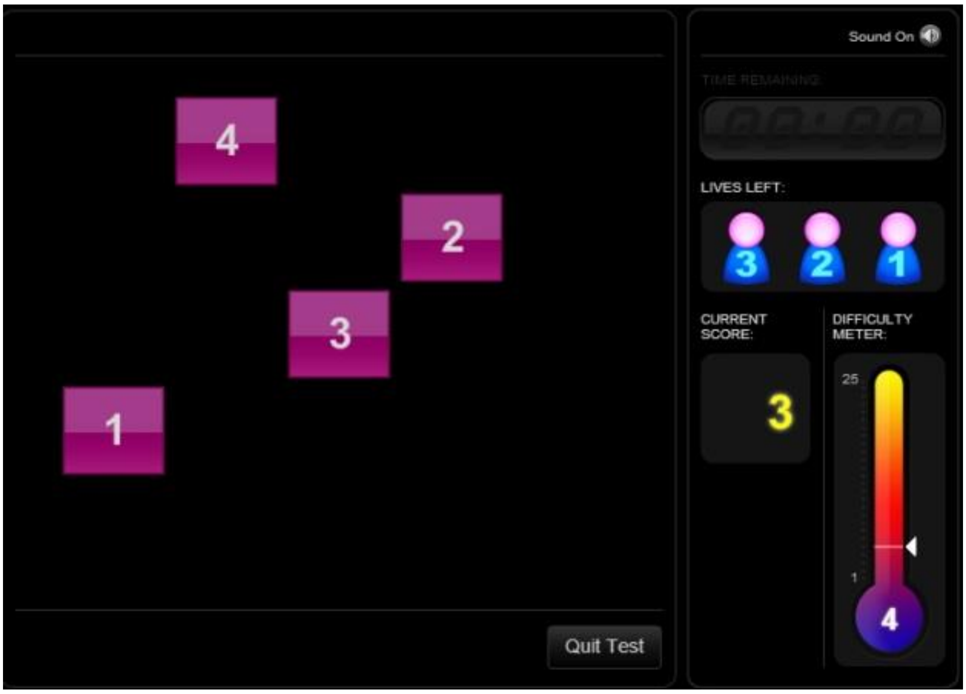

Figure 14 Sample screen image of monkey ladder task

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(4) Digit Span task

Participants were instructed to remember the digit sequence that successively appeared at the center of the screen. The flash rate of the digit was 500ms per each digit. After all the digits had shown up, participants were required to press the number pad on the keyboard in the same sequence of the appearance of the digits. If correct responses were made, participants would have one more digit to remember, otherwise one less digit. Possible maximum task scores were 25. After 3 errors were made, the test end. The test scores were the number of digits at the last correct trial. Digit span was associated with verbal information storage. In the working memory model (Baddeley & Hitch, 1974), digit span revealed the verbal working memory abilities, which allowed temporary verbal information storage and manipulation.

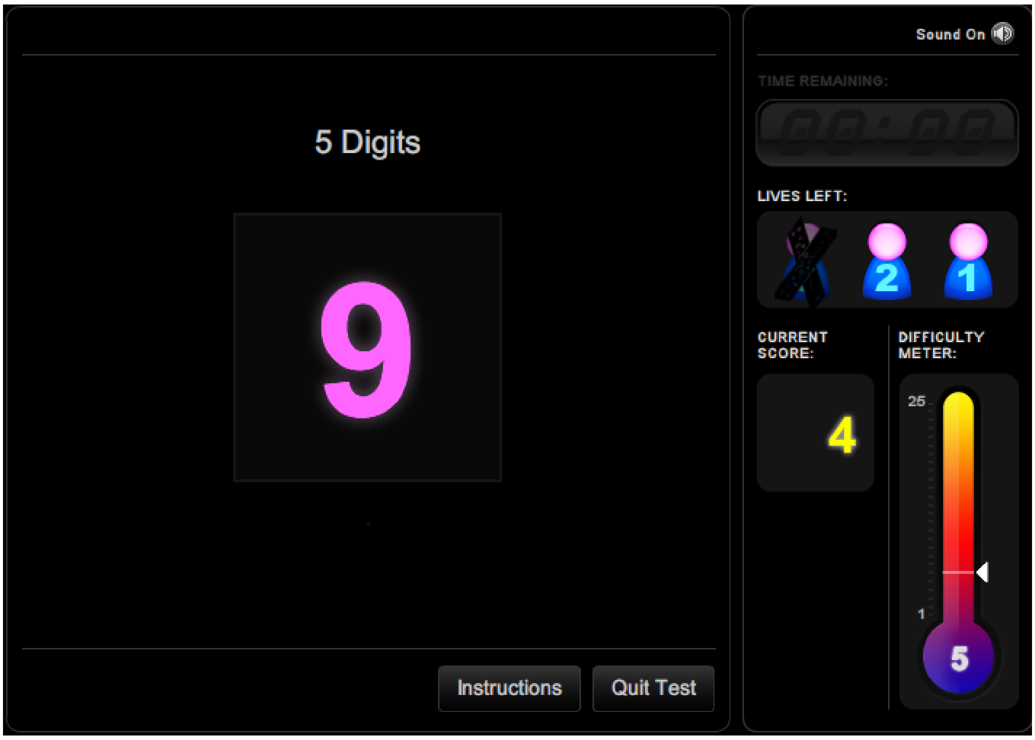

Figure 15 Sample screen image of digit span task

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(5) Santa Barbara Sense of Direction Scale (SBSOD)

The Santa Barbara Sense of Direction Scale included statements about sense of direction in Likert 7-point form (Hegarty, Richardson, Montello, Lovelace, & Subbiah, 2002). We translated the English version into the Chinese version (Figure 16). There were a total of 15 items, with item no. 2, 6, 8, 10, 11, 12, 13, 15 as reverse items. Total score were summary of 15 items (see Appendix B for full questionnaire).

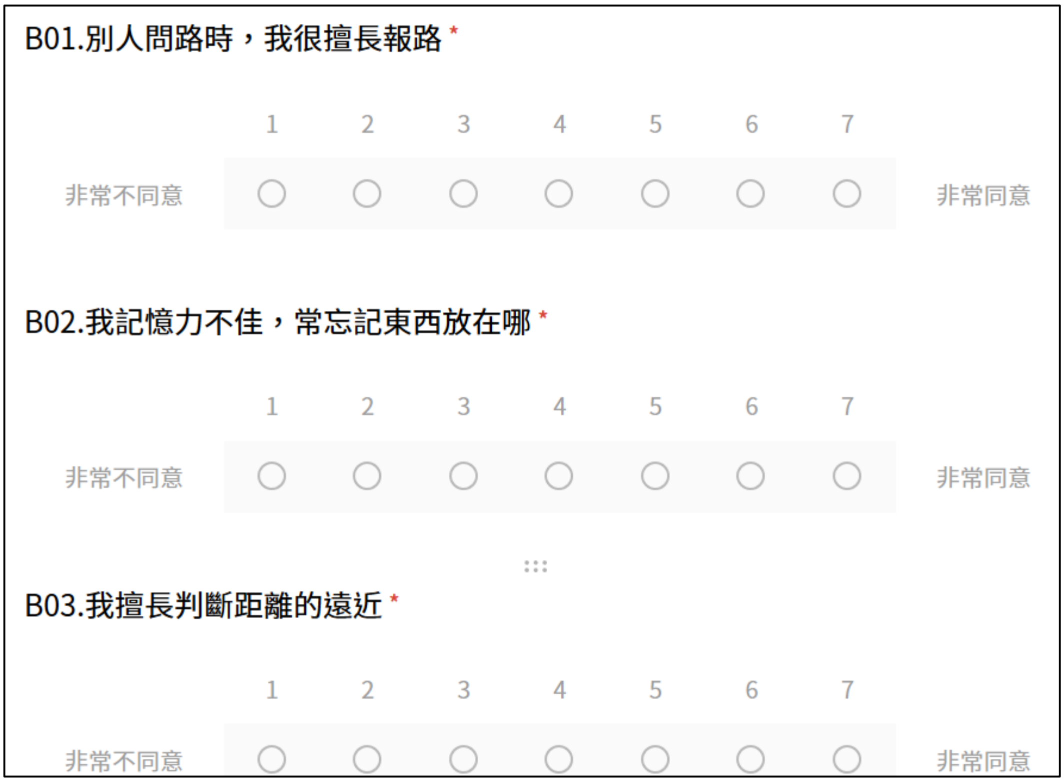
B01.別人問路時，我很擅長報路 *
1 2 3 4 5 6 7
非常不同意 非常同意
B02.我記憶力不佳，常忘記東西放在哪 *
1 2 3 4 5 6 7
非常不同意 非常同意
:::
B03.我擅長判斷距離的遠近 *
1 2 3 4 5 6 7
非常不同意 非常同意

Figure 16 Sample items of Santa Barbara Sense of Direction Scale

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(6) Geospatial Thinking Ability Test (GSTAT)

Geospatial Thinking Ability Test were developed in our lab (Lai & Wu, unpublished manuscript). Five geographical key concepts were embedded in GSTAT, which were direction, relief, pattern, overlay, and buffer (see Appendix C for full questionnaire). There were 24 multiple choice items in the test, and each item had only one correct answer. Total scores were the number of correct items.

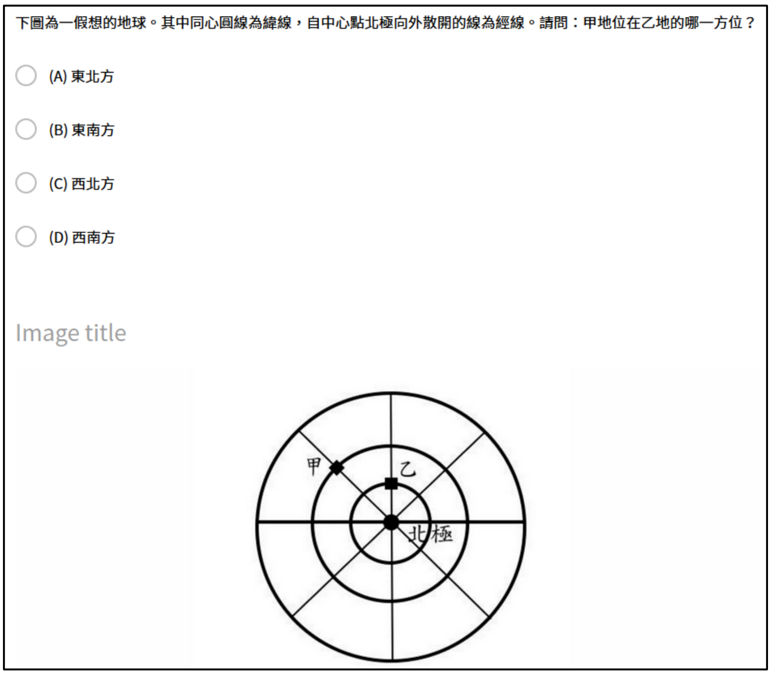

Figure 17 sample items of GSTAT

(7) Demographic survey

The last online form was a demographic survey. This surveyed included the gender, education level, department in college and birth year. Whether participants had the experience of GIS related class and how often they used the navigation aid per month were also investigated.

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3.4 Procedure

Each participant was tested individually. The experiment included 3 phases: wayfinding testing in real-world environment, wayfinding testing on Google Street View interface, and an online test battery of geospatial and psychological tests. See Figure 18 for a schematic flowchart of the experimental procedure of each cue type condition.

For participants in the map-cue condition, in the first phase they were instructed to study the map of wayfinding route for 4 min and were encouraged to take text notes or draw diagrams to help them remember the wayfinding route. Upon finishing studying, the map was retrieved and participants were lead to the starting point and asked to wear a Garmin Oregon 550t GPS receiver to track their navigation route. Participants were told that they would be followed by the experimenter at a distance of about 3 steps. They would be noticed if they had entered the wrong route. Participants could ask to see the map once they got lost in the campus. During the navigation of the participants, the experimenter recorded the wayfinding performance. Experimenter would note error routes, asking for help, stopping steps, and hesitation. After wayfinding test, participants were interview for the strategies they used during the map study period.

In the second phase, the procedure was quite similar except participants did the wayfinding testing on Google Street View. First a 1 min video clip was introduced to demonstrate how to navigate on the Google Street View interface and participants had 1

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min to gain acquaintance with the interface. Then a wayfinding route map was given and participants had 4 min to study. After studying, the map was retrieved and participants began the wayfinding test. The experimenter was seated aside and recorded the wayfinding performance of the participants (see Appendix D for full instructions). On finishing the wayfinding testing on Google Street View interface, participants were interviewed by the experimenter for their wayfinding behavior and their strategies when studying the map cue.

In the third phase, participants were instructed to complete an online test battery comprising an online wayfinding strategy questionnaire, 3 psychological tasks, 2 geospatial ability scales, and 1 demographic survey. Google form was adopted to organize the questionnaires and tasks into an online test battery, through which participants were self-paced to accomplish the third phase (Figure 19). Before each of the 3 psychological task, a short video clip of about 1 min was introduced to instruct our participants to perform the task on an English interface website. Participants were encouraged to respond quickly while maintaining accuracy. At the end of each task, participants were instructed to report the gained scores by themselves through Google form. The whole experimental session last for about 90 min.

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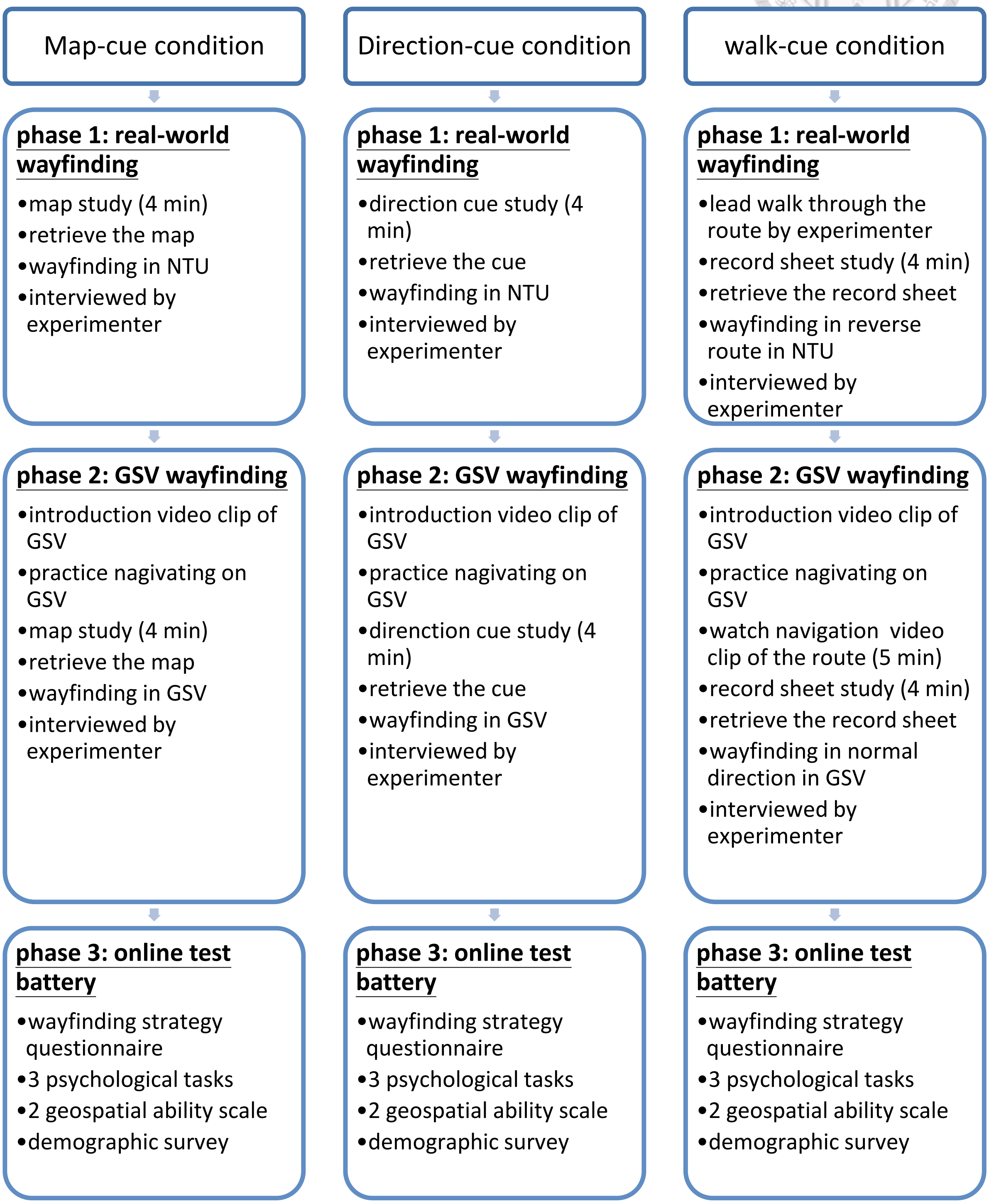

Figure 18 Schematic flowchart of experiment procedure

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Figure 19 Sample screen image of the online test battery

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For participants in the direction-cue condition, the procedure was quite alike except that participants received direction cue in both real-world and Google Street View wayfinding (see Appendix E for full instructions). In the first phase, participants were instructed to study the direction cue of the wayfinding route for 4 min. The direction cue was then retrieved and participants began to the wayfinding test in NTU campus. After wayfinding test, participants were interview for the strategies they used during the direction cue study period. In the second phase, participants were given a Google Street View demonstration video clip and then had 1 min to practice. Direction cue of GSV wayfinding was given for a 4 min study, followed by wayfinding test in GSV. The experimenter then interviewed with each participant to understand what strategies were adopted while wayfinding. In phase 3, participants were asked to complete an online test battery.

For participants in the walk-cue condition, in the first phase they were told that they would be accompanied walking throughout the wayfinding route by the experimenter and then they had to navigate the route in the reverse direction on their own. A record sheet was given and participants were able to take any notes that would help them remember the wayfinding route during the accompanied walking. After the accompanied walk, participants had a 4 min study of their record sheet, which was retrieved before wayfinding test. Participants wore a Garmin Oregon 550t GPS receiver and began their

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navigation in the reverse direction of the wayfinding route. Participants were followed by the experimenter and their wayfinding performance was noted. After wayfinding test, participants were interview for the strategies they used during the record sheet study period.

In the second phase, after viewing Google Street View navigation demonstration video and practicing on it, participants were asked to view a 5 min video clip showing the navigation process of the wayfinding route. They could take any notes on a record sheet while viewing and had a 4 min to study their record sheet. After study, participants were instructed to navigate in the normal direction, i.e. they did not have to travel in reverse direction. Their performance was noted by the experimenter (see Appendix F for full instructions). Participants were interviewed and proceeded to complete the online test battery and the experiment session ended.

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Chapter 4. Results and Discussion

4.1 Summary of variables in this study

In this study, a 2-factor mixed experimental method (phase 1 and 2) and a survey method (phase 3) were used to explore wayfinding. Since a complicated design was adopted and several tasks and questionnaires were administrated in our study, the number of variables generated was large. Here is a summary of all variables in each task or questionnaire. In experimental method, there were two independent variables (IV, shaded area in Table 2). Two levels of wayfinding testing environment and 3 levels of wayfinding route cue types produced 6 conditions. There were five dependent variables (DV, unshaded area in Table 2) in each condition. In survey method, there were 5 variables in psychological geospatial abilities and 6 variables in demographic survey (Table 3).

Table 2 list of variables in experiment method (phase 1 and 2)

IV: independent variable,

<table>
<tr><td colspan="2" rowspan="2"></td><td colspan="2">(IV) Wayfinding testing environment</td></tr>
<tr><td>Real-world wayfinding</td><td>Street view wayfinding</td></tr>
<tr><td rowspan="3">(IV) Wayfinding route cue types</td><td>Map cue</td><td colspan="2" rowspan="3">Dependent variables
1. Elapsed time in real-life wayfinding (sec)
2. Numbers of Errors made in real-life wayfinding
3. Elapsed time in street-view wayfinding (sec)
4. Numbers of Errors made in street-view wayfinding
5. Travelling distances in street-view wayfinding (m)</td></tr>
<tr><td>Direction cue</td></tr>
<tr><td>Walk cue</td></tr>
</table>

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Table 3 list of variables in survey method (phase 3)

Task or questionnaire	variables
Psychological geospatial abilities	1. Wayfinding strategy questionnaire 2. Mental Rotations task scores 3. Visuo-spatial working memory task scores 4. Digit Span task scores 5. Santa Barbara Sense of Direction Scale scores 6. Geospatial Thinking Ability Test scores
Demographic survey	1. Gender 2. educational level 3. major in college 4. Whether having taken GIS course (yes or no) 5. Frequency of using navigation aids per month 6. age

In wayfinding testing, the performance was measured with the following variables: elapsed time, travelling distances, and number of errors. The GPS receiver position uncertainty made the travelling distance measure in real-world setting unreliable. Therefore, the variable of travelling distance was discarded in later analysis in real-world wayfinding. The number of errors combined getting lost and asking for help from the experimenter.

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4.2 Descriptive statistics

4.2.1 Demographic variables

There were 45 participants (19 males and 26 females) in total. The distribution of age was between 20 and 44 (*Mean (M)* = 27, *Standard Deviation (SD)* = 6, Table 4). Average number of using navigation aid per month was 5.49 (*SD* = 3.67, Table 4). All participants had the education level of college or above. Only 6 out of 45 reported having GIS class experience before.

Table 4 Descriptive statistics for age and frequency of using navigation aid

	N	Mean	Std. Deviation	Minimum	Maximum
age	45	26.77	5.85	20.0	44.0
# using navigation per month	45	5.49	3.67	0	10

4.2.2 Wayfinding performance variables

Table 5 Descriptive statistics for wayfinding performance variables

	N	Mean	SD	Minimum	Maximum
Elapsed time_real world	45	633.13	89.49	394.0	790.0
Number of error_real world	45	3.02	2.37	0.0	9.0
Number of seek_real world	45	.66	0.82	0.0	3.0
Elapsed time_street view	45	360.93	128.41	114.0	659.0
Number of error_ street view	45	2.80	2.15	0.0	8.0
Number of seek_ street view	45	2.62	2.03	0.0	8.0

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In real-world environment wayfinding testing, average elapsed time was 633 s (*SD* = 89). The average number of seeking was 0.6 (*SD* = 0.8) and average number of errors was 3 (*SD* = 2.3). In Google Street View wayfinding testing, average elapsed time was 360 s (*SD* = 128) and average travelling distances was 2312 m (*SD* = 543). The average number of seeking was 2.6 (*SD* = 2) and average number of errors was 2.8 (*SD* = 2.1) (Table 5).

4.2.3 Psychological geospatial related variables

Table 6 Descriptive stat for spatial cognition related variables

	N	Mean	SD	Minimum	Maximum
orientation strategy scores	45	32.51	8.02	17.00	54.00
route strategy scores	45	26.04	3.83	16.00	30.00
mental rotation scores	45	77.31	40.94	-15.00	169.00
visuo-spatial WM task scores	45	8.44	1.27	6.00	12.00
Digit span (verbal WM) scores	45	9.64	1.71	7.00	14.00
SBSOD scores	45	68.93	14.74	32.00	104.00
GSTAT scores_total	45	15.84	4.40	7.00	23.00
GSTAT_direction	45	3.42	1.34	0.00	5.00
GSTAT_relief	45	2.42	1.45	0.00	5.00
GSTAT_pattern	45	3.60	1.12	2.00	5.00
GSTAT_overlay	45	2.89	1.03	1.00	4.00
GSTAT_buffer	45	3.51	1.25	1.00	5.00

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In this third phase of the experiment, an online test battery consisting of a wayfinding strategy questionnaire, 3 psychological mental processing capacity tasks (Rotations, Visuo-spatial working memory, verbal working memory), and 2 geospatial ability scales (Santa Barbara Sense of Direction Scale, and Geospatial Thinking Ability Test) was administrated. There were 2 subscales in wayfinding strategy, orientation strategy and route strategy. The average scores of orientation strategy and route strategy were 32.51 (*SD* = 8) and 26 (*SD* = 3). The average scores of Santa Barbara Sense of Direction Scale (SBSOD) and Geospatial Thinking Ability Test (GSTAT) were 68 (*SD* = 14) and 15 (*SD* = 4), respectively. The four subscales of GSTAT showed average scores of 3.4 (*SD* = 1.3) for direction, 2.4 (*SD* = 1.4) for relief, 3.6 (*SD* = 1.1) for pattern, 2.8 (*SD* = 1.0) for overlay, and 3.5 (*SD* = 1.2) for buffer. Rotations task indicated mean scores of 77 (*SD* = 44). Scores for visuo-spatial working memory task (VSWM) and verbal working memory task (VWM) were 8.4 (*SD* = 1.2) and 9.6 (*SD* = 1.7), respectively. See Table 6 for the details.

4.3 Performance comparison between real-world and Google Street View wayfinding testing environments

The concept of criterion-related validity was used here to test whether it was appropriate to parallel wayfinding testing on Google Street View interface to wayfinding testing in real-world environment. The performance between real-world and Google

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Street View wayfinding performance was correlated. The results showed that elapsed time and number of errors reached a significant correlation between both settings ($r(43) = .469$, $p < .01$ for elapsed time , $r(423) = .625$, $p < .01$ for number of errors) (Figure 20, Figure 21), suggesting that participants exhibited similar behavioral pattern in both real-world and Google Street View settings.

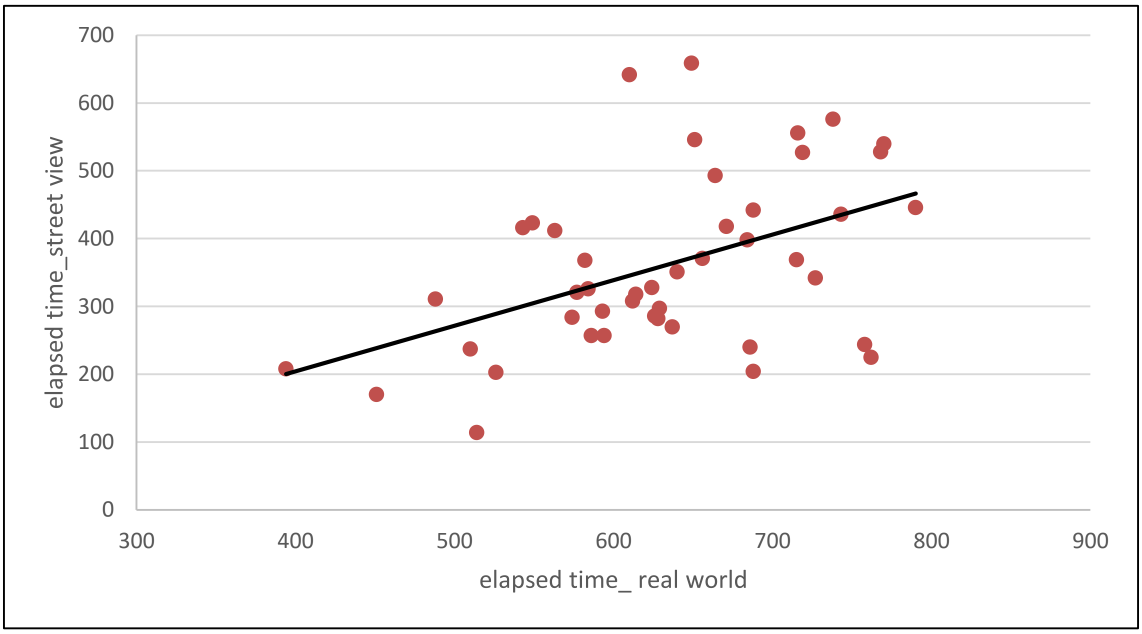

Figure 20 Scatter plot of elapsed time in real-world and street view settings. Line of best fit is indicated.

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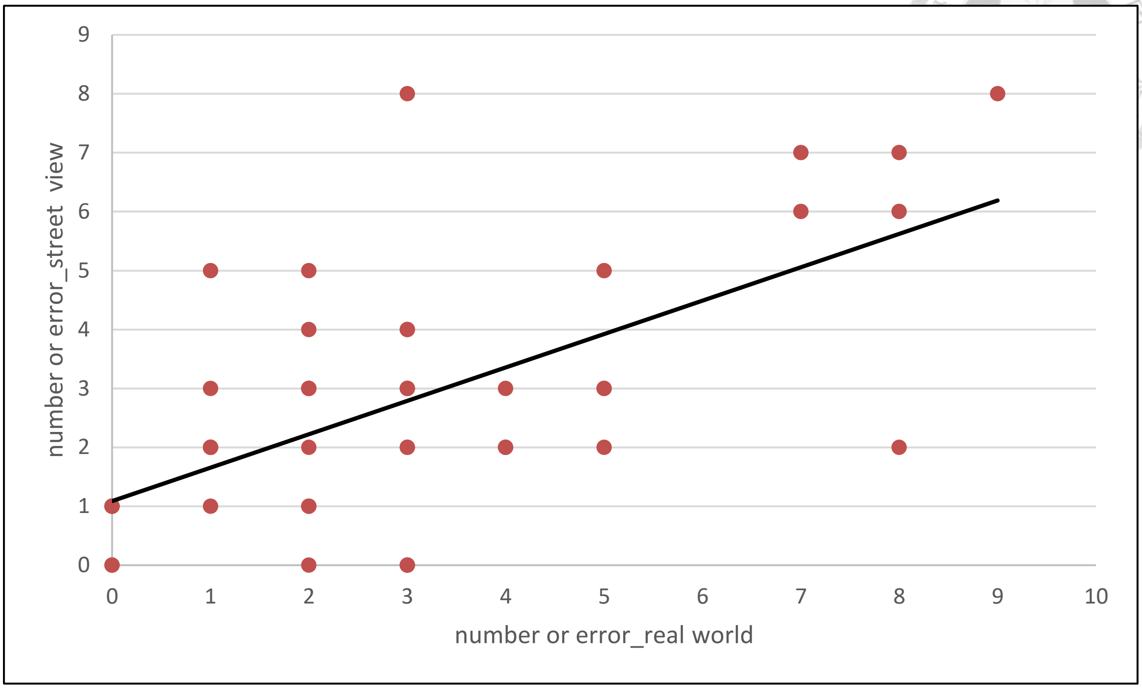

Figure 21 Scatter plot of number of errors in real-world and street view settings. Line of best fit is indicated.

4.4 Cue type effect on wayfinding performance

Analysis of variance (ANOVA) was used to analyze the effect of cue type on the performance variables in wayfinding tests. The results showed that cue type had main effect on the time elapsed in both real-world setting ($F(2,42) = 4.93$, $p < .05$) and Google Street View settings setting ($F(2,42) = 15.83$, $p < .01$). Tukey HSD post-hoc analysis revealed that participants spend less time navigating in walk cue condition than those in direction cue in real-world setting ($p < .05$). While in street view setting, participants spent less time in walk cue condition than those in direction cue or map cue conditions ($p < .05$ for each condition).

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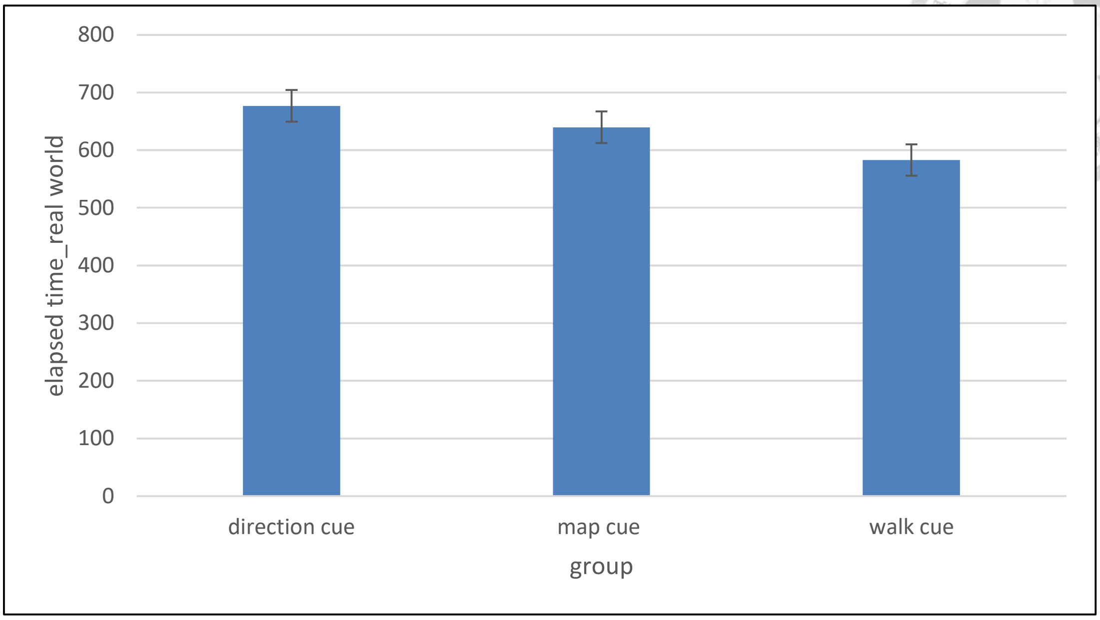

Figure 22 Mean elapsed time under different cue types in real-world wayfinding. Error bar is indicated.

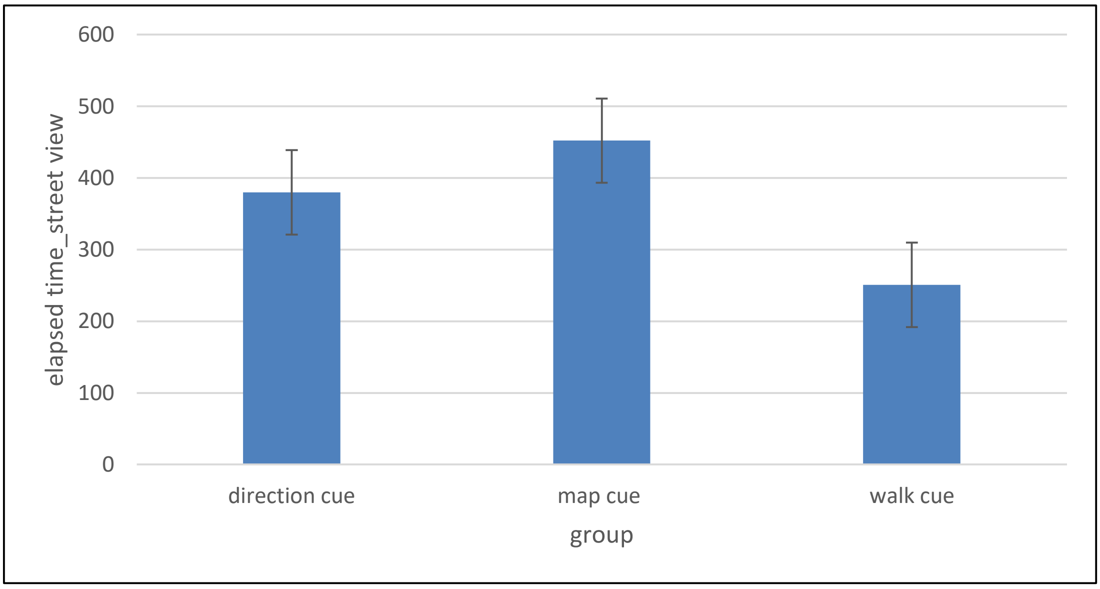

Figure 23 Mean elapsed time under different cue types in street view wayfinding. Error bar is indicated.

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4.5 Variables of interest in online survey

Before we proceed to further statistical analysis of wayfinding performance, a step was taken to seek for variables of interest. Since there were several tasks and questionnaires adopted in our online survey (phase 3), the number of variables mounted up to over ten. To seek for variables that had influential effect on wayfinding performance, preliminary linear regression analyses was executed.

A medical approach to build a regression model under several candidate predictors was followed (Harre Jr, Lee, & Pollock, 1988; Maldonado & Greenland, 1993). First, one variable at a time was put into the regression model as a predictor to test its significance. In other words, each variable in online survey was put into a simple regression analysis as predictor. Second, variables that had significant effect in simple regression were put into a multiple regression analysis to find the influential predictors.

The results of simple regression of elapsed time in real-world wayfinding on each variable in online survey was shown in Table 7. While the significance level was set to 0.2, the variables that reached significance were orientation strategy, route strategy, mental rotation, SBSOD scores, and gender. Next, these 5 variables were put into a multiple regression. The multiple regression model did not reach a significant level ($F(5,39) = 2.201$, $p > .05$) and no any variables show a significant coefficient.

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Table 7 statistical results of simple regression analysis of elapsed time of real-world wayfinding on each variable in online survey

PREDICTOR	F VALUE (F(1,43))	P VALUE
Orientation strategy	6.113	.017*
Route strategy	4.585	.038*
Mental rotation	1.862	.179*
Visual-Spatial WM	.849	.362
Verbal WM	.009	.925
SBSOD scores	1.86	.179*
GSTAT scores	.01	.901
GSTAT_direction	.178	.675
GSTAT_relief	.066	.799
GSTAT_pattern	.931	.340
GSTAT_overlay	.001	.982
GSTAT_buffer	.318	.576
gender	1.98	.166*
age	1.24	.271
GIS class experience	.182	.672
# using navigation aid per month	0	.994

*: $p < 0.2$

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The same procedure was applied to simple regression of elapsed time in Google Street View wayfinding on each online survey variables. The statistical results were shown in Table 8. While the significance level was set to 0.2, the variables that reached significance were verbal working memory scores and SBSOD scores. Next, these 2 variables were put into a multiple regression. The result indicated that these 2 predictors reached a significant level. The coefficient of verbal WM was 24.61 ($t(43) = 2.343$, $p < .05$) and the coefficient of SBSOD scores was -2.088 ($t(43) = -2.088$, $p < .05$).

The results showed above pointed out that most of our online survey variables failed to show associative relationship with wayfinding performance, whether in real-world or in GSV. With the exception that only 2 variables, verbal WM and SBSOD scores, showed a regression effect on elapsed time in GSV wayfinding. Therefore, it might be concluded that no variables other than wayfinding route cue type had an influential effect on wayfinding performance.

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Table 8 statistical results of simple regression analysis of elapsed time of Google Street View wayfinding on each variable in online survey

PREDICTOR	F VALUE (F(1,43))	P VALUE
Orientation strategy	1.659	.205
Route strategy	.016	.901
Mental rotation	.107	.746
Visual-Spatial WM	.020	.889
Verbal WM	4.656	.037*
SBSOD scores	3.523	.067*
GSTAT scores	.148	.702
GSTAT_direction	1.363	.249
GSTAT_relief	1.038	.314
GSTAT_pattern	.597	.444
GSTAT_overlay	.147	.704
GSTAT_buffer	.463	.500
gender	.177	.676
age	.130	.720
GIS class experience	.930	.340
# using navigation aid per month	.160	.692

*: $p < 0.2$

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4.6 Interactions between knowledge of the route and psychosocial geospatial abilities

Correlation analysis between wayfinding performance and psychological abilities and geospatial skills under different cue types meant to explore what mental functions or skills might be involved in wayfinding and how different cue types would adapt the required abilities. All three cue types combined, in real-world setting, elapsed time was negatively correlated with orientation strategy and route strategy scores (Pearson Correlation, $r(13) = -.35$, $p < .05$ and $r(13) = -.31$, $p < .05$, respectively). The above results suggested that orientation strategy and route strategy scores were a good predictor of wayfinding performance.

What's more important was the correlation analysis under different cue types. Under direction cue condition, neither a psychological or geospatial indicators were correlated with wayfinding performance. Under map cue condition, GSTAT scores, mental rotation scores, and VSWM were correlated with elapsed time ($r(13) = -.518$, $p < .05$, $r(13) = -.482$, $p = .06$, and $r(13) = -.491$, $p=.06$, respectively). Under walk cue condition, SBSOD scores and mental rotation scores were correlated with number of errors ($r(13)= -.512$, $p = .051$ and $r(13) = -.502$, $p = .057$, respectively).

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Chapter 5. Discussion

5.1 General discussion

In this study, wayfinding performance in two different testing environmental settings (real-world and Google street view) were simultaneously compared. The results showed that participants exhibited similar behavioral patterns. Previous studies have tested their ideas of wayfinding on single environmental setting, either on paper and pencil test, real-world environment, or virtual environment. However, whether study results on virtual environment setting have ecological validity as real-world ones do remains unsolved.

Theoretical gap between previous real-world and virtual environment studies that conducted at different time was filled. Our study provided evidence that performance in virtual environment setting was parallel to that in real-world setting in wayfinding. Our participants in both environments exhibit similar behavioral pattern. The pace and accuracy of wayfinding performance in Google street view were related to that in real world. The results suggested that although there are differences between real-world and virtual environment, cognitive processes involved in both settings might be very similar. Based on these findings, further wayfinding training on virtual environment settings would be made possible. Training effects on virtual environment are transferrable to real-world wayfinding performance. In the future, people with poor sense of direction might be trained and be improved through virtual environment device.

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Effect of different representations of the environments of wayfinding was also tested in our study. Participants were given different types of wayfinding route cue. The results indicated that when in an unfamiliar environment, performance in walk cue group was faster than direction cue in both environmental settings. These findings are consistent with the cognitive collage theory proposed by Tversky (1993). In a cognitive collage, rather than a detailed map, spatial objects are represented as a fragmented collection of bits of knowledge. Each bit might be visuo-spatial, textual, or even sounds. In the walk cue condition of our study, accompanied walking or navigation video clip provides multiple formats of information and that is beneficial for later travelling alone. These findings have great practical implications. One who wants to navigate in an unfamiliar environment would have the least possibility to get lost if he or she receives instructions comprised of different types of information, e.g. verbal texts, acoustic info, spatial info of maps, etc. The above would be easily implemented through Street View before navigation.

Finally, our study showed that different types of wayfinding cue involved different psychological geospatial abilities. In map description of environment, visual-spatial working memory and mental rotation ability played an important role, suggesting that mental processing resources, especially visual spatial working memory, influence wayfinding performance in graphical representation of the environment. Besides,

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geospatial thinking abilities (GSTAT) and wayfinding performance are correlated, indicating map reading skills are also essential.

In walk cue condition, the story is different. Sense of direction and mental rotation have an impact on wayfinding performance. While previous studies propose that visuospatial working memory is an important factor in wayfinding, neither visual-spatial nor verbal working memory is related to wayfinding performance in walk cue condition. The results imply that when human represent the wayfinding environment by direct experience, general mental resources are important, but does not limit to specific type of working memory.

5.2 Limitations and future work

Our study examined the effect of testing environments, route cue types and psychological geospatial abilities on wayfinding performance. There are, however, limitations in our study. First, real-life environment of wayfinding was located in NTU campus, where road instructions might not be complete. Therefore, there might be differences between campus and general road condition. Second, indoor environments were not tested here. Several studies have investigated wayfinding in indoor environment (Baskaya, Wilson, & Ozcan, 2004; Vanclooster et al., 2014; Walkowiak, Foulsham, & Eardley, 2015). Whether indoor and outdoor environments share similar mental processed remains to be tested in future studies.

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Third, though behavior patterns are similar in real-life and virtual environment settings, whether training effect is transferrable from VE to real-life lacks empirical evidence. It remains to be solved in future work.

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Appendix A. Wayfinding strategy questionnaire

1.我走路時隨時掌握所朝向的方向（東、南、西、北）。

2.我總是記住是從哪一方向進入大樓或建物群（例：從建築物的東、西、南、或北面進入）。

3.在大樓或建物群裡，我用東南西北方向來思考所在的地點。

4.我走路時隨時掌握自己與太陽（或月亮）的關係。

5.當我轉彎後，我知道自己朝向那個方向。

6.在街口或路標問路時，我會詢問關於東西南北的方向

7.我走路時隨時掌握自己與參考點（例如：大樓、河流、山丘）的相對關係。

8.當我走路時，我會在心中計算在不同的路上共走了多遠距離。

9.當我走路時，會在心中浮現該區域的地圖。

10.我隨時掌握「我目前的位置與我要轉彎的地方」的關係。

11.從我在大樓或建物群內所朝向的方向，我可以浮現出該方向建築物外的情況。

12.清楚可見的指向路標對我來說非常重要。

13.我對於可以告訴我方向的人（例：飯店櫃臺人員）非常欣賞。

14.大樓或建物群中清楚標示不同區域的代號或標號，對於我找到要去的方向非常有幫助。

15.我在問路時，會問在轉彎前會經過幾個路口。

16.我在問路時，會問是否在某個街口或路標時要左轉或右轉。

17.大樓或建築物群內，可以指出我現在所在位置的地圖，對我很有幫助。

18.你最常使用的通學/通勤方式為何（可複選，至多 2 項）。

他人駕駛（包括捷運、公車、鐵路、他人駕車接送等）

自行開車

騎機車

騎腳踏車

步行

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Appendix B. Santa Barbara Sense of Direction Scale (SBSOD)

請仔細閱讀每題幹敘述後，想想「它與自己實際經驗」的相同程度，並勾選您的同意程度；共計 15 題，請填答所有題目。

B01.別人問路時，我很擅長報路
B02.我記憶力不佳，常忘記東西放在哪
B03.我擅長判斷距離的遠近
B04.我的方向感非常好
B05.我傾向使用「東西南北」來思考所處的環境
B06.我容易在陌生的地方迷路
B07.我喜歡看地圖
B08.問路時，我通常無法理解別人給的路線指引
B09.我擅長看地圖
B10.坐車時，我通常不記得車子的行駛路線
B11.別人問路時，我不喜歡報路
B12.「我人在哪裡」對我來說並不重要
B13.旅行時，我通常讓其他人規劃路線
B14.在只有走過一次的情形下，我可以把沿路路線記住
B15.我不太能在腦海中呈現家裡附近的地圖

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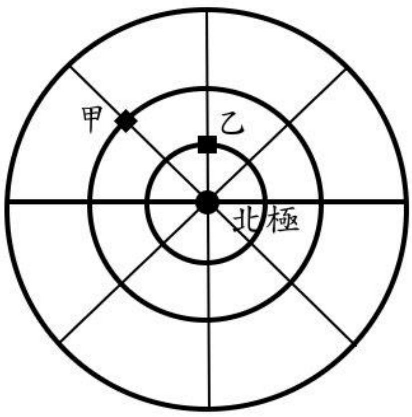
Appendix C. Geo-spatial thinking ability test, GSTAT

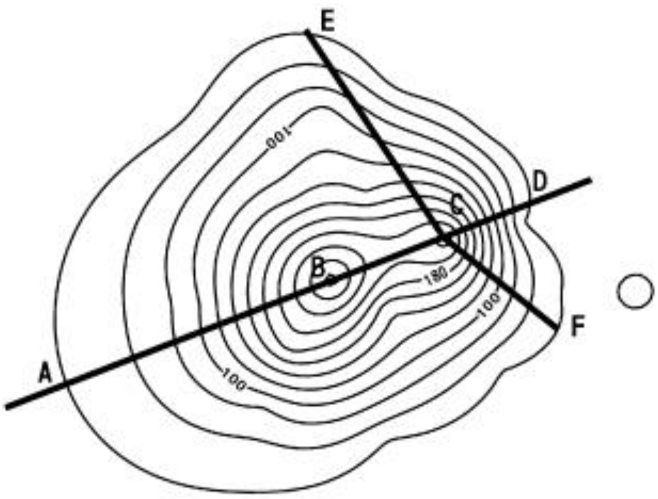
地理-空間思考能力測驗 (Geo-spatial thinking ability test, GSTAT)

本部份共計 24 題選擇題，每題僅有一個正確或是最佳解答，請填答所有題目，答錯並不會扣分。

1. (　　) 下圖為一假想的地球。其中同心圓線為緯線，自中心點北極向外散開的線為經線。請問：甲地位在乙地的哪一方位？ (A)東北方 (B)東南方 (C)西北方 (D)西南方。



2. (　　) 下圖是某座山的等高線圖，其中線段 AD、線段 CE、線段 CF 經過此山。請問下列選項的敘述中，何者是上坡且坡度最陡？
(A)A 點至 B 點 (B) C 點至 D 點 (C) E 點至 C 點 (D) F 點至 C 點



3. (　　) 下圖為小明家周遭地圖，並依照他家為中心，每 5 公里畫一同心圓。請由圖中算出，小明家方圓 20 公里內，有幾家便利商店？
(A)12 家 (B)15 家 (C) 16 家 (D) 18 家

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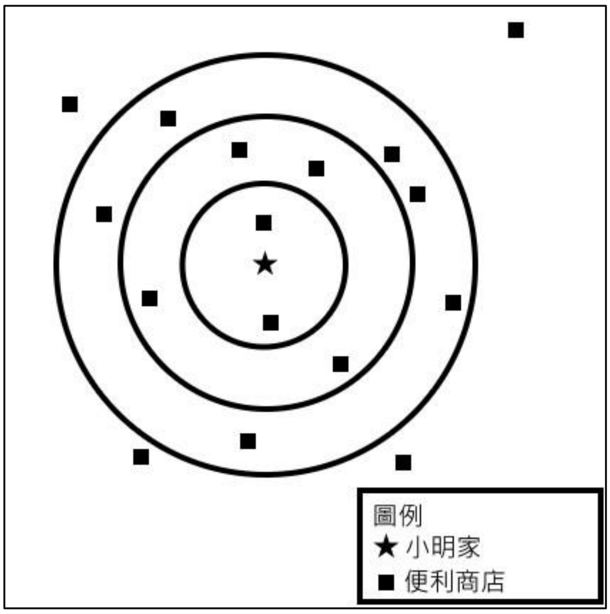

4. (　　) 下圖是某一地的衛星影像圖。請由該圖中判斷該張影像有幾個聚落存在？ (A)3　(B)5　(C)7　(D)9

5. (　　　　)　某國政府希望在一地區設立垃圾掩埋場(如圖，網格線部分為掩埋場預定地；星號為住家)，屆時除了掩埋場內的住家必須遷移之外，距離掩埋場 300 公尺內的住家也必須遷移。請問，這樣一來受波及而必須遷移的住家有幾戶？

(A)9 戶　(B) 12 戶　(C) 14 戶　(D) 18 戶

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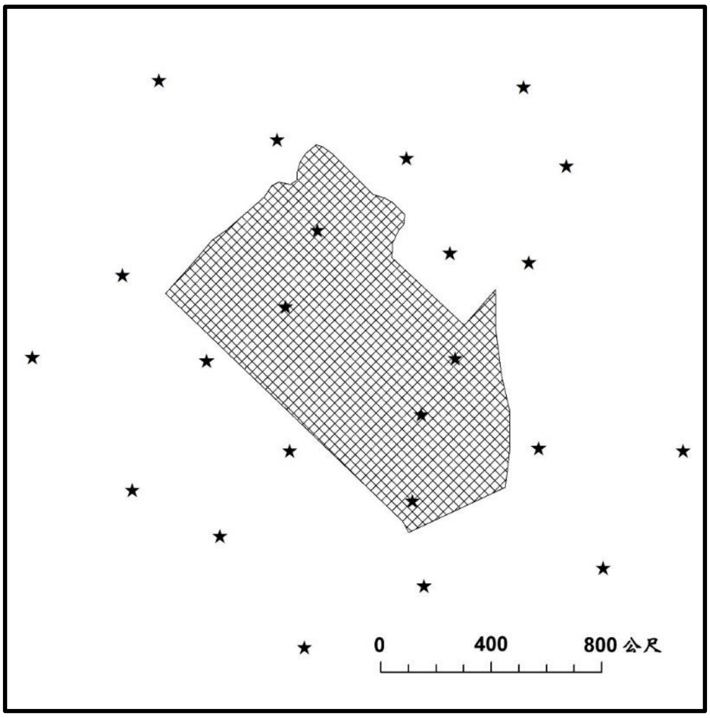

6. (　　)　　柯南撿到一張紙條，上面寫著案發現場當時四位嫌疑人的相對位置關係:「甲坐在乙的西北方，丙坐在乙的西方，丁坐在乙的北方」。請問：若從紙條敘述還原當時現場四位嫌疑人的位置，下列示意圖何者最正確？

(A) 

(B) 

(C) 

(D) 

7.（　　　　）下圖是某地區的行政區域圖，圖中的虛線是斷層線，圓點代表房屋。今日該地政府想要畫設距離斷層線X公尺內的房屋為危險房屋，應加強監測。若政府公告該區域的危險房屋有11間，則X應是多少？

(A) 250　(B) 500　(C) 750　(D)1000

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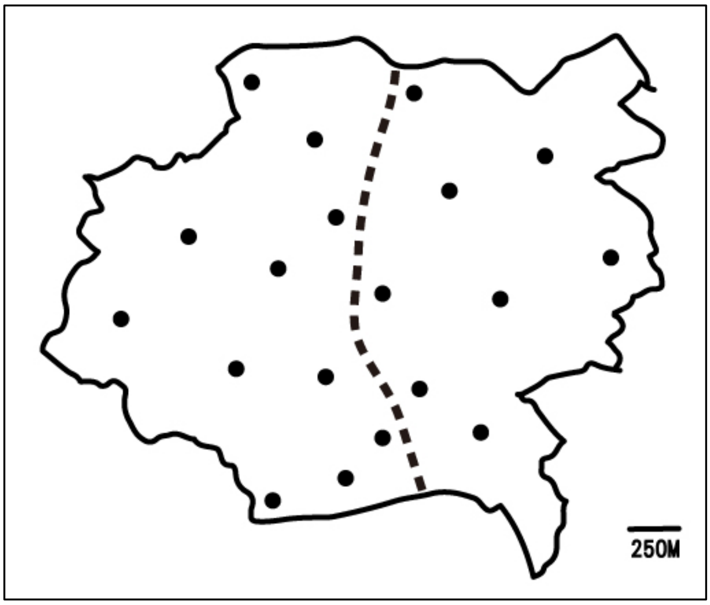


8. (　　) 下圖是某一地區樹種、溫度以及溼度的分布圖。其中樹種圖中數字越大代表越為易燃樹種；溫度圖中的數字表示攝氏溫度，數字越高越有可能發生火災；溼度表示相對濕度，數字越低越有可能發生火災。若森林火災的發生僅受樹種、溫度及溼度影響，則下列甲乙丙丁四個地區哪一地區發生森林火災的機率最大？

(A) 甲　(B) 乙　(C) 丙　(D) 丁

1	3	3	2	1
1	5	5	5	4
2	4	5	5	5
4	5	4	3	3
5	4	2	1	1

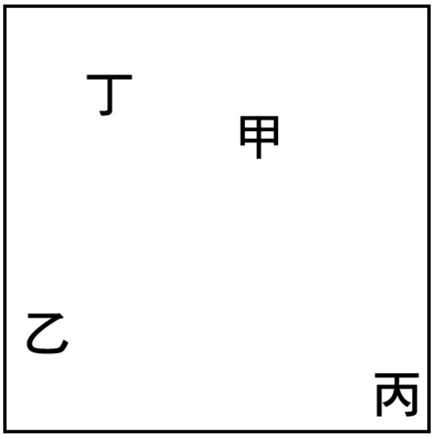
▲樹種分布圖

39	39	40	39	38
38	39	40	40	39
37	38	39	39	39
40	40	38	38	36
40	35	35	35	35

▲溫度分布圖

doi:10.6342/NTU201704041

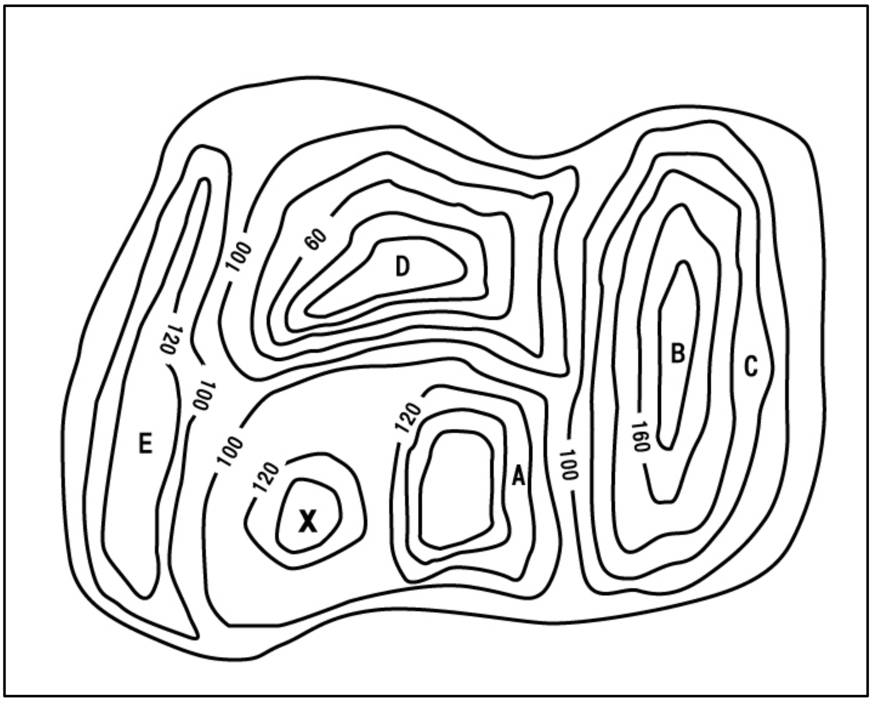
38	40	42	45	45
38	38	40	42	42
34	34	35	36	42
30	32	32	34	36
30	30	30	30	34



▲溼度分布圖

9. (　　) 下圖是某地區的等高線圖。請問，若小王站在圖中 X 所在的觀景台遠眺，則他看不到哪些英文字母所在位置的地點？

(A) 只有 C　(B)　A、C　(C)　B、C、D、E　(D)　A、E



10. (　　)　小明在一未知地區迷路，此時他發現燈塔在他的前方，煙囪在他的左後方。請問，下圖 W、X、Y、Z 四的中，何者最有可能是小明所在的位置？

(A)W　(B)X　(C)Y　(D)Z

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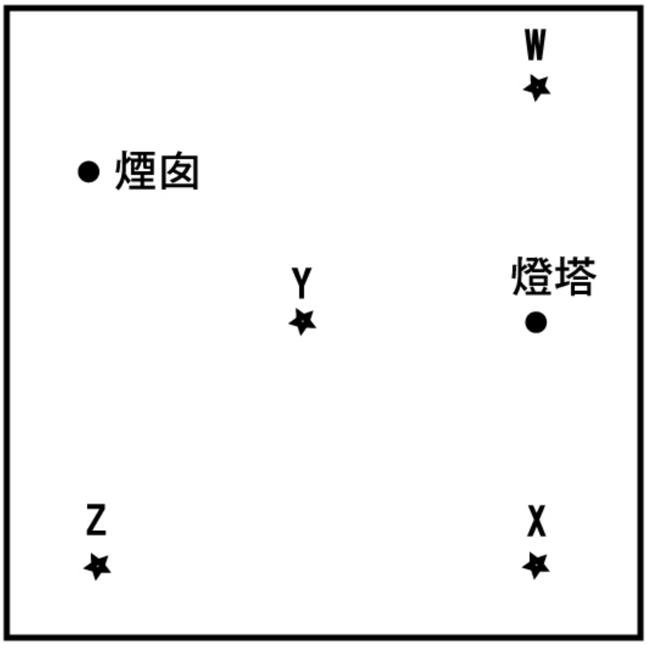
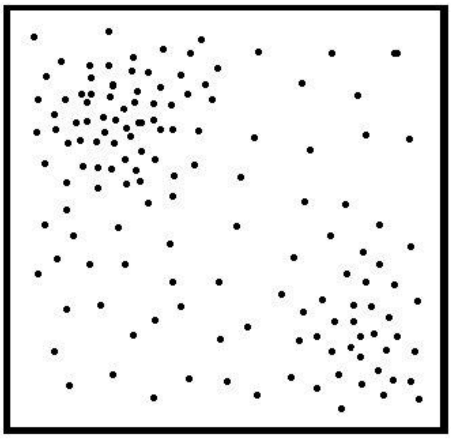
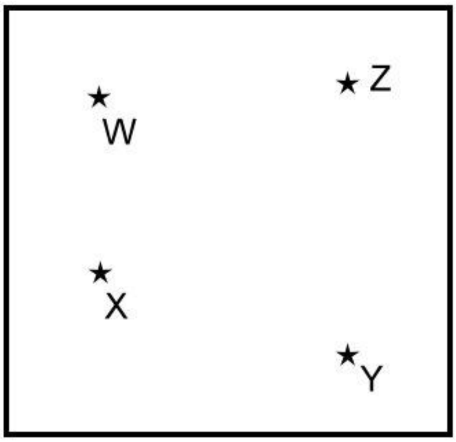


11. (　　)　左下圖是某鄉鎮的住家分布圖，今日政府想要在該鄉鎮人口稠密處建一座游泳池共大眾使用，請問應建築在右下圖中的何處較佳？



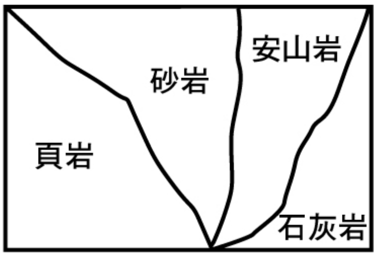


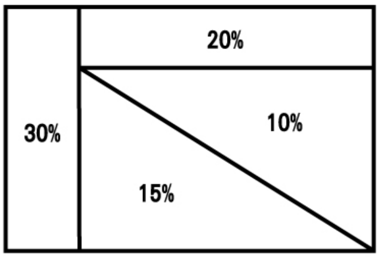
(A)W　(B)X　(C)Y　(D)Z

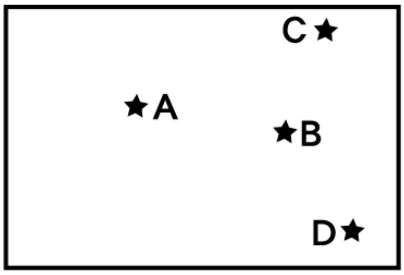
12. (　　)　王老先生有塊地，他想要在土地上蓋一間豪宅。他拿出那塊地的坡度圖以及地質圖(如下圖)。王老先生希望他的豪宅蓋在安山岩上面，且坡度越低越好。若依照王老先生的期望，請問下面 A、B、C、D 四點哪一點較適合蓋豪宅？

(A)　A　(B)　B　(C)　C　(D)　D

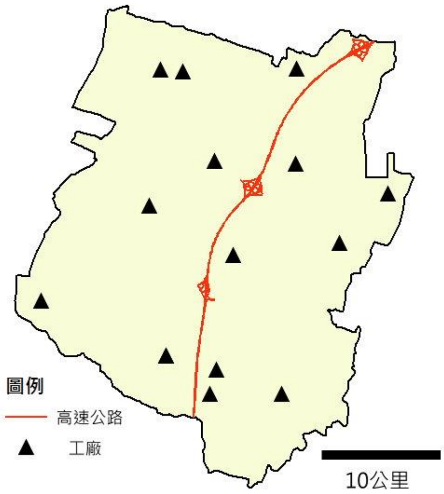
doi:10.6342/NTU201704041







13. (　　)　　下圖為某鄉鎮的交通路線圖。請估計該鄉鎮距離高速公路 5 公里內的工廠有幾家？

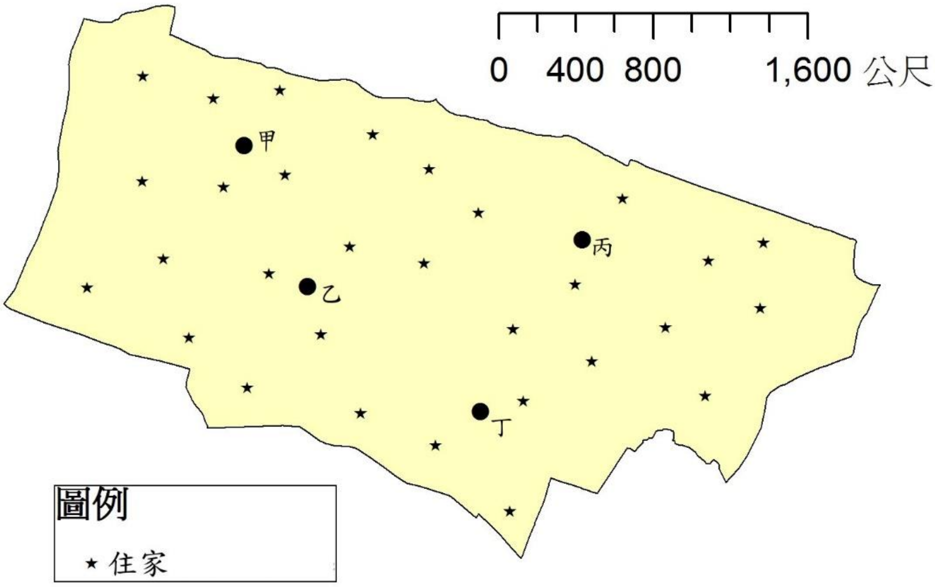


(A) 6 家　(B)　7 家 (C)　8 家　(D) 9 家

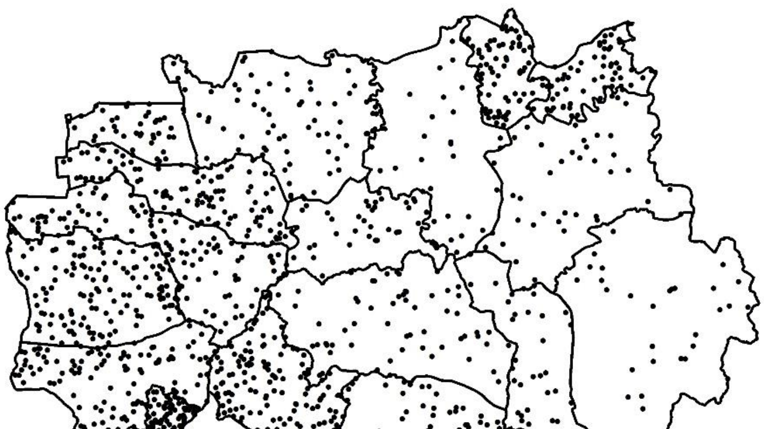
14. (　　)　　老王考慮在下圖四個黑原點中的某一處開設一間水電行。假設一間水電行的服務範圍為 400 公尺，則老王開設在哪一地點可以服務到最多住家？

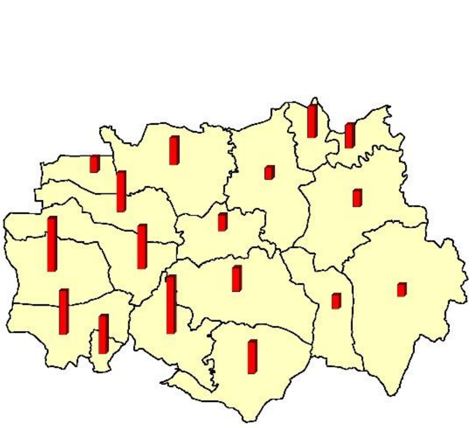
(A)甲　(B)乙　(C)丙　(D)丁

doi:10.6342/NTU201704041

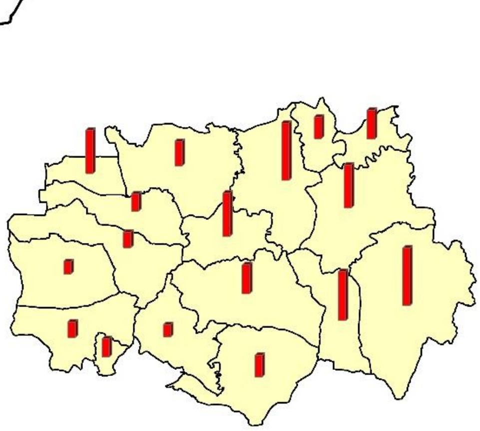


15. (　　)　下圖是某縣市中各鄉鎮的便利商店分布圖。若將每個鄉鎮的便利商店數量加總繪製成柱狀圖，則選項(A) (B) (C) (D)中何者最正確？



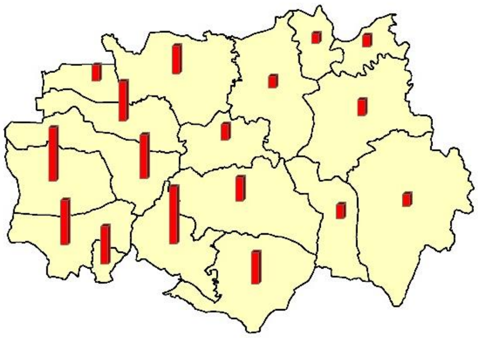


(A)

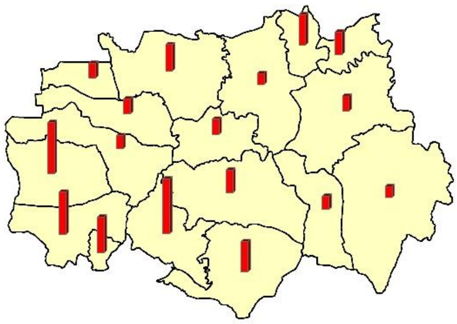


(B)

doi:10.6342/NTU201704041



(C)



(D)

16. (　　)　下列 A~D 選項中哪張圖的空間分布型態，與圖 I 的分布型態最像？

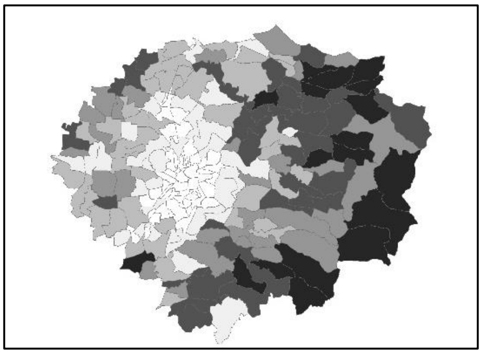
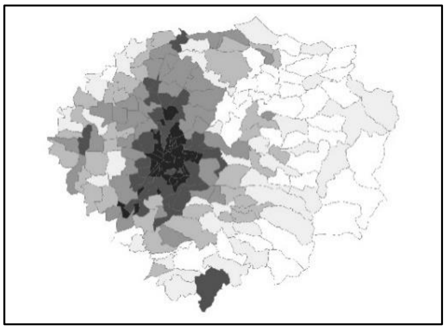
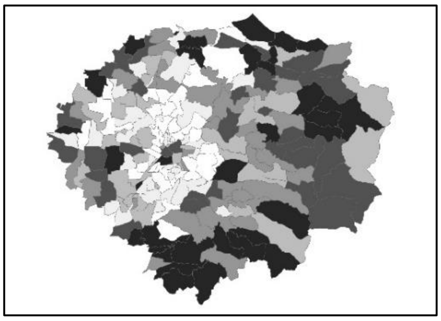


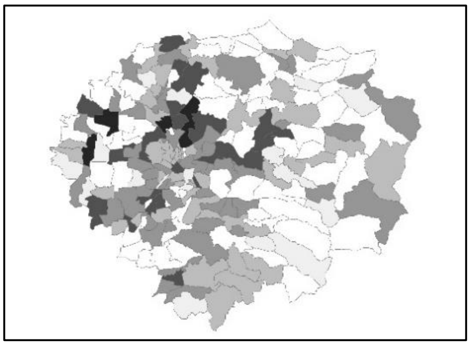
圖 I



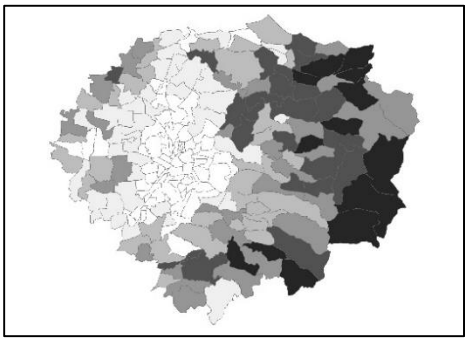
(A)



(B)



(C)



(D)

17. (　　　　)　老張是一位生物學家，想找尋某種水鹿的蹤跡，且身邊有一張等高線地形圖(如下圖)。已知該種水鹿的棲地在海拔 500-1000 公尺且常聚集於溪邊喝水。請問，下圖甲、乙、丙、丁四地中何處較有機會找到？

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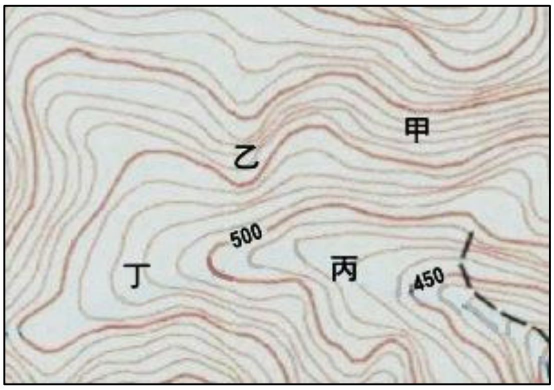
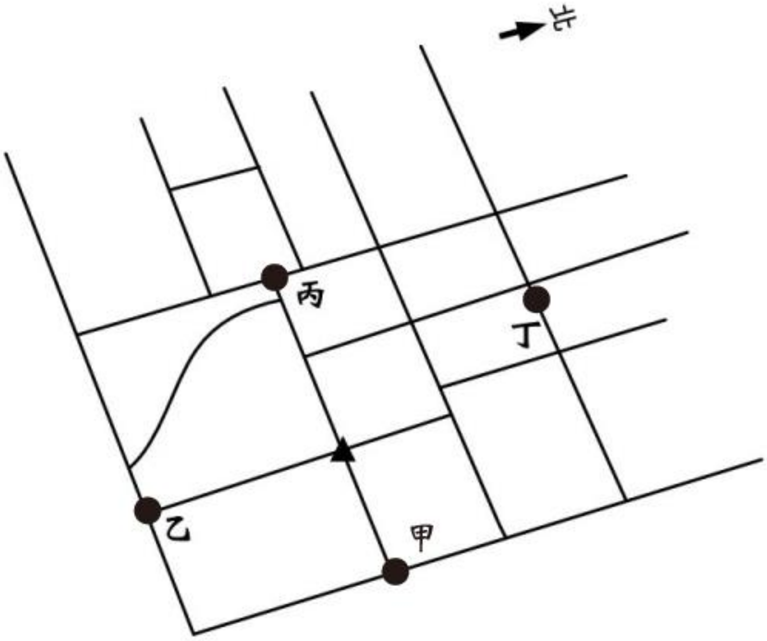
（A）甲　（B）乙　（C）丙　（D)丁。



18. (　　)　　下圖是某城市的街道圖。小敏站在圖中三角形的位置出發，向西走一路口，接著向北走一路口，再向東走兩個路口，最後向南走兩個路口。請問，圖中甲乙丙丁四個點，何者離小敏最後所在位置最近？

(A)甲　(B)乙　(C)丙　(D)丁。



19. (　　)　　下圖是某地區的等高線圖。請問，圖中A、B、C、D四點何者所在的海拔最低？

（A）A　（B）B　（C）C　（D）D

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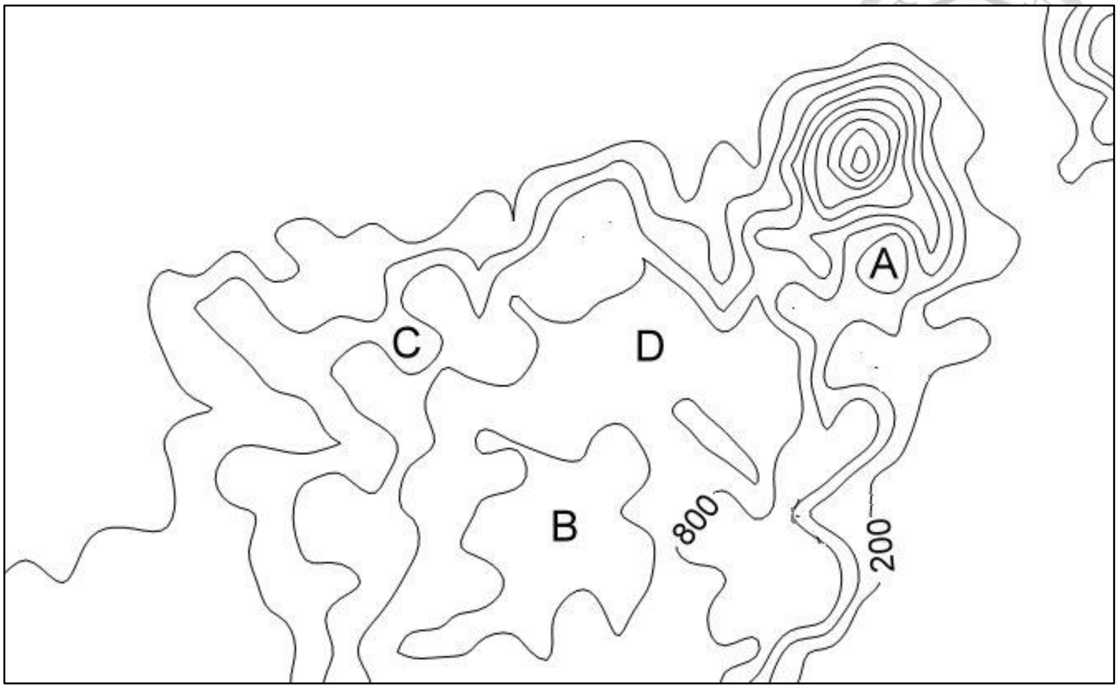
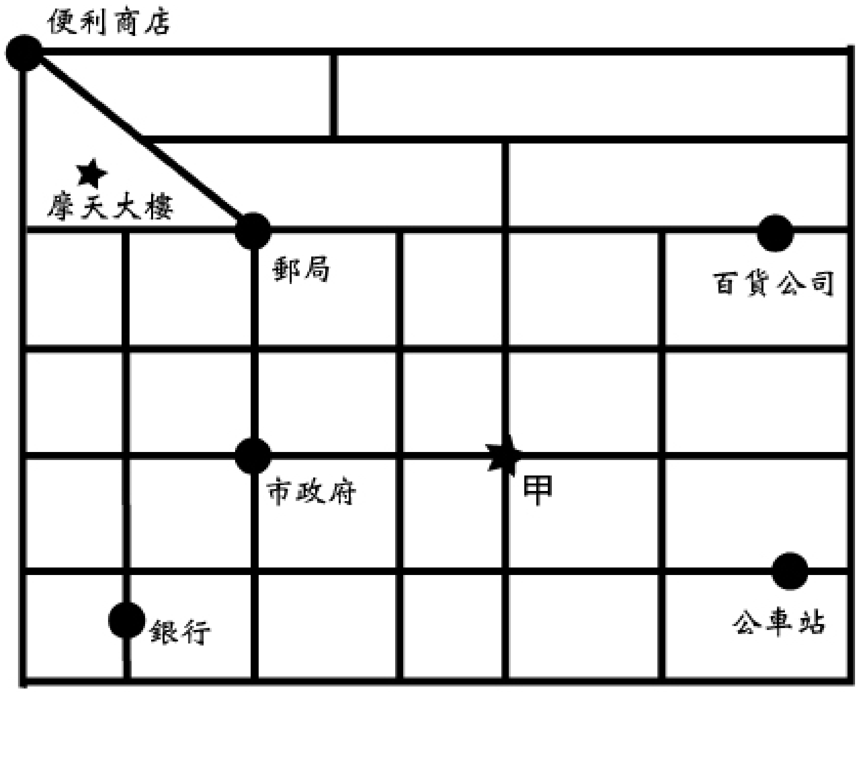


20. (　　)　　下圖為某個區域的街道圖，圖中的實線為道路。今日小華從打星號處的十字路口出發(甲點)，面向著市政府，往前走一個路口，再往左走二個路口，最後向右走一個路口。請問，小華最後的地點離下面哪一選項的地點最近？

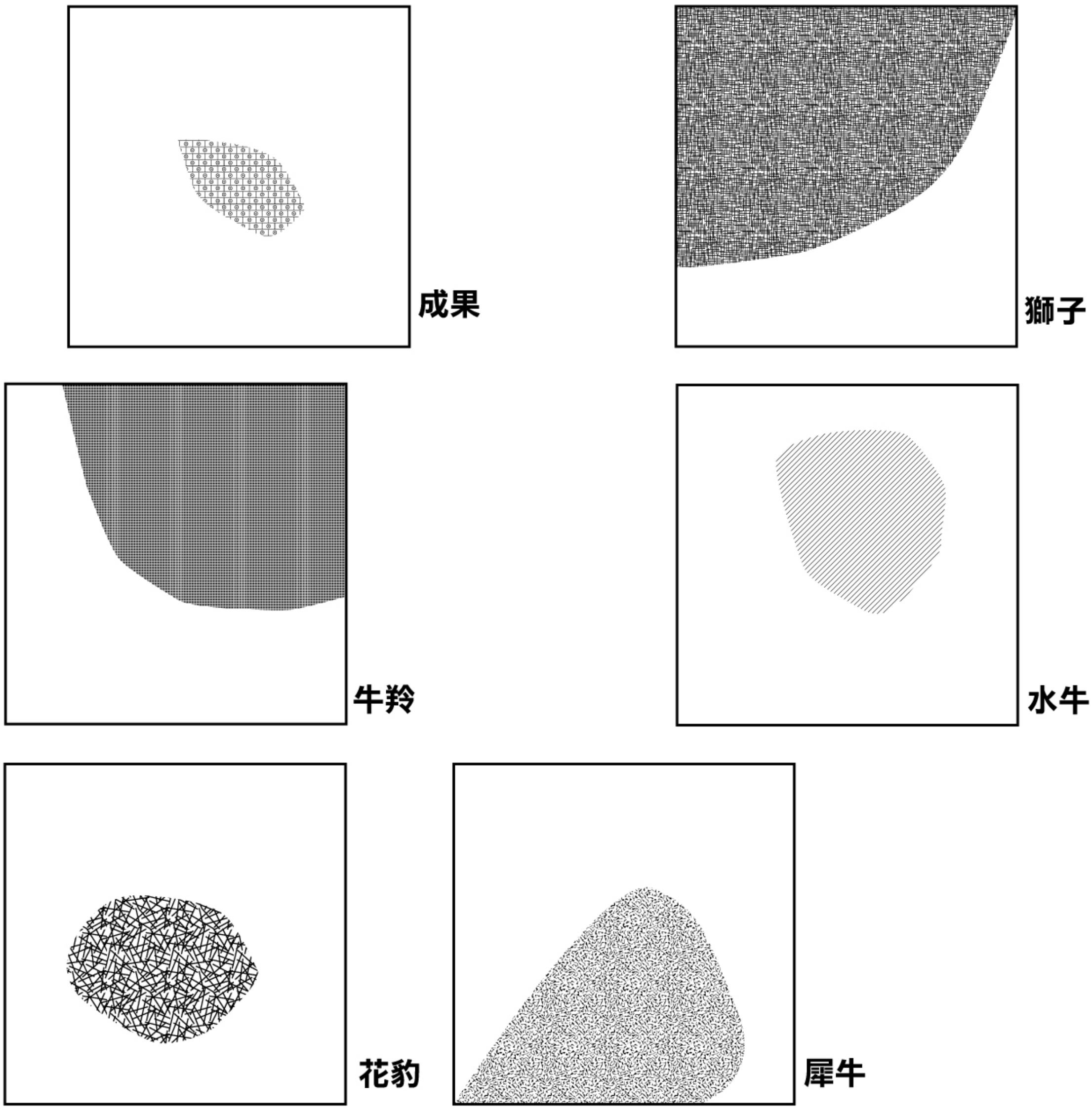
(A)市政府　(B)百貨公司　(C)公車站　(D) 銀行。



doi:10.6342/NTU201704041

21. (　　)　　下面結果圖是非洲某國家公園的研究人員將兩種動物棲息地疊合在一起得出的成果圖。請問，該圖最有可能是由哪兩種動物疊合而成？

(A)　獅子與牛羚　(B)　牛羚與水牛　(C) 水牛與花豹　(D)　花豹與犀牛



22. (　　)　　假設有一份新聞報導指出：「人口密度較高的地區，其交通事故發生次數也較多」。若圖 IV 是快樂國的人口密度圖，其中顏色越深代表人口密度越高，則 A~D 選項的圖何者最有可能是快樂國交通事故發生地點分布圖？

doi:10.6342/NTU201704041

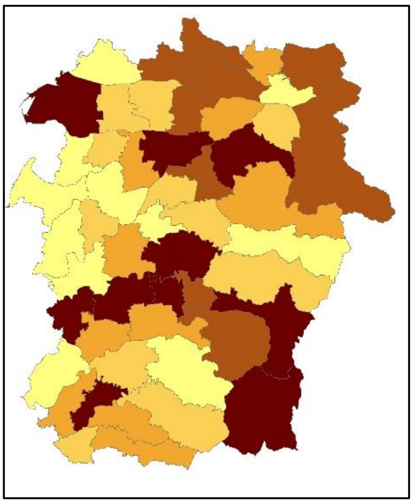
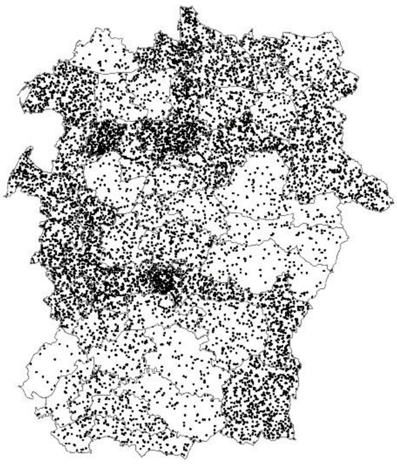
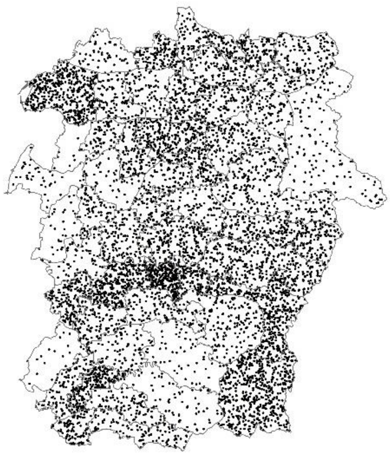


圖 IV

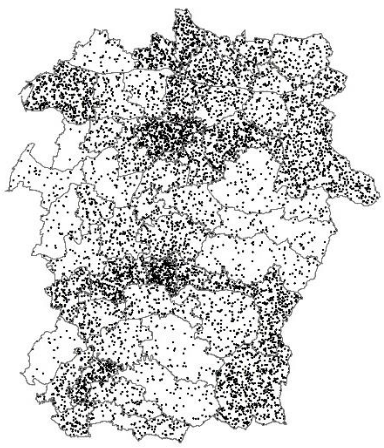


(A)



(B)

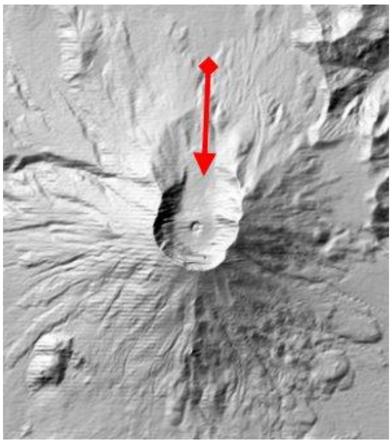
(C)

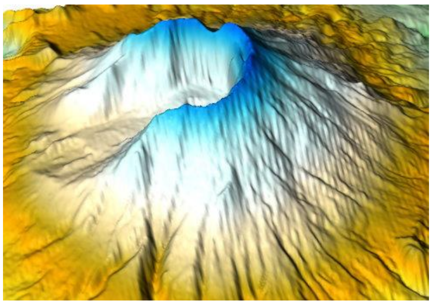
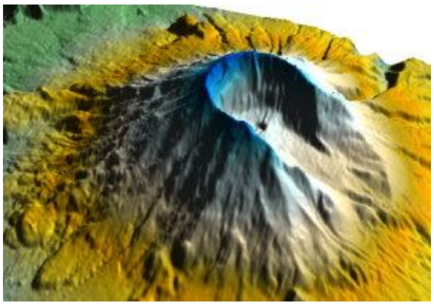


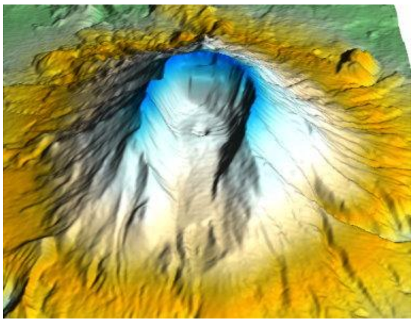
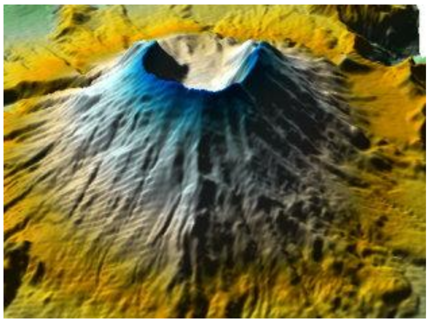
(D)

23. (　　)　　依據下圖呈現的暈渲圖，從菱形向箭頭處點45°視角俯看，其視野最接近下列哪一張圖？

doi:10.6342/NTU201704041



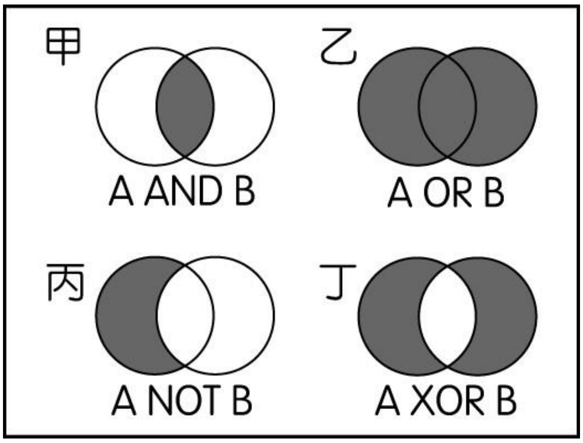
(A)  (B) 

(C)  (D) 

24. (　　)　圖一是四種布林運算的運作模式。圖四是將圖二及圖三採用圖一中某種布林運算運作模式得出的結果。請問，圖四是經由何種布林運算而得出？

(A) 甲　(B) 乙　(C) 丙　(D) 丁

doi:10.6342/NTU201704041



圖一

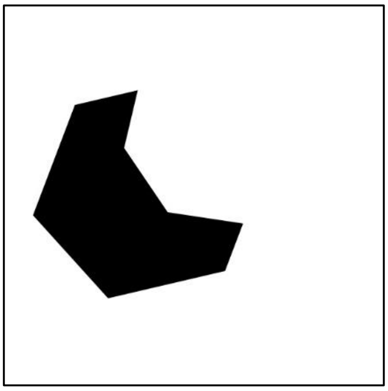


圖 二

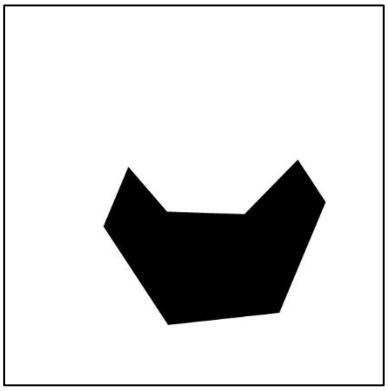
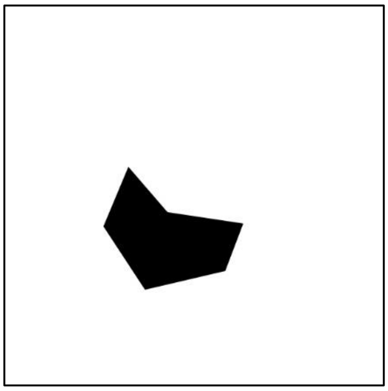


圖 三


圖四

doi:10.6342/NTU201704041

Appendix D. Instructions of the map-cue condition

1. 真實環境找路指導語：

你好，等一下你會在台大校園中進行找路測驗。

我們現在的位置在起點附近，稍候會帶你到起點位置。
起迄點之間的路線地圖稍候會發下。

你會有 **4 分鐘**的時間記憶路線地圖，同時你可以利用**紙的空白處寫下任何圖形或文字註記**，以幫助記憶。時間到了之後**會將路線地圖收回**，然後開始找路測試。

在找路過程中，將為你配戴 GPS 記錄器，同時實驗者會跟在你身後不遠處。

若你走錯方向，實驗者將會提示你走到錯誤路徑。
若真的忘記路線，可以要求再看路線地圖或直接詢問實驗者。
以上兩種情況，會導致你的表現成績降低。

若有不清楚的地方，請詢問實驗者；若沒有問題，請開始記憶路線地圖。

doi:10.6342/NTU201704041

2. Google 街景找路指導語：

你好，接下來你會在 Google 街景上進行找路測驗。

你的起點是從**面向台中火車站**開始，終點是**台中醫院**。
起迄點之間的路線地圖稍候會發下。

注意：發下的地圖只畫出了「路與街」，略去巷弄。 巷弄為路或街兩邊的狹小通道。

你會有 **4 分鐘**的時間記憶路線地圖，同時你可以利用**紙的空白處寫下任何圖形或文字註記**，以幫助記憶。時間到了之後**會將路線地圖收回**，然後開始找路測試。

在找路過程中，實驗者會在旁觀看。

若你走錯方向，實驗者將會提示你走到錯誤路徑。
若真的忘記路線，可以要求再看路線地圖或直接詢問實驗者。
以上兩種情況，會導致你的表現成績降低。

若有不清楚的地方，請詢問實驗者；若沒有問題，請開始記憶路線地圖。

doi:10.6342/NTU201704041

Appendix E. Instructions of the direction-cue condition

1. 真實環境找路指導語：

你好，等一下你會在台大校園中進行找路測驗。

我們現在的位置在起點附近，稍候會帶你到起點位置。
起迄點之間的路線指示稍候會發下。

注意：本測驗所定義的道路：路面材質須為**磚材或柏油**。

你會有 **4 分鐘**的時間記憶路線指示，同時你可以利用**紙的空白處寫下任何圖形或文字註記**，以幫助記憶。時間到了之後**會將路線指示收回**，然後開始找路測試。
在找路過程中，將為你配戴 GPS 記錄器，同時實驗者會跟在你身後不遠處。

若你走錯方向，實驗者將會提示你走到錯誤路徑。
若真的忘記路線，可以要求再看路線指示或直接詢問實驗者。
以上兩種情況，會導致你的表現成績降低。

若有不清楚的地方，請詢問實驗者；若沒有問題，請開始記憶路線指示。

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2. Google 街景找路指導語：

你好，接下來你會在 Google 街景上進行找路測驗。

你的起點是從**面向台中火車站**開始，終點是**台中醫院**。
起迄點之間的路線指示稍候會發下。

注意：本路線指示只包含「路與街」，略去巷弄。 巷弄指的是路或街兩邊的狹小通道。

你會有 **4 分鐘**的時間記憶路線指示，同時你可以利用**紙的空白處寫下任何圖形或文字註記**，以幫助記憶。時間到了之後**會將路線指示收回**，然後開始找路測試。

在找路過程中，實驗者會在旁觀看。
若你走錯方向，實驗者將會提示你走到錯誤路徑。
若真的忘記路線，可以要求再看路線指示或直接詢問實驗者。
以上兩種情況，會導致你的表現成績降低。

若有不清楚的地方，請詢問實驗者；若沒有問題，請開始記憶路線指示。

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Appendix F. Instructions of the walk-cue condition

1. 真實環境找路指導語：

你好，等一下你會在台大校園中進行找路測驗。
我們現在的位置在起點附近，稍候會帶你到起點位置。

實驗者將會帶著你走一遍這條路線，同時會發下一張**記錄紙供你註記路線過程中你覺得重要的任何訊息**，以幫助記憶。

回到終點後會有 **4 分鐘**回顧你的記錄紙，時間到了之後會將記錄紙收回，然後你自己必須要**獨自反向走過剛剛的路線，也就是你要自己從終點走回起點**。
你的路徑軌跡請盡量**與實驗者帶領你走時的路徑完全相同**。

在找路過程中，將為你配戴 GPS 記錄器，同時實驗者會跟在你身後不遠處。
若你走錯方向，實驗者將會提示你走到錯誤路徑。
若真的忘記路線，可以要求再看記錄紙或直接詢問實驗者。
以上兩種情況，會導致你的表現成績降低。

若有不清楚的地方，請詢問實驗者；若沒有問題，我們將開始。

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2. Google 街景找路指導語：

你好，接下來你會在 Google 街景上進行找路測驗。

你的起點是從**面向台中火車站**開始，終點是**台中醫院**。

你會看一段從起點走到終點的影片，同時會發下一張**記錄紙供你註記路線過程中你覺得重要的任何訊息**，以幫助記憶。

回到終點後會有 **4 分鐘**回顧你的記錄紙，時間到了之後會將記錄紙收回，然後你自己必須要獨自走過剛剛的路線。

若你走錯方向，實驗者將會提示你走到錯誤路徑。

若真的忘記路線，可以要求再看記錄紙或直接詢問實驗者。

以上兩種情況，會導致你的表現成績降低。

若有不清楚的地方，請詢問實驗者；若沒有問題，請開始記憶路線指示。

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