Can I reach ‘this’? Or is ‘that’ too far?

Exploring the relationship between language and spatial perception

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Abstract

This thesis examines the relationship between space perception and spatial language. The work presented focuses on the use of demonstratives (*'this'* and *'that'*) and prepositions in healthy participants and right-brain stroke patients in English and Italian.

In the first series of experiments, the mapping between demonstratives and perceptual space across sagittal and lateral planes in left-handed and right-handed participants is analysed. Using an adapted version of the *'memory game procedure',* in three experiments we manipulated object locations, hands used to point, the handedness of the participant and tool use, to elicit the production of demonstratives. The results support a strong mapping between demonstratives and reachability of objects; the use of *'this'* increases when the hand used to point could reach the object compared to when the object is not reachable but placed in the same location. No effect of handedness was found.

In the second set of experiments, we analysed the use of demonstratives for images of objects or real objects. A large PC screen table was used to show the 2D images of the objects and to place the 3D objects at different sagittal distances. Results showed no difference in the use of demonstrative for type of objects, a main effect of distance was registered congruent with previous literature.

In the third, and last, set of experiments the use of Italian demonstratives and prepositions were tested in healthy participants and right-brain stroke patients. A strong effect of distance for the use of demonstratives was found in Italian, congruent with the results found in English. Stroke patients showed no deficit in the use of demonstratives, although impairments in the use of prepositions were found.

The work presented in this thesis shows a strong mapping of space perception and demonstratives use in English and Italian. In addition, to our knowledge, this is the first time that the use of demonstratives has been tested in stroke patients. The results presented have implications for spatial language theories, embodied cognition and patients' rehabilitation, widening the literature about space perception and demonstratives use in healthy participants and stroke patients.

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Author’s declaration

I declare that the work contained in this thesis has not been submitted for any other award and that it is all my own work. I also confirm that this work fully acknowledges opinions, ideas and contributions from the work of others.

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Section I

Perceiving and describing objects in space.

Chapter 1

Introduction

"Many years later as he faced the firing squad, Colonel Aureliano Buendía was to remember that distant afternoon when his father took him to discover ice. At that time Macondo was a village of twenty adobe houses, built on the bank of a river of clear water that ran along a bed of polished stones, which were white and enormous, like prehistoric eggs. ***The world was so recent that many things lacked names, and in order to indicate them it was necessary to point****."*

(Gabriel Garcia Marquez, One hundred years of solitude,1967)

Try to put yourself in a one-year-old baby's shoes. The world is new for you. You are attracted by all the stimuli surrounding you, but you do not know a lot of words and you cannot talk yet. Prior to using language, you can nevertheless communicate using pointing to attract the attention of your caregiver to objects, such as food, that you want. Such gestures appear to be universal, and arguably have preceded spoken language in evolutionary development (Liszkowski, Brown, Callaghan, Takada & deVos, 2012). Regardless of that condition you can communicate with others and express your wishes. Thinking that you are hungry, pointing at food could be a good way to show your interest in it and having someone grabbing it for you. With this gesture the infant is able to direct the caregiver attention without using words, but using a deictic gesture. After we learn to talk, gestures and pointing continue to be used to direct the hearer's attention. And in particular pointing is used with demonstratives (words such as *'this'* or *'that'*), words that have the role of indicating the object/subject the speaker is referring to, without clearly stating the name of it.

Spatial demonstratives are present in all languages, and they are among the highest frequency words within a language (Deutscher, 2005, Diessel, 1999, Diessel, 2006), in addition they are also among the earliest words to be acquired (Clark, 1978, Clark, 2003). Despite the importance of demonstratives, much debate is still present on the mapping between language and perception. The main goal of this thesis is to explore the mapping between demonstratives and the vision and action systems, with a view to furthering understanding of this essential word class. We will do that in a series of seven experiments, the first few studies will focus on healthy subjects and in the last experiment we will focus on right-brain stroke patients (patients with impairments in processing of space).

In the remainder of this chapter, a literature review with a focus on spatial perception is presented, in particular on the perception of the peripersonal and extrapersonal space, and in the second part of the chapter we will explore the literature about spatial language, with a focus on experimental methods used to test the use of prepositions and demonstratives.

In the second chapter, we will present three studies designed to examine the possible mapping between demonstratives and perceptual space. In two studies, building on earlier studies using the *'memory game paradigm'* (Coventry et al., 2008; 2014, Gudde et al., 2018; see review below) the mapping between demonstrative use and space will be tested for the first time in the lateral axis (in addition to the sagittal plane) in both right-handed and left-handed participants pointing with their preferred and dispreferred hands. In the last study, we test the influence of pointing with hand versus a tool in the lateral and sagittal plane, with participants using their preferred and dispreferred hands, to test whether the use of a tool can extend peripersonal space, and therefore extend the use of the proximal demonstrative to space beyond immediate reach.

In the third chapter, two studies explore the use of demonstratives to describe the location of virtual objects. In the first study, we will explore the use of demonstratives for 2-dimensional images and for 3-dimensional objects. We will then test whether the features of the object, and specifically whether those objects are graspable or not affects the use of demonstratives.

In the fourth chapter, we first present a study run with Italian native speakers on the use of demonstratives and spatial prepositions in Italian. These studies serve to test whether effects found for English also occur in another language, while also serving as a baseline for the remaining studies conducted with Italian-speaking participants. The last study presents analyses of the use of spatial language in right-brain stroke patients with and without Unilateral Spatial Neglect (USN). Patients with USN are unaware of objects that are placed in the contralesional space. If a mapping between space perception and demonstrative use is indeed present, we would expect that patients with problems in space perception will also have problems in the production of demonstratives.

In the fifth and final chapter we will discuss the results of the seven experiments and the methodologies, in addition, we will explore future directions of the studies and the implication of the findings.

1.1 Space perception and language

"*Space is not something objective and real, nor a substance, nor an accident, nor a relation; instead, it is subjective and ideal, and originates from the mind's nature in accord with a stable law as a scheme, as it were, for coordinating everything sensed externally.*" (Kant, Inaugural dissertation, 1770 Ak 2: 403)

1.1.1 The visual system: From the object to the cerebral cortex

When we see an object, the image is not projected in full in our brain like the object is printed on photographic film, but the full picture is dismantled by our brain and different areas of the brain are designated to elaborate a feature of the object, such as the colour, the shape and the structure. All these elements are then constructed into a unique image thanks to the visual system and its major sections: the eye, the visual tract and the visual cortex. Other than an object's features, we also need to judge the distance from the self to the object. Correct distance judgements are crucial to interact with the world, to reach and manipulate objects. Humans are able to make fine depth judgements by using stereopsis: integrating different information coming from the two retinas.

Perception comes through two different pathways: the *'where-pathway'* (dorsal) and the *'what-pathway'* (ventral) (Goodale and Milner, 1992). The cortical area that is involved in both pathways is the visual cortex, V1 area. The *'what-pathway'* runs dorsally into the inferior temporal lobe, while the *'where-pathway'* proceeds dorsally through the posterior parietal lobe. These pathways serve different functions; the first pathway is dedicated to object recognition, while the second pathway processes spatial information. Much debate about the dorsal stream is present in literature. In fact, the dorsal stream has been named as the 'where', the 'how' or the 'when', depending on the perspective used to define it (Raushecker, 2018). Kravitz et al. (2011) devised a model assigning three different functions to the dorsal stream: spatial working memory, visually guided actions and spatial navigation. The distinction between the ‘where’ and ‘what’ pathways was first theorized by Schneider (1969), in a study with hamsters, showing that the ablation of the superior colliculus results in the loss of the ability to orient toward an object, but not to recognise it. The opposite effect was obtained ablating the visual cortical area. More than 50 years after the publication of Schneider’s paper, the distinction and connection of the networks is still a hot topic. In fact, some authors argue that the two networks are highly interconnected (Zachariou et al., 2014, Kravitz et al., 2008; Pisella et al., 2009; Cloutman, 2013). Goodale and Milner (1992) theorize a model that separates the ventral stream, based on visual perception, that mediates the recognition of objects and the dorsal stream that intervenes in visual guided actions. The two systems have very different use in the development of the subject, but they are also strictly connected. In fact, during our everyday life, the two systems often work together, for example when we want to grasp an object not only do we need to know how far away the object is, in order to move according to the distance, but object recognition also plays an important role in the grasping movement. For instance, moving to grasp a hammer would be very different from moving to grasp a mug. Hence, the two visual streams are constantly working together to correctly reach the required distance and move the fingertips in a way that would not crush the object, if it is delicate, nor let it slip from the grip if it is heavy.

Strong support for the division between the two networks in humans comes from patient studies and fMRI studies. In stroke patients, depending on the injured area, it is possible to observe disorders in object recognition (visual agnosia), or in object spatial processing (unilateral neglect, optic ataxia) (Ungerleider and Mishkin, 1982; Deubel et al., 1998). Patient D.F. is well known in the literature because of rare brain damage: visual agnosia (the inability to recognise an object) (Murphy et al., 1998; Carey et al., 2006; Whitwell et al., 2015). In particular, D.F. was not able to recognise the shape of the objects, also the most simple shapes, for example she could not visually recognise the difference between a square wood cube or a rectangular wooden cube (Whitwell et al., 2015). She also was not able to recognise alphabet letters, drawings and common words, like *'up'*, *'on'* were misidentified. However she was able to read complex words and auditory and tactile object recognition was preserved (Milner et al., 1991; but see Rossit et al. 2018). If asked to manually represent the width of the cube she could not do it, but when asked to grasp it, the thumb and fingers scaled at the correct width to pick up the object. This dissociation can be seen as proof of the distinction between the two visual streams (Whitwell et al., 2015).

A separate case is the behaviour shown by patients affected by optic ataxia: a neuropsychological disorder where patients have issues reaching an object under visual guidance. This disorder is not a motor disorder, in fact the deficit can occur only in a particular zone of the field and using a specific hand; patients usually manifest an increased deficit when acting with the contralesional hand in the contralesional space (Jackson et al., 2009; Pisella et al., 2009). In addition, it has been shown that ataxic patients can accurately reach, or correct reaching in central vision, but not in peripheral vision (Perenin & Vighetto, 1988; Khan et al., 2005; Pisella et al., 2009). Different hypotheses have been formulated to explain the errors occurring in patients with ataxia; some authors, for example, think that a lesion in the dorsal stream does not entirely explain the syndrome (Jackson et al., 2005, Pisella et al., 2009; Jackson et al., 2018). While past literature strongly suggests a division between the two streams (e.g. Milner and Goodale, 1995; Ungerleider and Mishkin, 1982; Goodale and Milner, 1992), more recent literature supports the connection between the two streams, in fact, the processing for the shape and the location can be found in both paths (e.g. Zachariou et al., 2014, Pisella et al., 2009; Cloutman, 2013).

Zachariou et al. (2014) studied the contribution of the two streams to object perception and localisation in healthy adults. The first experiment took place in an MRI scanner where participants were shown two objects on screen, and they had to indicate if they matched in shape. The objects appeared in the top or bottom left/right corners, in an opposite corners combination (Figure 1.1). A distance-matching task and a side-matching task were also performed. In the distance-matching task a dot and a line were shown and participants had to compare the distance between the line and the dot across two panels. In the side matching task, the horizontal distance between the line and the dot was always identical. In the main task, participants were asked to compare two panels with objects images presented on each side of the screen. Different levels of difficulty were set for the matches. In a second behavioural study, the authors tested whether the processing of the location and of the shape involves different processes. Images of two objects were shown separate from a line on two panels on a screen. The two panels could be identical, or to show some differences (difference in shape and location)(Figure 1.1). Participants had to indicate the number of shape differences or location differences, and reaction times and accuracy were calculated. In the fMRI study an activation of dorsal areas was found when a location change was observed, and an activation was found in the ventral areas when a change of shape was observed. However, an activation was found in the dorsal area in response to shape and in ventral area in response to location. This experiment provided evidence that indeed, the two areas have specialised functions, but also that they are interconnected and the functions are not confined to those areas. Nevertheless, the activation found in the dorsal stream, in response to the expected change in location detection, was more robust than the one found in the ventral stream. The results show that shape change detection can activate both the visual streams, however, the dorsal cortex is activated significantly more than the ventral cortex. The behavioural experiment showed an interference of the shape on the localisation, with the shape distractor resulting in slower reaction times in location matching, showing that the two functions are not disjointed. These results contrast with the results of an earlier study obtained by Chan and Newell (2008), in which results of 3 experiments showed that the two streams are independent in vision and touch.

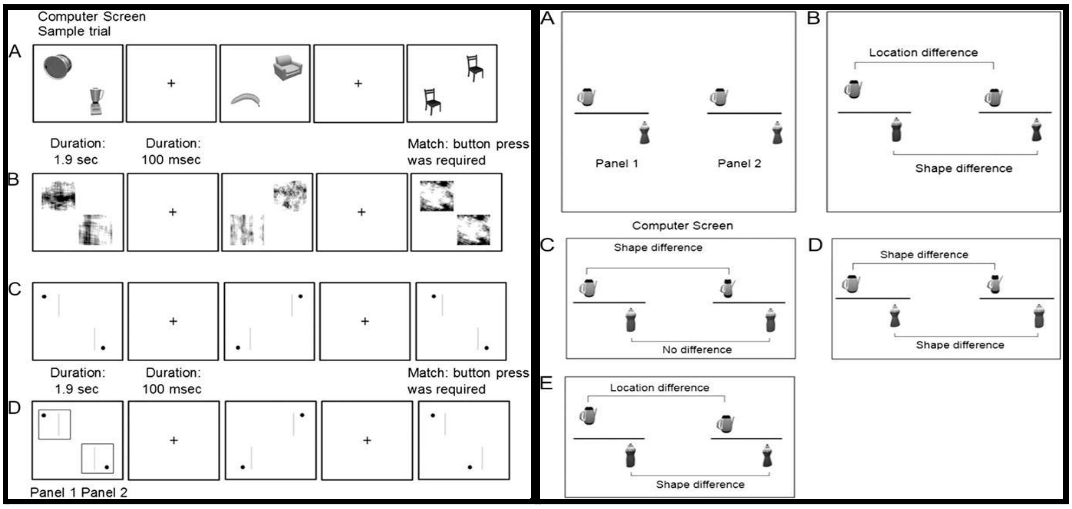


Figure 1.1 *Example of stimuli used by Zachariou et al. (2014) in their first experiment.*

Left - Experiment 1 A. Sample of the whole-matching trial, with two examples of a no shape match and last one with shape match. B. An example of a scramble-blocked condition. C. An example of a distance estimation block. D. An example of a side matching block.

Right - Experiment 2 A. Sample of the stimuli used in the behavioural study. In each panel two objects were shown always separated by a line. B. Example showing the presence of shape difference for the top objects and the absence of difference for the bottom objects. C. Example showing the shape difference in both couples. D. Example showing the location difference in one couple and the shape difference in the other one.

Budisavljevic et al. (2018) studied the interaction between the ventral and the dorsal streams during grasping, reaching and lifting actions. Participants were sitting at a table, a target was placed 300 mm from the participant and participants were instructed to 1) move their hand toward the target, or 2) to reach toward the object and grasp it or 3) to reach, grasp and lift the object. Kinematic movements were tracked and an MRI scan was performed. Results showed that the two streams are not independent, but they collaborate. The authors showed that this cross-talk is mediated by occipital and temporal-parietal white matter.

It is clear that specialised areas are present in the brain, and that areas activate differently for the shape and the location of the object, but with close interaction between them. It is important to note, though, that the majority of the studies reviewed in the previous paragraphs used a screen to show the stimuli. While in real life the brain usually processes real 3-dimensional objects, many people now spend much of their day interacting with an object on a screen and a virtual environment; the real object has been substituted by a picture of it. The use of technology in real life and in psychology studies raises the question if an image of an object is processed in the same way as a 3-dimensional object, and therefore if we can extend the data collected with images to the 3-dimensional world. A considerable amount of research is now taking place on a screen or through a VR headset, affording the opportunity for participants to take part in studies without the need for them to visit a laboratory. Despite being more convenient to use computers and pictures instead of humans and real stimuli, recent findings suggest differences in the processing of real objects versus pictures. Snow and colleagues (2011) showed different brain activation patterns (a robust repetition effect was found along the dorsal and ventral stream area for 2D images, but not for 3D object, for more details see page 99) for real objects and 2D images of those same objects, making it difficult to generalise the results obtained in the MRI scanner, with images, to the real world. Differences between images and real objects have also been found in studies investigating memory (Gerhard et al., 2016), willingness to pay (Romero et al., 2018), attention (Gomez et al., 2017) and language (Bara and Kaminski, 2019; Saryazdi and Chambers, 2018). It is therefore necessary to further investigate how people perceive images and the difference between the images and real objects, to better understand if and how the results of the experiments that use VR and/or images on a screen can be extrapolated to the real world. In chapter 4 in two experiments we will explore the use of language for real objects and images of the objects, to better understand the differences in the use of demonstratives (such as the word *'this'* and *'that'*) for real and virtual images.

1.1.2 Peripersonal and extrapersonal space

Next, we will explore the concepts of peripersonal and extrapersonal space, prior to exploring in a later section how language maps onto this distinction. We will start by analysing the *'body schema'*, or rather how the body experiences the environment. We will then lay the groundwork for a definition of peripersonal space with a brief literature review of the major theories, and we will then underline the anatomical differences between peripersonal and extrapersonal space in the more recent literature. Finally, we will talk about how peripersonal space remaps with the use of a tool and how other non-distance based variables, such as social interactions, affect the perception of peripersonal space.

1.1.2.1 Body schema

Before starting to explore the space that surrounds a person, we need to dwell on how we perceive the body and its position in space (as a total and as a multi-part structure), and its relation with space perception. Two elements are involved in the creation of the *'body schema'*: proprioception and vision. Gallagher (1986) defines the body schema as the way that the body (consciously) experiences its environment, and it is distinct from *'body image'* that acts in a non-conscious way. The body image entails the motor abilities and the maintenance of posture; there is no intentionality in this schema. On the one hand, I can voluntarily reach an object placed on a shelf, and consciously move my hand toward it; on the other hand, without being cognizant, the body will send the message to the other muscles to contract or relax to compensate the arm movements (Gallagher, 1995). The body schema is not fixed, but the boundary can extend and incorporate the tool used, for example a carpenter using a hammer all day while at work will incorporate that tool extending their arm and therefore, their body schema boundary (Head, 1920).

1.1.2.2 Toward a definition of peripersonal space

In this section we will analyse the major theories regarding peripersonal space found in the literature.

The division of space and how the brain elaborates it has been a matter of discussion for the last century, and even if neuropsychological research gave us more knowledge about how the brain works, the definition of what is considered proximal and what is considered distal continues to be debated.

In the early '40s, Brain (1941) was one of the first to show different spatial deficits after the lesion of distinct areas of the parietal lobe. Specifically, he showed that the estimation of grasping-distance (near space) was driven by the neural link between the visual cortex and the hand and arm area; on the other hand, the estimation of walking distance (far space) was driven by the neural link between the visual cortex and the post-central gyrus (Brain, 1941). In the following decade, Hediger (1955), observing animal behaviour, formulated the concept of *'flight zone'*. He noticed that seeing a predator is not enough to trigger a flight for the animal. But only when the predator enters into the flight zone the prey attempts an escape (Lourenco, Longo & Pathman, 2011).

Some decades later, Rizzolatti, Matelli and Pavesi (1983), based on a brain lesion study involving primates, divided space into 3 parts: the *'peribuccal space'* (area located in the face), the *'distant peripersonal space'* (that is considered the space within reach) and the *'far space'*. Results showed that different brain lesions create deficits in attention and movement in one or more of the three previously distinguished spaces.

In contrast, Grüsser (1983) proposes a model based on primate and human studies, that divides space into four different compartments. Firstly, he identifies an area surrounding the body, *'grasping space'*, that can be further divided (similar to Rizzolatti's model) into oral grasping space, manual grasping space and instrumental grasping space. As a second compartment he identifies the *'near-distant'* action space, followed by the third compartment, the *'far-distant'* action space. Finally, he locates the visual background.

More recently, a model based on human studies was proposed by Previc (1990). He divides the space into three major parts: peripersonal space (the area surrounding the body), the focal extrapersonal space (located at a greater distance from the body) and the ambient extrapersonal realm (an additional extrapersonal region). The first area serves an important function in visual reaching and manipulation. The second one is involved in visual search and object recognition. The last area is important for the maintenance of spatial orientation and postural control during locomotion (Previc, 1998).

Analysing different theories based on animal behaviour and animal brain anatomy showed that there are some differences in how the authors describe what peripersonal space is, and in how many regions we can divide it into (for example the areas in Rizzolatti's model compared to Previc's model). However, all the authors seem to agree that the peripersonal space is an area very close to our body, and that the brain responds differently to objects closer or farther to the body. But there are still some unanswered questions. First, the studies that we reviewed thus far do not explain how the brain is responding to space and what areas of the brain are mostly activated in humans. Second, the early theories are almost all based on animal anatomy and behaviour, thus we also need to know how humans interact with the space and with objects and other people in space.

1.1.2.3 Brain representation of peripersonal space - studies with primates

In this section we explore the brain anatomy of peripersonal space, reviewing some papers about brain anatomy studies involving primates.

The brain reacts differently to a stimulus near the body or to a stimulus far from the body. This makes sense from an evolutionary point of view; a dangerous stimulus becomes more alarming when it is close to my body than when it is farther away. This space, that serves a protective function, is called the defensive peripersonal space (DPPS) (Bufacchi, Liang, Griffin and Iannetti, 2016). Bufacchi and colleagues (2016) studied the hand-blink reflex (HBR), a pure defensive reflex not influenced by the change of position of the hand in egocentric coordinates. They found that the HBR is changed depending on hand position in the coronal space, along the medio-lateral and the vertical axes. Moreover, the response increases monotonically and nonlinearly in the area that extends upward and forwards from the face. In addition, results showed stronger activation for the middle position compared to the lateral and inferior positions.

The representation of space has been argued to be multisensory and studies with primates appear to corroborate that theory (see Van der Stoep, Nijboer, Van der Stigchel, Spence, 2015, for a review). These studies have laid the groundwork for the neural correlates of space elaboration. In monkeys, the premotor cortex exercises a motor function. In this area bimodal neurons are present; those are neurons that can be activated by visual and tactile stimuli, with receptive fields (RFs) for both modalities. By varying the gaze and the arm's position Fogassi and colleagues (1992) studied the visual responses in the premotor cortex (ventral area 6) and they showed that most of the cells in that area encode the space in arm-centred coordinates (in contrast to retinocentric coordinates). More recently, the encoding of peripersonal and extrapersonal space has been studied in mirror neurons. Mirror neurons are a set of neurons that discharge not only when an action is accomplished, but also when the subject is observing someone else performing that same action. Those neurons were found in the macaque premotor cortex (F5) and were described for the first time by Di Pellegrino, Fadiga, Fogassi, Gallese and Rizzolatti in 1992.

'*Mirror neurons'* could be involved in better understanding actions. The findings were soon extended to the human cortex (Fadiga et al., 1995). Moreover, it has been found that the neurons in F5 respond differently when an action is performed in the monkey's peripersonal (less than 37cm) or extrapersonal space (further than 37cm). Those neurons elaborate the space based on distances, but also based on operations that can be performed on objects. In fact, if the monkeys are prevented from reaching the object, extrapersonal space neurons will start firing also in peripersonal space (Caggiano, Fogassi, Rizzolatti, Their and Casile, 2009). Bonini et al. (2014) further investigate the neurons in area F5 in grasping and observational tasks. They showed that both canonical and mirror neurons are present in the same cortical areas. In addition, they found a new type of neurons that have both properties (canonical-mirror neurons). Lastly, they showed that to register a response in canonical and canonical-mirror neurons the object needs to be placed in peripersonal space, whether to register observation responses in mirror and canonical-mirror neurons the stimulus can be in the peripersonal or extrapersonal space.

1.1.2.4 Brain representation of peripersonal space - studies with humans

Evidence on an anatomical difference in the elaboration of peripersonal and extrapersonal space has been found also in humans. In this section, we analyse the brain areas involved in the perception of space in humans.

Gallivan and colleagues (2011), in an fMRI experiment, studied the activation of superior parieto-occipital cortex (SPOC) during reaching movements in left-handed and right-handed participants. BOLD (blood-oxygenation-level dependent) responses were measured when participants were looking at reachable and unreachable objects. The experiment was divided into action trials and viewing trials. In the action trials, participants were asked to reach-to-touch or reach-to-grasp the object in position H, the position in the middleline, just in front of the participant (Figure 1.2). In the viewing condition the participant was asked to look at the object without performing any movement. Objects were placed in locations NR (near right), NL (near left), FR (far right) and FL (far left) (Figure 1.2). The NR position was within the action space of the right hand and not of the left hand and vice versa. Results show an activation of SPOC for the within reach positions not only when the participant is performing the reaching/grasping action, but also when they are passively seeing the object. In addition, brain activations were linked to the participant handedness; right-handed participants showed an enhanced response for the near right location. Left-handed participants, consistent with the results previously found by Gonzalez et al. (2007), showed no difference between the preferred and dispreferred hand when performing the grasping or reaching task.

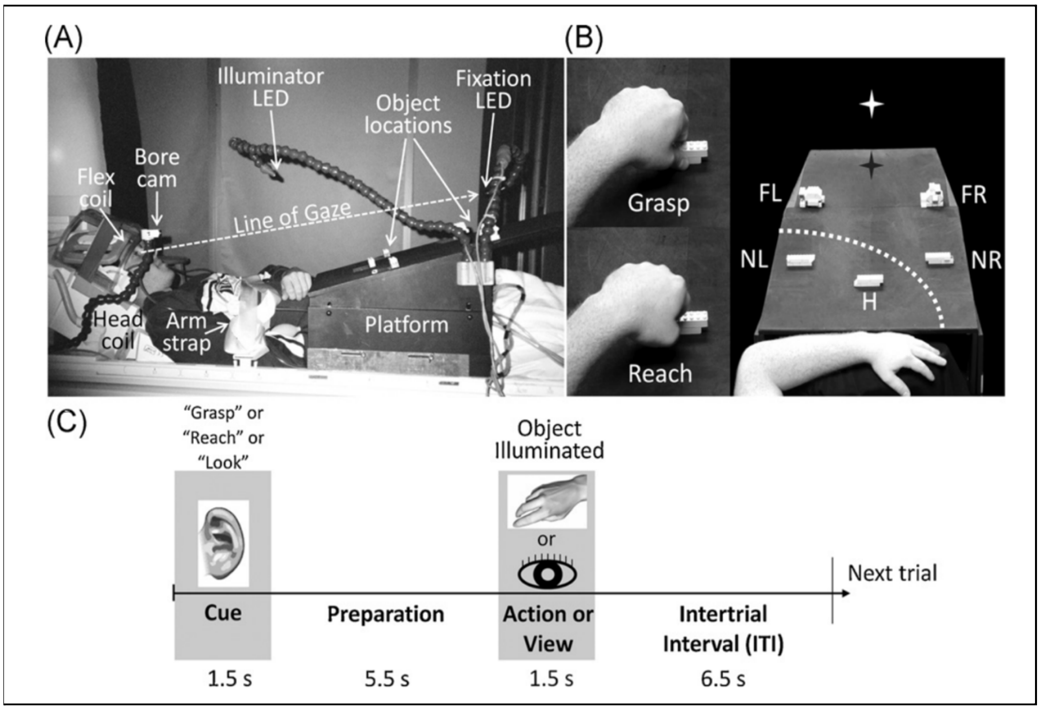


Figure 1.2 *A. Setting used by Gallivan et al., (2011). B. Experimental conditions used by Gallivan et al. (2011). C. Timing of each trial.*

Makin and colleagues (2007) studied the activation of the right-brain hemisphere in healthy participants during the presentation of a target in their peripersonal and extrapersonal space. Participants were laying in an MRI scanner and they were presented with a ball attached to a stick moved by the experimenter. The participant was instructed to indicate, by saying *'yes'* or *'no'*, if the ball will hit the target. Targets were cardboard pieces hanging within the participant's visual field, one in the near space (within the space of action of their left hand) and one in the far space. Participants took part in four different conditions (Figure 1.3): the '*real-hand condition'* where the left hand was placed on the table, within view; the *'retracted-hand condition'* where the participant was asked to keep the hand attached to their left shoulder and it was not visible; the *'occluded-hand condition'* where the left hand was placed in the same position as the *'real-hand'* condition but the view of it was occluded by a cardboard shield; the *'dummy-hand condition'* where a rubber hand was placed on the table in the same position as before and the real hand was retracted to the shoulder outside the visual field.

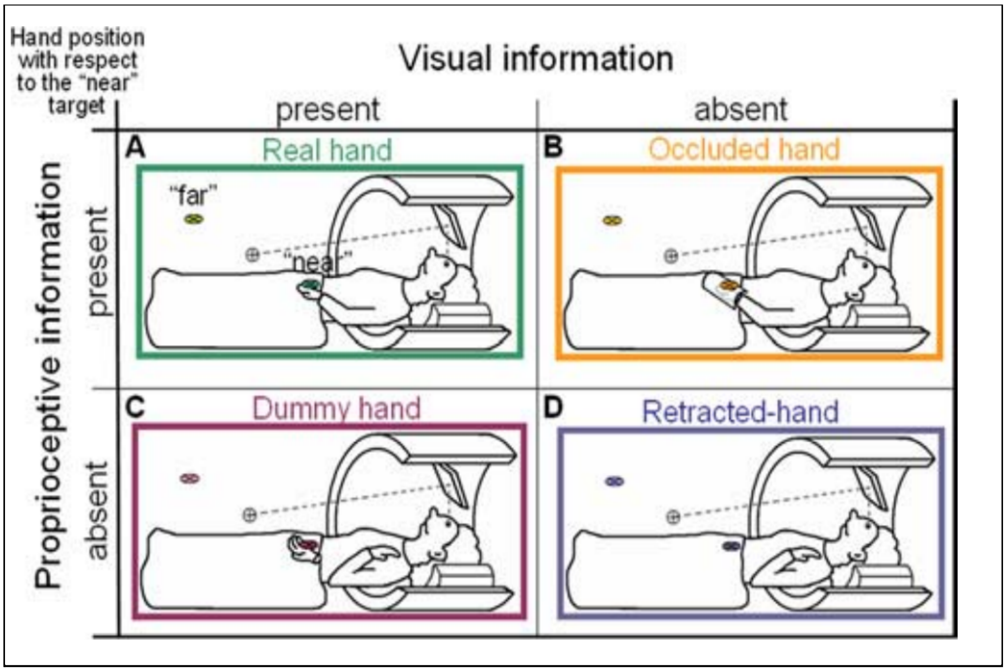


Figure 1.3 *Example of the setting used in each condition by Makin and colleagues (2007).*

Results showed an activation of the intraparietal sulcus (IPS) and of the lateral occipital cortex (LOC) for the near stimuli. Participants did not report an effect of the dummy-hand illusion, but imaging analysis showed that the presence of the rubber hand modulated the preference for a near stimulus in the posterior IPS and LOC (Figure 1.4).

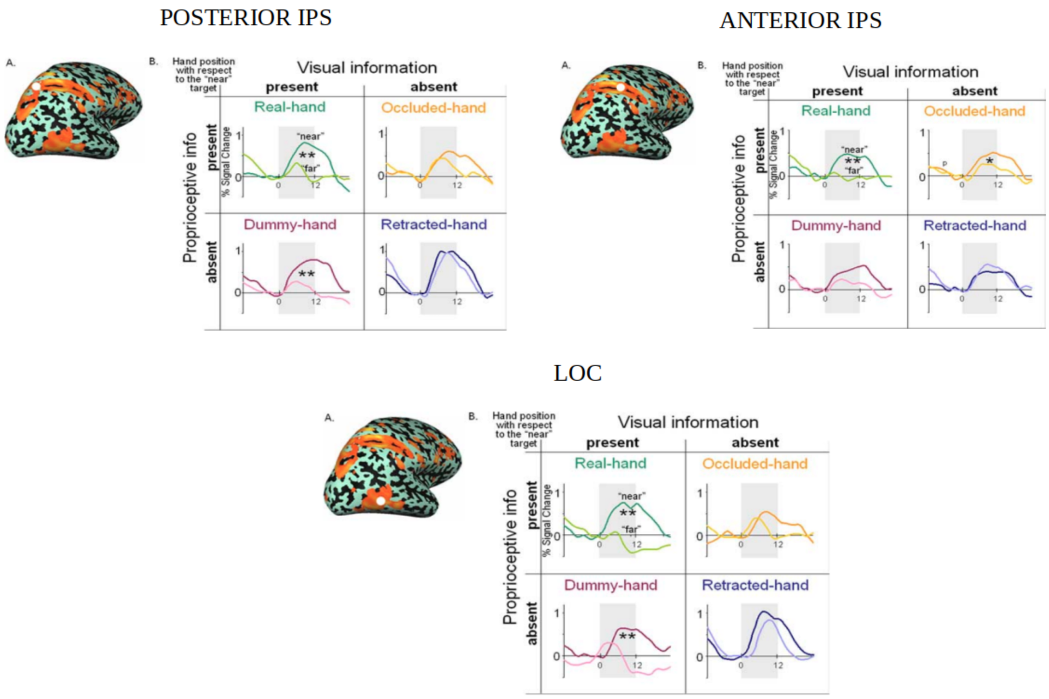


Figure 1.4 *The figure shows the results of the ROI analyses run by Makin and colleagues (2007). The top panels represent, from left to right, the analyses in the posterior IPS, the anterior IPS areas; the bottom panel represents the analyses in the LOC area. For all three panels:* ***A****. It is showing the area with significant preference for the near compared to the far for the real hand condition.* ***B.*** *Averaged hemodynamic response curves of the percentage signal change, in dark the near and in light the far trials. Significances are reported as ** p<0.05; *p<0.01.*

1.1.2.5 Peripersonal space and space remapping

In this section, we will focus on extrapersonal space and on how the brain remaps extrapersonal space onto peripersonal space when using a tool.

The models of space we previously discussed agree in the definition of peripersonal space as the space surrounding the body, but when that becomes extrapersonal space is not clear; as a matter of fact, the use of a tool can extend the person's reach and accordingly the perception of the PPS (Berti &Frassinetti, 2000; Farné, Bonifazi, & Làdavas, 2005; Longo & Lourenco, 2006; Maravita, Spence, & Driver, 2003). On the other hand, the use of weights on the hand can contract the PPS (Lourenco & Longo, 2009). In more recent times, research continues to focus on giving a more precise definition of peripersonal space and on its boundaries. Most notably, research with primates, patients and healthy subjects has focused on what happens when a tool is used to manipulate an object that cannot be reached with the hand (see Ladavas, 2002). Iriki and colleagues (1996) trained macaque monkeys to use a tool to reach far objects, and brain activity during the task was recorded. The brain activity recorded in the caudal postcentral gyrus showed that bimodal neurons code the hand schema and that when a tool is used the visual field activity is modified to be able to fit the entire length of the tool. Tool use and space remapping can also have an effect on specific neuropsychological disorders. Berti and Frassinetti (2000) described the case of a patient showing symptoms of Unilateral Spatial Neglect (USN), a neuropsychological syndrome where the patient fails to attend to the contralesional side, usually the left side of space, in the near space, but not in the far space (see chapter 4, for a thorough review of the syndrome). Patient P.P. manifested USN on the bisection test in the near space, but not in the far space. They were asked to bisect lines of different dimensions, by using a laser pointer or by reaching them with their finger (near space) or a stick (far space), in the near and far space. Line bisection is a widely used test to detect the presence of USN; the patient is asked to indicate the middle of a line on a sheet of paper, patients with USN bisect the line toward the right side (Figure 1.5). The authors hypothesized that using a stick to reach the far space will remap the extrapersonal space in peripersonal space and, therefore, the patient will show USN in the far space when reaching with a stick the line in the far space, but not when pointing at the line. Results supported the hypothesis (Figure 1.6).

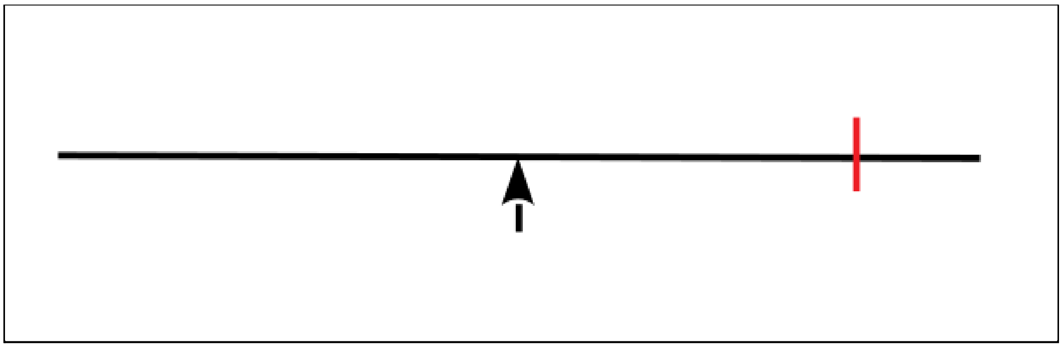


Figure 1.5 *An example of a bisection test (Berti et al., 2007). In the image, we can see a line in black. patients are presented with the line on an A4 sheet centered on their middle line. In red is an example of how a patient with USN might bisect the line. Usually we consider a significant bias an average error of 1 cm or more toward the right side. The black arrow indicates the true middle.*

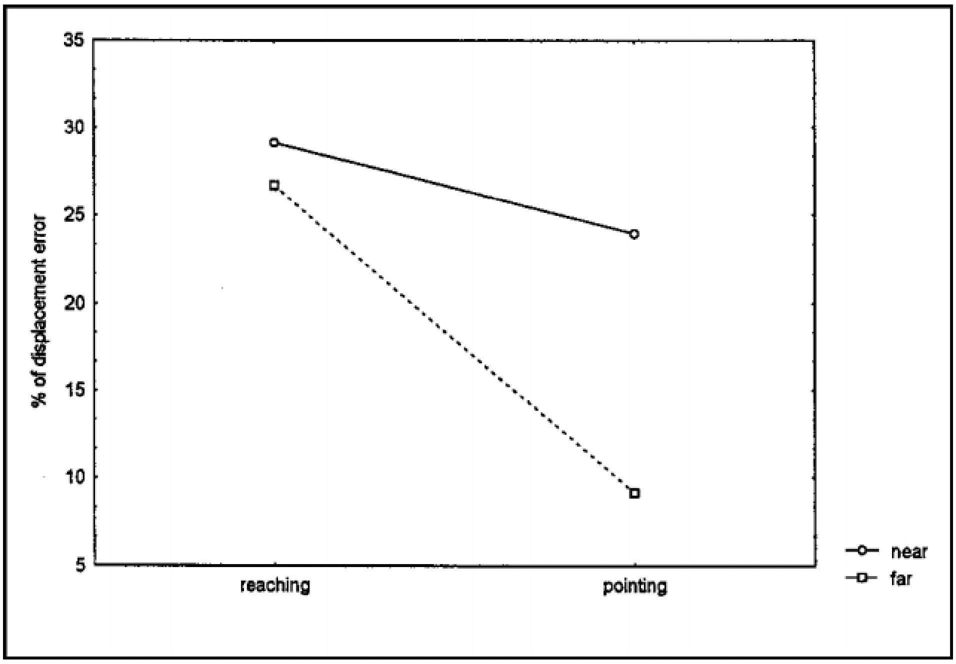


Figure 1.6 *The chart is representing the percentage of the rightward bias in the two conditions, reaching and pointing for the near and the far space (Berti and Frassinetti, 2000).*

Another single case study has been run by Farné and colleagues (2005) investigating the effect of a hand-held tool on the elongation of the PPS. A right-brain stroke patient took part in the study. The patient presented a residual USN bias on some tests, but he showed visual and tactile extinction and cross-modal visuotactile extinction (see box 1 in chapter 4 for details about the disorder and related tests). The patient was asked to sit at a table with their hands resting on it. Tactile stimulations (brief touches) delivered to their hand and/or visual stimulations (rapid flexion-extension of the experimenter's left index finger) were administered. The experimental conditions were as follows: *'unimodal tactile condition'*- the somatosensory stimuli were delivered to the left, right hand or both hands; *'cross-modal condition 1'*- the left hand was screened and visuotactile extinction was tested by delivering a visual stimulus near the patient's right hand; *'cross-modal condition 2'*- it is similar to the previous one, but the visual stimulus was delivered 60 cm away from their right hand; *'cross-modal condition 3'*- it was identical to condition 2 , but the patient was holding a stick (60 cm) in their right hand, and the patient was instructed to hold the stick without moving it for 5 minutes and after the presence of extinction was tested; *'cross-modal condition 4'*- the patient was instructed to reach some objects with the tool for 5 minutes, after extinction was assessed with the modalities of condition 3; *'cross-modal condition 5'*- modalities were the same as condition 4, but this time the stick was shorter (30 cm) (Figure 1.7).

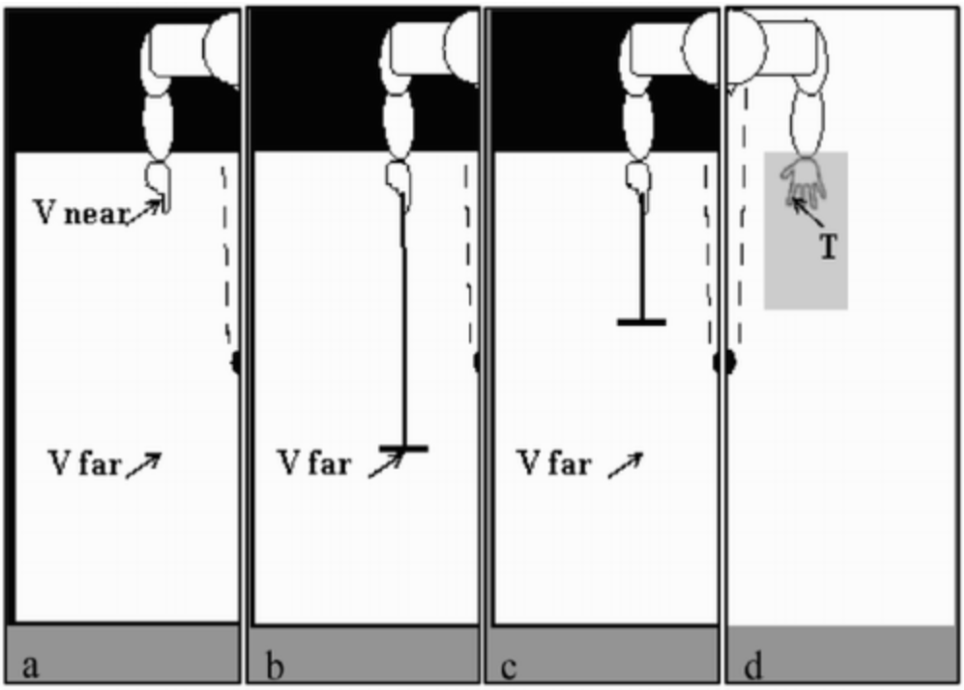


Figure 1.7 *Example of the setting and conditions used by Farné et al. (2005). A) example of conditions 1&2. B) example of conditions 3&4. C) example of condition 5 D) left hand stimulation.*

Results showed an elongation of the peripersonal space was found when the tool was actively used. However, when the patient was passively holding the rack ('*cross-modal condition 3')* no effect was found.

Pizzamiglio and colleagues (1989), on the other hand, found no dissociation in the results of the tests in the near and far space. They tested 70 USN patients showing a modified version of the Wundt-Jastrow illusion in the near and far space. No patient showed a dissociation in the manifestation of USN. One explanation for these results can be that no motor action was performed by the patients, contrary to

Berti and Frassinetti (2000) study where patients were asked to point to bisect a line. Alternatively, it is possible that only a very small number of patients manifest this dissociation and that a focal lesion is necessary to develop the dissociation. No brain analysis has been carried out in Pizzamillio's et al. study, in addition in literature only a few cases of patients presented this dissociation has been described. Hence, we might conclude that a dissociation is indeed present but related to a focal lesion and therefore very rare to assess in literature.

Moreover, the remapping of peripersonal space can be identified in healthy subjects. Longo and Lourenco (2006) used the line bisection test to investigate the effect of the use of a tool on space perception. Similarly to Berti and Frassinetti's (2000) study, healthy participants were asked to bisect lines using a stick or a laser pointer at different distances. There is evidence that pseudoneglect, the tendency of healthy people to bisect a line with a left-ward bias, is affected by participants' visual angle (McCourt and Garlinghouse, 2000; Schintu et al., 2017). Results showed left to right bias shift increasing with distance when the participants were using the laser pointer. When the stick was used, no effect of distance was found.

Gamberini and colleagues (2008) asked healthy subjects to bisect a line in peripersonal and extrapersonal space, at different distances. Two experiments were run, one in a real environment, one in a VR environment. The participants were instructed to point with a stick (real or virtual) or with a laser pointer (real or virtual). Results showed a dissociation between the peripersonal space and the extrapersonal space, with a bias toward the left side for the near space and a bias toward the right side for the extrapersonal space. In addition, they found that the passage to the extrapersonal space is not gradual, but an abrupt transition is present. Lastly, the results showed that the tool can extend the peripersonal space, showing no effect of distance when a stick was used compared to the laser pointer. Both the experiments showed similar results, meaning that the results obtained in the virtual environment, exploring the space division and the space remapping, can be extended to the real world (Gamberini et al., 2008).

Brozzoli and colleagues (2010) explored different actions (grasping and pointing) and how they interact and modulate peripersonal space. Space remapping was found to be action-dependent, showing a stronger visuo-tactile interaction for the grasping condition. This study provided strong support for the effect of peripersonal space on actions, and that a constant space remapping takes place during voluntary actions. Other evidence of this effect comes from Noel and colleagues' (2015) study. Results showed a space remapping occurs when walking. Participants were walking or standing still on a treadmill, 8 speakers were placed alongside the participant simulating a sound source approaching, a vibrotactile apparatus was placed on participant's chest. Participants were instructed to press a button, as fast as possible, when they felt the vibrotactile stimulation. A significant difference was found between the two conditions, with faster RTs for the farther sounds when walking compared to when standing, proving an expansion of the peripersonal space when the participant was walking.

In chapter 3 we will further investigate the phenomena of tool-use and its link with language and peripersonal space.

1.1.2.6 Not only a matter of distance

Humans are sociable animals, during everyday interactions we do not always act alone, but often there is someone else with us. What does this sociability mean for our perception of space and what happens when another subject gets close to us? In this section we will try to analyse the influence of social interaction in the perception of peripersonal space.

Personal space is also the space that separates us from others. It is not only based on reaching, but on the vital space a human being needs, the personal space can be seen as a soap bubble that surrounds us to protect us from invasion from others. Different variables influence the perception of personal space, such as cultural factors, stigma, similarity, gender, personality, and much more (see Sommer, 2002).

Teneggi and colleagues (2013) showed that social interactions can modify the perception of space. They used a tactile detection task on participant's faces. A sound approaching or moving from the face was used, and reaction times were calculated. In a first experiment, a shrinkage of space occurred when the participant was facing another individual, compared to when a mannequin was placed in front of the participant. In further experiments they tested participants after playing a cooperative economic game and results showed that cooperation led to the merging of the boundaries of the two peripersonal spaces. Similarly Maister and colleagues (2015), found partial incorporation of the confederate PPS into their own PPS after a shared experience.

It is clear that the peripersonal space can be modulated by the presence of another person. In chapter 5 we will further investigate the modulation and remapping of the PPS and the use of demonstratives in the Italian language.

1.1.3 Spatial language

In this section we will investigate the relationship between language and space perception focusing on spatial language (demonstratives and prepositions in particular); we will explore how people use language to describe object locations in near and far space.

Previously, we explored how people perceive and how the brain elaborates the location and shape of the object. Different terms can be used to describe the location of an object or the movement or an object in space and to direct a hearer's attention to it. The three main classes terms used in English are spatial prepositions, motion verbs and spatial demonstratives. First, prepositions are used to describe where something is located, for example *"the dog is on the sofa"* where the word *on* is used to describe that the subject (*"the dog"*) is placed in contact with the reference object and placed at a higher position than the reference object. Second, some verbs intrinsically convey spatial relations, for example the verb *enter* conveys the meaning of *to get into*, *to approach something that has the capacity to contain other objects* (Landau and Jackendoff, 1993). The last type of spatial terms are demonstratives; demonstratives are deictic expressions such as *this* and *that*. For example, we can analyse the sentence: *"this is my book".* Try to picture the scene in your mind; you might see two people, in front of a desk with a few books and one of them is pointing at a book saying*"this is my book"*, and the hearer moves their attention toward the book the speaker is pointing at. But why did you picture the speaker pointing at the book? That is because demonstratives are often paired with a pointing gesture to direct a hearer's attention. Although, as we will see later, a lot of variables influence the use of demonstratives, such as distance; in fact, you might have pictured the book the speaker was pointing at as closer to them than to the hearer.

Below we will mainly focus on the use of demonstratives, the main topic of this thesis (in-depth review of the experimental methodologies used to test the use of demonstratives will be presented in chapter 2) and we will delve into different variables that can affect the use of such words. In the next section, we consider spatial language more broadly, with more in-depth review in the experimental chapters 2 and 4.

1.1.3.1 The geometry of language: spatial prepositions

In the English language, prepositions are usually short words, such as *in*, *on*, *over*, and they are usually placed in front of a noun. Spatial prepositions can be divided into locative terms that represent the static location of a subject (such as *in, over, on*) and directional terms that represent the movement of a subject (such as *across, toward, into*) (Zwarts, 2005). To describe the position of an object, a sentence requires three elements: the object (noun phrase), the reference object (noun phrase) and the relation between the two (a preposition) (Landau and Jackendoff, 1993). For example we can take the sentence:

The dog | is sitting | on the bed.

This sentence is composed of:

Object | verb | prepositional phrase

| preposition + reference object

Not only prepositions can be used to describe locations, some verbs can depict spatial relations. Verbs such as *enter*, for example, can be substituted by the words *getting into*, thus by a construct containing a verb and a preposition. In addition, the same preposition can be used in different contexts in very different ways and can acquire very different situation-specific meanings. Depending on how we count them, we can identify from 80 to 100 different prepositions in the English language. Landau and Jackendoff (1993) report 90 prepositions (Table 1.1) including polysemous prepositions (words that can have different meanings, such as the multiple senses of the word *over*) and non-spatial prepositions (such as *during*, that conveys a temporal sense).

Table 1.1 *List of prepositions in English*

Preposition of English					
About	Between	Outside	**Intransitive prepositions**		
Above	Betwixt	Over	Afterward(s)	Forward	Right
Across	Beyond	Past	Apart	Here	Sideways
After	By	Through	Away	Inward	South
Against	Down	Throughout	Back	Left	There
Along	From	To	Backward	N-ward (e.g. homeward)	Together
Alongside	In	Toward	Downstairs		Upstairs
Amid(st)	Inside	Under	Downward	North	Upward
Among(st)	Into	Underneath	East	Outward	West
Around	Near	Up			
At	Nearby	Upon	**Non-spatial prepositions**		
Atop	Off	Via	Ago	Despite	Of
Behind	On	With	As	During	Since
Below	Onto	Within	Because of	For	Until
Beneath	Opposite	Without	Before	Like	
Beside	Out				
Compounds					
Far from	In front of	To the left of			
In back of	In line with	To the right of			
In between	On top of	To the side of			

A central topic in the use of prepositions is the prevalence of the extent to which their use is determined by geometric relations versus the prevalence of functional relations. If we are describing the position of an object it is clear that the geometric relationship between the object and the referent object affects the choice of the preposition. However, the change of position of the objects and how the objects are interacting in the scene is also important (Garrod & Sanford, 1988). Let's look at *'the pear is **in** the bowl'* example (Figure 1.8). In the first and second image (Figure 1.8a and Figure 1.8b) we can describe the location of the *pear as 'in the bowl'*, in this case the same preposition can be used for both images despite the fact that the Euclidean distance between the pear and the bowl is different; other objects intervene in the choice of the preposition, in fact in figure 1.8b the amount of 'white balls' is higher, but the contiguity between the bowl and the pear is maintained, making the preposition *in* appropriate. On the other hand, figure 1.8d shows the object hanging with no contact with the bowl or any other objects that are placed in the bowl. In this last case, despite the fact that the pear is located within the space the bowl occupies, the preferred description is *'the pear is over the bowl'.* So not only a change in the position of the object can affect the use of prepositions, also a change in the position of the referent object affects the use of prepositions. If we rotate the bowl of 180º with the pear placed on the same surface (Figure 1.8c), the distance between the pear and the bowl does not change much from the previous examples, however, the pear is more appropriately described as *'under the bowl',* rather than *'in the bowl'.* Such examples illustrate that the geometry of spatial relations affects the choice of preposition to describe a given scene, but geometry on its own is not sufficient to explain the mapping between prepositions and spatial scenes.

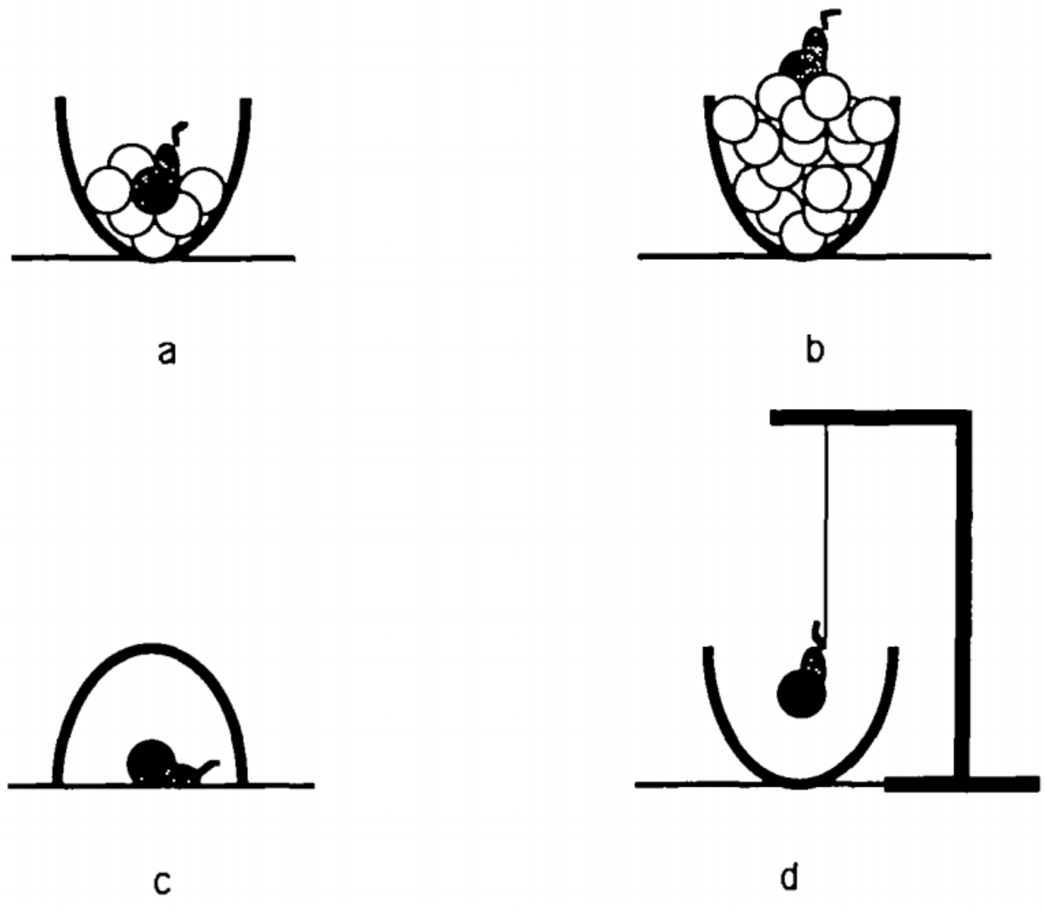


Figure. 1.8 *Example of the use of preposition used by Garrod and Sanford (1988).*

Coventry and Garrod (2004) propose a functional geometric framework for spatial prepositions where both geometric and extra-geometric relations come together to determine preposition use. The authors argue that not only the geometric relations are taken into account when a preposition is chosen, but that spatial language also informs us about the relationship between objects and how objects interact. The *functional geometric framework* brings together geometric relations, and a range of extra-geometric relations to jointly constrain spatial language choice. Spatial language can tell us that objects stay in the same relative positions over time. For example, the preposition *in* implies containment, but also force dynamic relation: when we apply a force to move a container the contained object is also moved by consequence. So judgements about the use of *in* rely not only on processing of the geometry of a spatial scene, but also on judgements about how objects are interacting or will interact, such as how one object in this case is able to control the location of another object. If we have a container, such a bowl, and a contained, such an apple, we know that the container controls the positions of the contained and a series of inferences can be taken into account (if we move the bowl the apple will move with it). However, we could argue that this model does not take into account other variables such as the force applied and the geometric relationships present at each time. First of all, applying a force to the container will change the geometric relationship between the two objects, the apple might still be in the bowl, however the spatial relations have changed as the force of the movement has been applied to both the objects. Now let's think we applied too much strength to the movement of the bowl, the apple might now be on the floor and the proposition is not appropriate anymore to describe the relationship. In addition, if we apply too much strength the relationship between the two objects at the end of the movement might be the same, but if we analyse each time frame we can see that the apple for a few milliseconds has lost the contact with the bowl due to the force, hence changing the geometric relationship and maybe the most appropriate preposition.

Coventry and colleagues (2013) in an MRI study tested the effects of prepositions on processing of static visual images. Participants were asked to take part in a sentence-picture verification task. Participants had to judge whether a sentence (in the form of: the + noun1 + is + term+ the + noun2) presented was an appropriate description of the picture shown immediately after the sentence. Pictures showed one object positioned higher or lower than another object, such as a packet (of pasta) higher/lower than a pan, and the sentences either described the spatial relation between the two objects (e.g. *'the packet is over the pan'*) or the relative size of the objects (e.g. *'the packet is smaller than the pan'*). Results showed that participants' brain activation patterns when looking at the picture were affected by the preceding sentence. Specifically, Medial Temporal/Middle Superior temporal regions (regions involved in motion processing) were more activated when a picture was preceded with a spatial preposition than when it was preceded by a comparative adjective. Therefore, spatial language seems to drive processing of spatial relations in a visual scene, with spatial terms driving *'mental animation'* of static images. In other words, participants judge whether a term like over is appropriate by working out if the pasta pouring from the packet will end up in the pan or not. Such interactive properties are not only important for prepositions, but as we shall see, it has been proposed that interaction/action has also been proposed to be central to spatial demonstrative use also.

1.1.3.2 Spatial Demonstratives

There are other words used to describe the location of an object/subject other than prepositions. Spatial demonstratives (e.g. *'this', 'that', 'there', 'here')* are a class of words used to describe object location, among other functions. Demonstratives can be pronouns or determiners, meaning that they appear in front of a noun or instead of the noun. Demonstratives are words that cannot be understood outside of the context; the word *'this'* does not have a meaning if we do not know what the speaker is referring to. Demonstratives are closely linked with the action system and they often involve pointing at objects (Clark, 1996, Diessel, 2006), and in some languages it is obligatory to point when using such terms (*Goemai*, Hellwig, 2003; *Kilivili*, Senft, 2004).

Despite being present in every language and being among the most used words in a language, demonstrative systems vary across languages (Deutscher, 2005; Diessel, 1999, 2006). Diessel (2005) analysed 234 languages, most languages (54. 4% of the sample), such as English, use a two-way demonstratives system with a proximal demonstrative (*'this'*) and a distal demonstrative (*'that'*). The second most frequent system is the three-way system (37.4% of the sample), used in languages such as Spanish or Japanese. For example in some accounts of Spanish there is a term to indicate something close to the speaker (*'este'*), the second term serves to describe something at a medium distance (*'ese'*) and last one it is used to indicate something far away from the speaker (*'aquel'*) (see for example Anderson &

Keenan, 1985). However, Spanish and other languages often glossed ‘person-centred’, nevertheless still have a distance-based demonstrative system. Coventry and colleagues (2008) showed that both English and Spanish divide the space into peripersonal and extrapersonal space, with an increased used of *‘this’* and *‘este’* for the reachable space and an increased use of *‘that’* and *‘este/ aquel’* for the not reachable space.

1.1.3.3 Experimental methodologies for the testing of demonstrative

In this section we will review some of the experimental methodologies used for testing the use of demonstratives.

Coventry and colleagues (2008) devised the *‘Memory game’* task to study the relationship between space and the use of demonstratives in two languages: English (2-way demonstratives system) and Spanish (3-way demonstratives system). Objects were placed on a table where the participant was seated, and positions of object placement varied in distance in the midline, farther or closer to the participant (Figure 1.9).

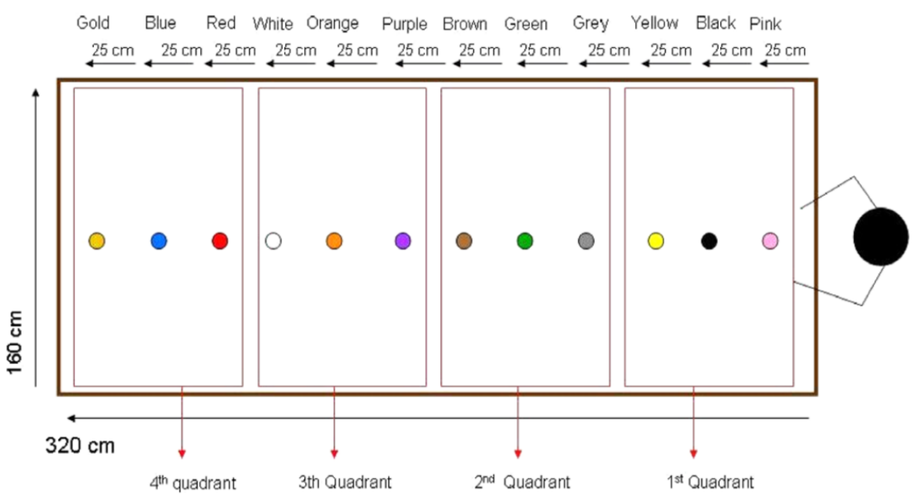


Figure 1.9 *The table used by Coventry and colleagues (2008) with the distances used to place the objects.*

Once the object was placed (by the experimenter or by the participant) and the actors were back in their seats, the participant was instructed to point at the object and to name it, using only three words: a demonstrative (either *'this'* or *'that')*, the colour of the object and the shape of it (e.g. '*this orange square'*). Experimenter position was varied as well; they were sitting either close to the participant or at the end of the table, opposite and facing the participant, to test whether the use of demonstratives in Spanish (that is a 3-way system) was influenced by the position of the hearer, by distance or by both. In addition, a stick was used by half of the participants to point at the object, to test whether the stick can elongate the PPS and, therefore, to extend the use of *'this'* to farther locations (Figure 1.10).

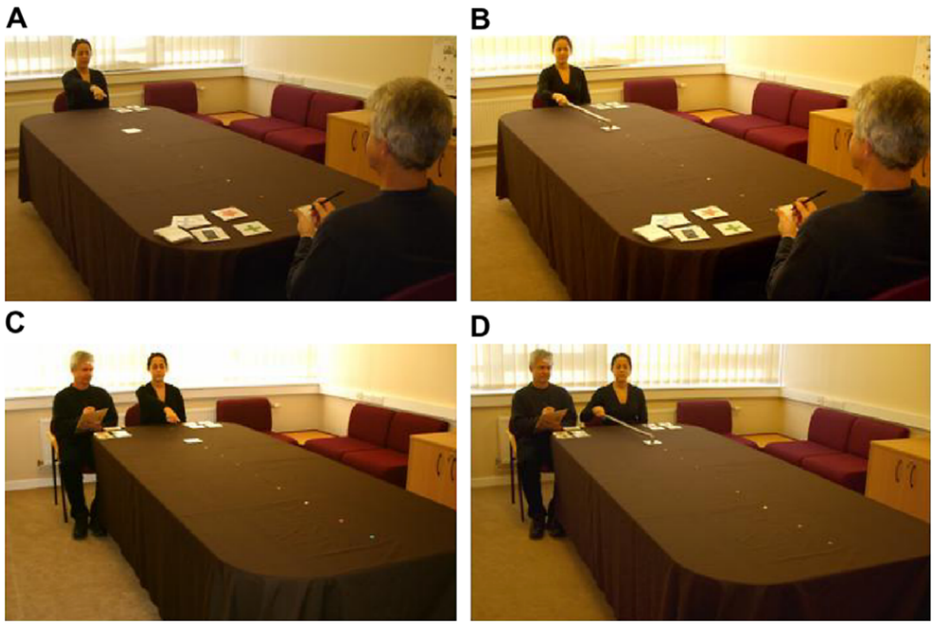


Figure 1.10 *Setting used by Coventry et al. (2008) representing the four conditions used: experimenter seated opposite to the participant pointing without tool (A) and with the tool (B); experimenter seated near the participant pointing without tool (C) and with the tool (D).*

Results found that both *this* and *este* were used in PPS (Figure 1.11), with a rapid graded drop off in the use of *this* in English and *este* in Spanish to describe object locations in egocentric space when the object moves across the graded boundary to extrapersonal space (see also Maes et al., 2007, Stevens and Zhang, 2013). Moreover, when participants point at objects with a stick, the area in which *this* and *este* are used extends to the area reachable with the end of the stick, consistent with the extension of near-space neglect reported by Berti & Frasinetti (2000). The actor had also an effect on the production of demonstratives, with an increased use of '*this'* when the participant placed the object. Results also showed that the position of the addressee has an important role in the choice of demonstrative (Coventry et al, 2008). This study proves a strong mapping between perceptual space and demonstrative use.

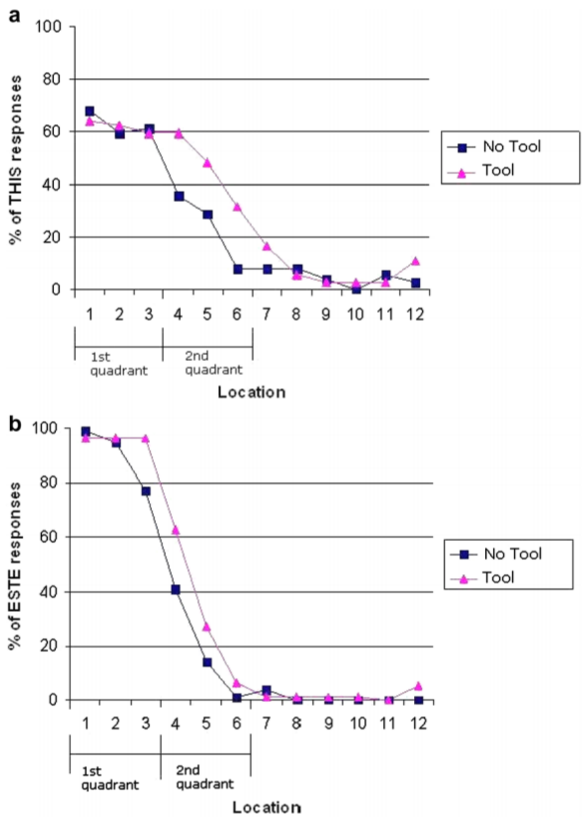


Figure 1.11 *Charts representing the results obtained by Coventry et al. (2008). a. The mean percentage use of 'this' when using the tool and when pointing with the hand. b. The mean percentage use of 'este' when using the tool and when pointing with the hand. The first quadrant was reachable with the hand, the second quadrant was reachable with the tool, the farther positions were not reachable.*

Later, in 2014, Coventry and colleagues added more variables to the *'Memory Game'* paradigm. In a series of seven experiments, both language and memory were tested. The first variable tested was *ownership,* where objects that belonged to the participant or belonged to the experimenter were used. Another variable tested was *visibility*, where the visibility of the object was changed. The object was placed uncovered, or covered with a glass container or with a metal container. In the first two cases the object is visible, but in the case of the glass container the object is not accessible. In the third case, the object covered with the metal container is neither accessible nor visible. Lastly, the effect of *familiarity* was tested. Familiar colour-shape combinations (e.g. *yellow heart*) and unfamiliar colour-shape combinations (e.g. *cerulean ranuncoloid*) were used as objects. Results showed not only that demonstrative choice is influenced by distance and tool use, but also by *visibility, ownership* and *familiarity*. For example, the proximal demonstrative is used more when the object is visible than when the object is covered by the metal container. In addition, memory tasks were carried out in the absence of language, and the data showed that the visibility, familiarity and ownership also affect memory for object location, with the owned object, the familiar shape and visible objects remembered as being closer. To explain the memory results Coventry and colleagues used the *'expectation model'*. The model takes into account the distance where an object is expected to be located and it combines it with the actual distance of the object (plus the associated estimation error) in memory:

$$M_D=f(D_a, D_{exp}, D_{err}).$$

where *M* = signed memory error, *D* = distance, *a* = actual, exp = expected and err = estimation error.

If we apply this function to the visibility variable, we will have a lower value for the expected distance of the visible object compared to the hidden object. However further research is needed to establish the magnitude of the different variables.

Gudde and colleagues (2016) further developed the paradigm testing the influence of demonstratives on object-location memory. The participant was provided with instruction cards, and on each trial they were instructed to take one and read the instructions out loud to the experimenter. Instruction sentences had the form of: place + demonstrative (either *this, that or the*) + object's *colour & shape* + on + *colour* dot (*e.g. place this/that/the green star on the orange dot*). Following the experimenter placed the object as instructed, participants were given a fixed time to memorise the location, and then the object was removed. The participant was then presented with an indication stick and was instructed to indicate the object's location by verbally instructing the experimenter to move the indicator closer or farther. Results, in accordance to the expectation model (Coventry et al., 2014) showed a more accurate memory when objects had been placed with *'this'* at instruction compared to '*that'*.

The literature that we have reviewed thus far argued in favour of a mapping between the use of demonstratives and the peripersonal and extrapersonal space, but there are different views on the role of the egocentric distance on the use of demonstratives in the literature. Kemmerer (1999) argued that the use of language does not map onto space perception, and that the use of demonstratives is not related to the near and far space, but it is rather based on language-internal factors, such as abstract semantic representations. The use of demonstratives is related more to an abstract meaning and their use varies depending on context (Kemmerer et al., 2006; Kuntay & Özyürek, 2006); the distance base use of demonstratives is, therefore, more one of psychological proximity (Peeters & Özyürek, 2016). It has been argued that the joint attentional function of demonstratives is the primary function, and that use is not affected by egocentric distance (Peeters and Özyürek, 2016, Peeters et al., 2015).Peeters and colleagues (2015), in two EEG studies contrasted two theoretical models: the egocentric proximity account and the dyad-oriented account (demonstratives use is anchored on body position). The dyad-oriented theory proposes that in Spanish the choice of a demonstrative is based on the relative orientation of the speaker and the addressee (Jungbluth, 2003). Rather than the proximal term referring to an object in the PPS of the speaker, this alternative account proposes that in a face-to-face setting the proximal term is used in shared space (i.e. at any distance between the speaker and hearer). Participants were presented with pictures depicting an actor and two objects (one near and one far the actor; Figure 1.12). Firstly, an introductory image was presented where the actor was not looking at the object, nor pointing at it. Then a target image was shown depicting the actor looking and pointing at either the near or the far object.

Objects were placed either on the sagittal plane or the lateral plane (Figure 1.12). Whilst the participant was seeing the target picture a spoken sentence was presented (*'I have bought this plate at the market'*), sentences could present a congruent (*'plate'* indicating a plate) or incongruent name (*'mango'* indicating a plate). Demonstratives were manipulated as well; the proximal demonstrative was used for the object close and far and same for the distal demonstrative. Experiments were run in Dutch.

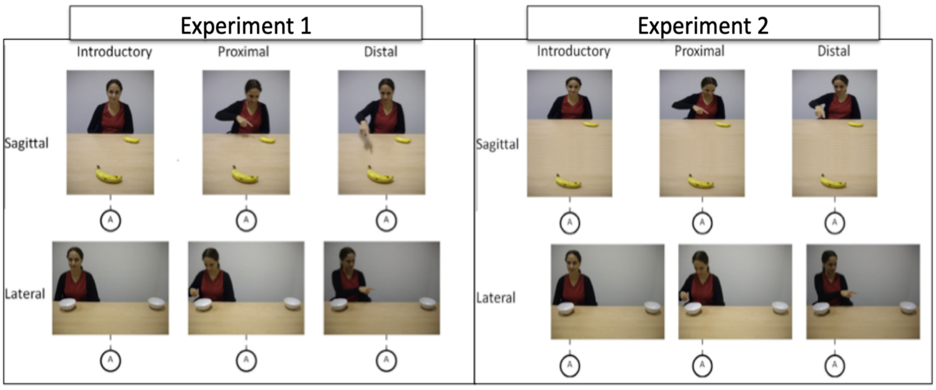


Figure 1.12 *An example of the images used by Peeters et al. (2015). On the left an example from experiment 1, on the right an example from experiment 2. The top panel shows an example of the sagittal object placement in three conditions. The bottom panel shows an example of the sagittal object placement in three conditions. The circled A marks the position of the addressee (the participant).*

In contrast with the pretest results (where participants were asked to indicate the appropriate demonstrative to use for each position), supporting the egocentric distance account, the analyses of the ERP analyses lean toward the dyad-oriented account, as no interaction between demonstrative and distance was found and the orientation of the object played a crucial role. In the sagittal plane condition, a more negative ERP component (N400) was found for the distal demonstrative compared to the proximal, and no difference was found in the lateral plane.

In the second experiment, two adjustments were made to experiment 1 stimuli: in the lateral condition the participant was aligned with the speaker and for the sagittal conditions the stimuli were modified to make the objects seem farther from each other (Figure 1.12). Results again supported the dyad-oriented account, showing a preference for the proximal demonstrative to refer to an object in the shared space, only if all the possible referents are located in that space.

The authors conclude that the choice of demonstratives is primarily driven by socio-centric approach. However, the results are inconsistent: in fact the results of the pretest contradict the results of the two experiments. We should also point out that the EEG experiments were comprehension studies whether in the pretest study they were asked to indicate the most appropriate demonstratives. Therefore, they did not test the production of demonstratives, making it more difficult to compare it with the results obtained by Coventry and colleagues (2008; 2014). Lastly, the participants heard the sentences through the headphones, hence they were not placed in a social situation with the speaker, and it is difficult to understand what perspective they took; it is possible that hearing sentences through headphones cued participants to assume that the speaker was using the participant's perspective.

A possibility that might still be consistent with the experimental data on demonstratives to date is that the proximal-distal contrast may have to do with a more general distance contrast rather than a direct mapping between peripersonal-extrapersonal space and demonstratives. For example, it is possible that the stick manipulation simply rescaled space in some way, extending the proximal scope that supplied a new artificial proximal-distal boundary. Such a possibility might be consistent with a point made by Kemmerer (1999) that one can use *this* and *that* (e.g. *this* planet and *that* planet) when objects are clearly not in peripersonal space (although one needs to be cautious extrapolating from contrastive to non-contrastive uses of closed class terms), and in a similar vein, the distal term can also be used in peripersonal space (see for example Bonfiglioli, Finocchiaro, Gesierich, Rositano, & Vescovi, 2009).

In summary, while there is evidence for a mapping between perceptual space and demonstrative use, some studies have challenged these findings, and there is indeed evidence that a wide range of variables including distance affects demonstrative choice. In chapters 2 and 3 we further investigate the mapping between perceptual space and demonstratives use, focusing on variables that might affect how interacting with objects can take place. In chapter 2 the link between reaching (and, therefore, peripersonal space) will be further investigated and the effect of the handedness of the participant will be explored. In chapter 3, we will analyse the difference in the use of demonstratives for an image of the object or for a real object. And finally, in chapter 4 we will analyse the use of spatial language in right-brain stroke patients.

Section II

Experimental chapters

Chapter 2

Space perception and demonstratives:

the effect of hand, handedness and tool use

2.1 Introduction

As we discussed in chapter 1, spatial demonstratives, including the words *'this'* and *'that'* in English, constitute an important class of lexical items across all languages. Not only are they present in all languages and are among the highest frequency words within a language (Deutscher, 2005; Diessel, 1999; 2006), but they are also among the earliest words to be acquired (Clark, 1978, 2003). Demonstratives are often used together with pointing movements, suggesting strong links to the motor system. On the one hand, deictic pointing serves to show the location of the object and on the other hand deictic pointing can be used to direct the focus of attention of the hearer (Diessel, 2006). In some languages, such as Goemai (Hellwig, 2003) and Kilivili (Senft, 2004), it is mandatory to point whilst using demonstratives. Despite being present in every language, differences in the use of demonstratives have been found across languages. The most common system is a two-way system, found in 54.4% of languages, used for example in English where we can find one term (*'this'*) used to refer to an object close to the speaker and another term used to refer to something far from the speaker (*'that'*) (Diessel, 1999, 2005). A 3-way system (e.g. Spanish and Japanese) is less common, present in 37.4% of languages. Different uses of the third demonstrative have been found across languages. The 3-way system can be distance based, with one proximal, one middle and one distal demonstrative; or it can be person centred, with one demonstrative describing something close to the speaker, the second one referring to something far from the speaker, but close to the hearer and the last one referring to something far from both, hearer and speaker (Diessel, 1999; 2014). Systems with more than three demonstratives have been also found in grammars, with choice of demonstrative terms affected by other variables, such as the visibility of the object or object ownership. However, the common (and perhaps universal) binary distinction, between the proximal and distal demonstrative as set out by linguistic typologists, naturally leads to the view that demonstratives are linked to the space perception and elaboration, and notably to the distinction between peripersonal space (PPS) and extrapersonal space. While some have argued for a close mapping between the use of demonstratives and the peripersonal/extrapersonal space distinction (Coventry et al., 2008, 2014; Diessel, 2014), others have argued that distance from a speaker does not affect demonstrative choice (e.g. Kemmerer, 1999; Peeters, Hagoort, & Özyürek, 2015).

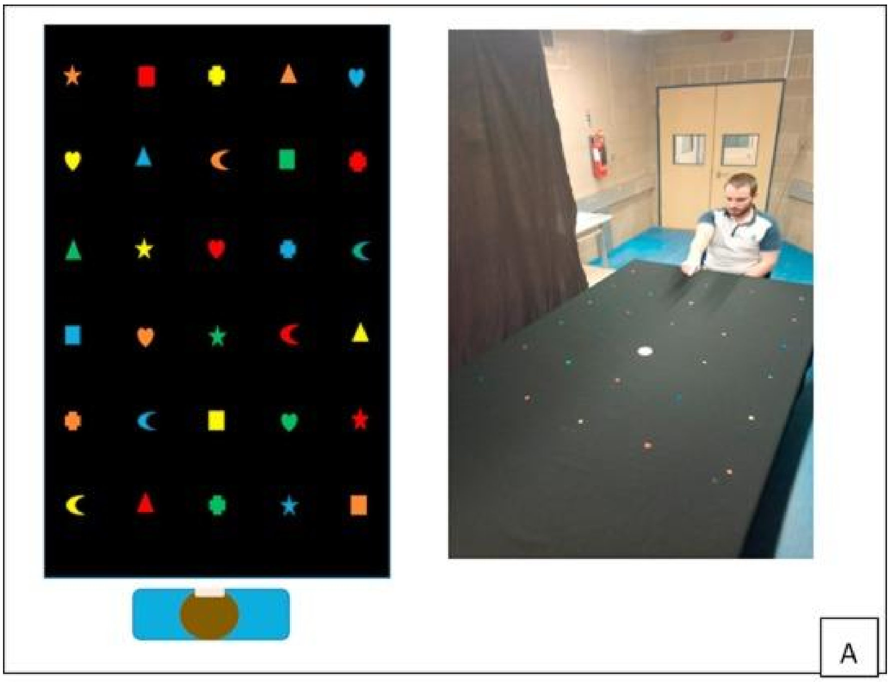
In chapter 1 we have reviewed the studies examining the use of demonstratives experimentally. After reviewing the major literature on the connection between language and space, it seems arguably that a connection between the two processes is indeed present. In addition, the previous literature seems to demonstrate that the use of demonstratives is affected by multiple factors, with perceptual space among them. However, much debate is still present on the factors influencing the use of demonstratives and the role of the mapping between demonstratives and perceptual space has been challenged on two grounds. More research is therefore needed to better understand the variables influencing the use of demonstratives.

Hence, in a series of three experiments we will further test the mapping between perceptual space and demonstratives use, examining space in both the sagittal and lateral planes systematically for the first time. We will use a modified version of the *'memory game'* where lateral positions will be added to test the mapping of the space surrounding the participant. New variables will be considered in addition to the lateral space, participants will be pointing with their preferred and dispreferred hand and the effect of handedness will be analysed. Demonstratives can be used temporarily to denote objects and events in current focus of attention/temporal proximity (*'this' month*) versus objects and events that appeared in the past (*'that' was a particularly good year*), and the proximal term usually occurs first when referring to two objects (e.g. *'this cup and that cup'*). Moreover, there is a general processing bias in the left visual field (Marzoli, Prete, & Tommasi, 2014), for example, manifest in facial asymmetries in face processing and visual attention to faces (see for example Burt & Perrett, 1997). Given the processing biases from left to right, often also associated with writing direction (Bergen and Lau, 2012, Shaki et al., 2009) or the dominance of right handers (Marzoli et al., 2014), one can postulate that this might be used more in the left visual field than in the right (and vice versa for that). In the first experiment, right-handed English native speakers were tested. They were asked to point and name objects placed in their midline and in their left and right lateral spaces in their peripersonal and extrapersonal space. Further, the effect of handedness was tested. It is generally easier to manipulate objects with one's preferred hand, so one can also predict that pointing with the preferred or dispreferred hand potentially could affect the language one uses to describe object location, with this being used more when pointing with the preferred hand. This would be consistent with results showing mappings between preferred hand and other categories of language (see Casasanto, 2011), and how such mappings can be disrupted by changing the manipulability of objects (Casasanto & Chrysikou, 2011). Furthermore, there is evidence for differences in the representation of body space as a function of handedness and of lateralized mental imagery of actions (Willems, Hagoort, & Casasanto, 2010). Moreover, an effect of object affordance and participants' handness on memory span has been found by Apel and colleagues (2012); an increase in the number of instructions retained was found when the affordance (the verse of a mug handle) was congruent only in right-handed participants. Neurologically healthy subjects have the tendency on line bisection tasks to bisect with a bias toward the left (a phenomenon labeled 'pseudoneglect'). Pseudoneglect is influenced by a range of variables included handedness, with dextrals manifesting a slightly bigger bias toward the left side than sinistrals (Jewell and McCourt, 2000; Luh, 1995).

People are not used to using their dispreferred hand to perform actions, so we might expect an effect of the hand used to point on the use of demonstratives. In a second experiment, left-handed participants took part in an experiment with the same modalities of experiment 1, to test whether left-handed participants behave differently than right-handed participants. For the purpose of this thesis, the two experiments have been treated and analysed separately at first due to the number of participants and the novelty of the variable tested. The results of the two experiments will then be analysed through a mixed methods ANOVA to better understand if there are differences between right-handed and left-handed participants. Third, the same setting was used to test right-handed participants pointing with a tool, to test whether tool use and its effect on the peripersonal space boundary can be extended to the lateral space.

2.2. Experiment 1- Use of demonstratives in the lateral space in right-handed participants

The main goal of this experiment was to investigate the use of demonstratives in right-handed English native speakers in the lateral space and the effect of the hand used to point with. Adding lateral positions to the setting will help us to precisely test the mapping between peripersonal/extrapersonal space by manipulating when an object is reachable and when it is not, depending on the hand used to point at the object. If the PPS/EPS space distinction is indeed important for demonstrative choice, one should find a drop off in the use of *this* in lateral locations dependent on the hand used to point at the object when naming it (Figure 2.1). Specifically, pointing at an object on the far left should be associated with increased use of *this* when pointing with the left hand (as the object can be reached) compared to the same location when pointing with the right hand (where the object cannot be reached). And the reverse should be the case for an object positioned at an equivalent contralateral location. Therefore, the lateral axes affords a strong test of the mapping between perceptual space and the use of demonstratives. In addition, the effect of gender was analysed. Coventry and colleagues (2014) found an effect of gender in the language study, with women using *'this'* more than men, besides no significant interaction was found and no effect of gender was found in the memory condition. Therefore, adding the gender variable to this study will help us better understand if a gender difference in the use of demonstratives is indeed present and what variables can influence it. Although, due to the lack of literature on the argument and the effect being found only in one study we would not expect any difference between genders. The data will be treated as exploratory data-analysis.



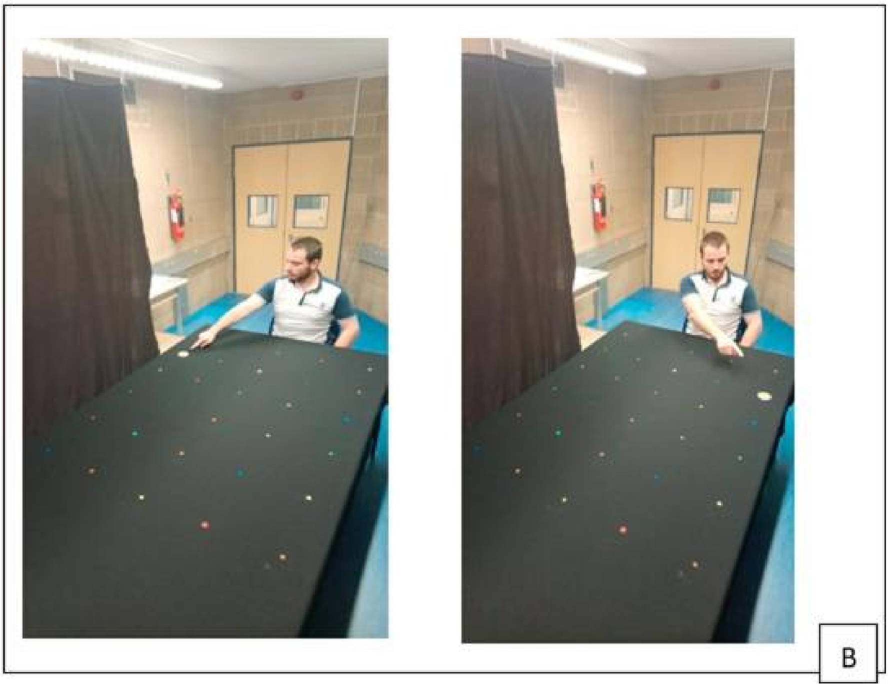


Figure 2.1 *A. Left panel: a schematic representation of the table used for the study, with all the placement positions marked. Right panel: a picture of a participant pointing at an object placed on one of the midline locations. B. An example of a participant able to reach the object on their right with their right hand but not at the equivalent contralateral location.*

2.2.1 Methods

The method employed the *'memory game'* previously used to elicit demonstratives without participants being aware that language data are being collected (Coventry et al., 2008, 2014; Gudde, Griffiths, & Coventry, 2018). Objects (6 coloured disks) were placed in front of participants in 30 different positions (25 cm apart) on a table, resulting in a 6 sagittal X 5 lateral grid (Figure 2.1).

2.2.1.1 Participants

32 right-handed participants (16 males) took part. The age range was 18–26 (M=19.83; SD=1.29). All were English native speakers receiving payment or course credit for their time. The sample size has been chosen based on previous literature (Coventry et al., 2014; Gudde et al., 2016).

2.2.1.2 Procedure

Handedness was assessed with the Edinburgh Handedness inventory (Cohen, 2008 version adapted from Oldfield, 1971) and Stereo acuity was tested using the Randot Stereo Test (Stereo Optical Inc. Chicago, USA) (all participants had a threshold of at least 40 arcseconds). Participants were then asked to sit at the table where the 30 different positions were marked on a tablecloth. Participants were instructed to touch several key locations on the tablecloth so reaching distances to locations were strictly controlled (moving the tablecloth according to reach ensured participants were able to reach the second far right position with their right hand, but not with their left hand and vice versa, to test our main hypothesis: Figure 2.1B).

Participants were then told they were taking part in a *'memory game'* task assessing the possible impact of language on memory for object location (based on

Coventry et al., 2008, 2014). On each trial, the experimenter placed an object (one of 6 coloured plastic disks) on one of the 30 marked positions. When the experimenter was behind the participant, they were instructed to point at the object, half of the time with their preferred hand and half of the time with their dispreferred hand, and to name the object using a combination of three words (so all participants used the same amount of language on each trial): a demonstrative (the word *'this'* or *'that'*), the object colour and the word disk, e.g. *this red disk or that red disk*. To maintain the memory cover, after a random number of trials, participants were asked to recall the position of an object previously placed. At the end of the experiment, the experimenter ensured that the 'memory game' cover persisted during the entire experiment by checking that the participant was not aware the experiment was testing demonstrative use.

2.2.2 Results

The percentage of the use of *'this'* was calculated (see Table 2.1) for each of the location × pointing hand combinations. We ran two analyses, first considering the middle locations on their own, and then the outer (lateral) locations. The mean use of *'this'* per position and hand are reported in table 2.1. When running the ANOVAs Greenhouse-Geisser correction will be used and reported where sphericity has not been met. Whereas, for the post-hoc test Bonferroni correction will be used and reported in text when appropriate.

Table 2.1 *Percentage use of 'this' and SD pointing with the left hand and the right hand. Each cell represents a position used to place an object. Below the table the gradient legend of the color used, where red represents a high percentage and green a low percentage of the use of 'this'.*

RIGHT-HANDED										
LEFT HAND POINTING						RIGHT HAND POINTING				
29 (.23)	26 (.26)	29 (.25)	30 (.27)	26 (.26)		26 (.29)	30 (.24)	28 (.32)	30 (.27)	23 (.23)
23 (.24)	20 (.24)	40 (.32)	30 (.27)	28 (.27)		34 (.30)	32 (.21)	26 (.25)	30 (.29)	26 (.26)
23 (.23)	43 (.29)	35 (.28)	34 (.33)	36 (.30)		33 (.24)	46 (.35)	40 (.30)	37 (.22)	35 (.28)
41 (.27)	52 (.31)	50 (.29)	47 (27)	45 (.31)		44 (.28)	47 (.27)	52 (.32)	46 (.29)	40 (.28)
53 (.35)	66 (.30)	63 (.32)	60 (.31)	39 (.32)		50 (.28)	55 (.30)	69 (.25)	55 (.30)	60 (.26)
63 (.26)	71 (.27)	73 (.28)	63 (.28)	62 (.35)		63 (.29)	70 (.29)	80 (.27)	70 (.33)	63 (.28)

Firstly a 2-way mixed ANOVA (6 distance X 2 hand X 2 gender) was run. The assumption of sphericity for the distance variable was violated, therefore Greenhouse-Geisser correction was used. Results showed a main effect of distance $F(2.598, 77.931) = 23.176$, $p < .001$, $\eta p^2 = .436$, with a decreased use of *'this'* for further distances (Figure 2.2). Follow up analyses (LSD) showed significant differences between the first 3 positions and the other positions (for position 1 and 2 all $p<.01$; for position 3 all $p<.05$), no significant difference was found between position 3 and 4 and between the last 3 positions. No effect of hand ($p=.70$) and of gender were found (all $p>.165$), no significant interactions were found.

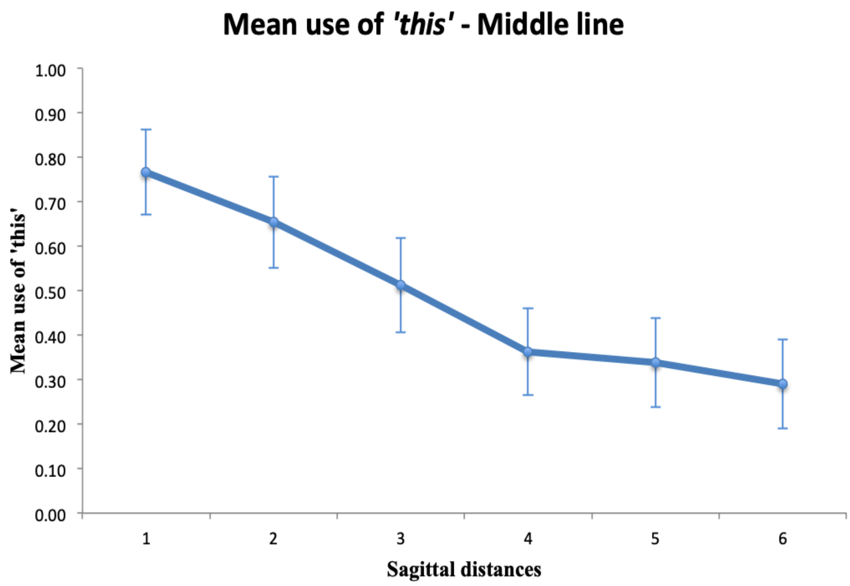


Figure 2.2 *Line graph showing the mean use of 'this' for the 6 positions in the middle line. Error bars show 95% confidence intervals.*

Secondly, a 5-way mixed ANOVA (6 distance X 2 hand X 2 lateral distance X 2 side X 2 gender) was processed.

A main effect of distance was found. The sphericity condition was violated, so Greenhouse-Geisser correction was used, $F(1.847, 55.405) = 33.747$, $p < .001$, $\eta p^2 = .529$. Follow up tests (LSD) showed significant differences between all distances (all $p < .01$, but p=.011 between distance 3 and 4), except the last two (p=.786). There was also a main effect of later distance, $F(1, 30) = 13.842$, $p = .001$, $\eta p^2 = .316$; with an increased use of *'this'* for the nearer positions toward the midline ($M_{near}= 0.45$; $M_{far}= 0.40$).

Of most interest was a significant 3-way interaction (hand X side X distance), $F(5, 150) = 3.638$, $p = .004$, $\eta p^2 = .108$ (Figure 2.3). Separate analyses were then run per sagittal distance. A significant hand x side interaction was found in the second further distance $F(1, 31)= 6.143$, p=.019, $\eta p^2 = .165$ and in the fifth farther distance $F(1, 31)= 10.781$, p=.003, $\eta p^2 = .258$. As shown in figure 2.12 in the second farther distance participants used *'this'* more when pointing with their right hand toward the right side compared to when using the right hand on the left side and vice versa. In the fifth further distance the opposite effect was found when pointing with the left hand, that is an increased use of *'this'* when pointing with the left hand toward the right side compared to when pointing toward the left side and vice versa.

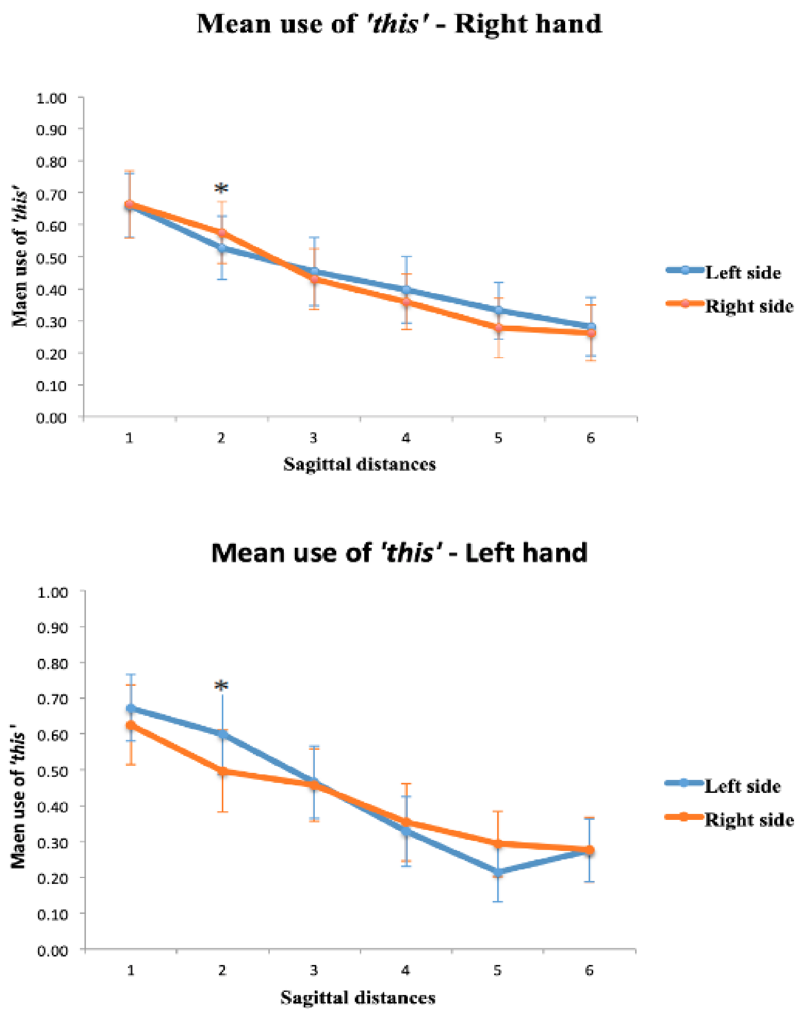


Figure 2.3 *Line graph showing the use of "this" for the 6 sagittal positions when participants pointed toward the left side and right side with their right hand (top panel) and left hand (right panel). Error bars show 95% confidence intervals.* $^{*}p < 0.05$.

No main effects of side nor hand were found. No other significant interactions were found, and gender did not affect the use of demonstratives.

2.2.3 Conclusion

Results support the mapping between language and space. The outcome of the study is consistent with previous research with a use of the proximal term mainly restricted to the PPS (Coventry et al., 2008, 2014). Most interestingly, an interaction between the hand used, the side where the object was placed and the distance was found. When the object was on the left side and the participant was pointing with their right hand we found a drop in the use of *'this'* compared to when the participant was using the right hand in the right space. A similar but contrary effect was found on the fifth farther positions. Contrary to the attentional hypothesis no effect of side was found, suggesting that pseudoneglect and the attentional shift do not influence the use of demonstratives.

2.3 Experiment 2- Use of demonstratives in the lateral space in left-handed participants

Experiment 1 showed an effect of distance and an interaction between hand and distance. This last interaction strengthened the theory of a link between space perception and language. In fact, in the second line, where the far-left position was reachable with the left hand but not with the right hand, we observed a drop in the use of *'this'* when pointing with the contralateral hand. The same behavior was found with the left hand pointing toward the far right.

However, the first study was conducted only with right-handed participants. It is possible that handedness could play a role in the use of language and in the perception of space. Usually people have a clear hand dominance and manipulating objects with the preferred is obviously easier. In our daily life we are always acting and manipulating objects and more and less complex actions (such as writing or holding a bag) are made quickly and instinctively with our preferred hand. We could, therefore, predict an increased use of *'this'* when pointing with the preferred hand.

In this second experiment we will use the same methods used for experiment 1 in a group of left-handed participants.

2.3.1. Methods

Apparatus and procedure were the same as experiment 1 with the exception that all participants tested were left-handed.

2.3.1.1 Participants

31 left-handed participants (9 males) took part. The age range was 18–30 (M= 21.32; SD=2.70). All were English native speakers receiving payment or course credit for their time. The sample has been chosen based on previous literature (Coventry et al., 2014; Gudde et al., 2016) and the sample size of experiment 1.

2.3.2. Results

The percentage of the use of *'this'* was calculated (see Table 2.2) for each of the location × pointing hand combinations. We ran two analyses, first considering the middle locations on their own, and then the outer (lateral) locations. Average use of *'this'* per position and hand are reported in table 2.2. Due to the not significant results of the 'gender effect' on right-handed participants the gender variable was not taken into account in the analyses of left-handed participants. When running the ANOVAs Greenhouse-Geisser correction will be used and reported where sphericity has not been met. Whereas, for the post-hoc test Bonferroni correction will be used and reported in text when appropriate.

Table 2.2 *Percentage use of 'this' and SD pointing with the left hand and the right hand. Each cell represents a position used to place an object. Below the table the gradient legend of the color used, where red represents a high percentage and green a low percentage of the use of 'this'.*

LEFT-HANDED										
LEFT HAND POINTING						**RIGHT HAND POINTING**				
27 (.28)	21 (.24)	29 (.26)	17 (.83)	29 (.27)		20 (.28)	26 (.25)	36 (.26)	23 (.24)	27 (.23)
22 (.28)	31 (.28)	34 (.33)	31 (.28)	29 (.25)		31 (.32)	24 (.31)	33 (.33)	32 (.32)	24 (.26)
32 (.30)	35 (.26)	37 (.29)	34 (.27)	34 (.29)		29 (.28)	43 (.29)	43 (.31)	28 (.26)	28 (.29)
35 (.28)	48 (.27)	63 (.32)	48 (.34)	51 (.30)		41 (.25)	43 (.30)	53 (.27)	48 (.33)	40 (.28)
56 (.56)	64 (.29)	69 (.27)	57 (.37)	49 (.28)		46 (.30)	62 (.33)	64 (.36)	63 (.32)	52 (.33)
65 (.29)	64 (.34)	68 (.33)	65 (.29)	60 (.28)		60 (.29)	67 (.31)	70 (.29)	61 (.29)	60 (.34)

Firstly a 2-way ANOVA (6 distance X 2 hand) was run. The assumption of sphericity for the distance variable was violated, therefore Greenhouse-Geisser correction was used. Results showed a main effect of distance $F(2.894, 86.815) = 20.942$, $p < .001$, $\eta p^2 = .411$, with a decreased use of *'this'* for farther distances (Figure 2.4). Follow up analyses (LSD) showed significant differences between the first 3 positions and the farther positions (all $p \leq .01$) and between position 4 and 6 ($p = .034$), no significant difference was found between the other positions (contrary to the previous results no significant results were found between the first 3 positions). No effect of hand was found, nor other significant interactions.

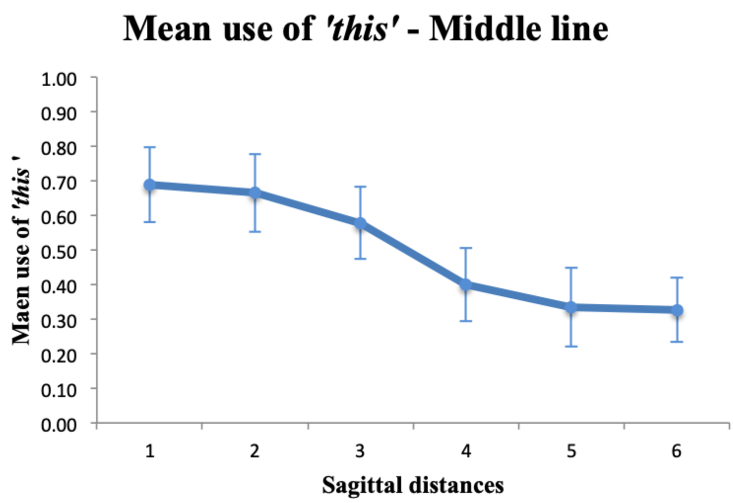


Figure 2.4 *Line graph showing the mean use of 'this' for the 6 positions in the middle line. Error bars show 95% confidence intervals.*

Secondly, a 4-way ANOVA (6 distance X 2 hand X 2 lateral distance X 2 side) was processed.

A main effect of distance was found. The sphericity condition was violated, so Greenhouse-Geisser correction was used, results showed a main effect of distance $F(1.690, 30.00) = 27.607$, $p< .001$, $\eta p^2 = .479$, with a decreased use of *'this'* for farther distances (Figure 2.9). Follow up analyses (LSD) showed significant differences between the first 3 positions and the other positions (all $p \leq .01$), a marginal significant difference was found between positions 4 and 5 (p=.051) and between positions 5 and 6 (p=.051). There was a main effect of lateral distance, $F(1, 30) = 7.595$, p=.010, $\eta p^2 = .202$; with an increased use of *'this'* for the nearer positions toward the midline.

A 2-way interaction (lateral X distance) was found, $F(5, 150) = 2.593$, p=.028, $\eta p^2 = .080$ (Figure 2.5). Post-hoc analyses were then run per sagittal distance. A significant difference was found in the second farther distance $F(1,30)$=14.771, p=.001, ηp^2= .145. After Bonferrroni correction was applied, the third farther distance (p=.031) resulted non-significant. No other significant result was found.

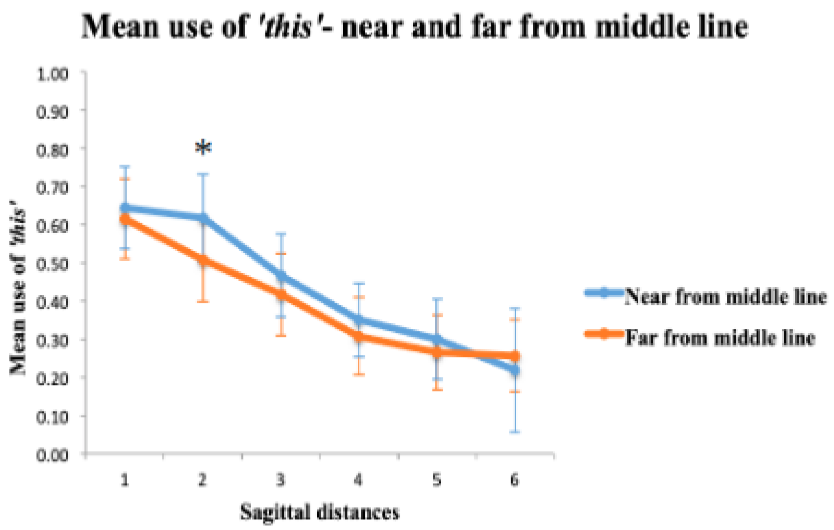


Figure 2.5 *Line graph showing the use of "this" for the 6 sagittal positions closer to the middle line and farther from the middle line. Error bars show 95% confidence intervals. *p < 0.025 (Bonferroni correction).*

Contrary to the previously found results in right-handed participants, no significant 3-way interaction between hand, lateral and sagittal position was found. However, looking at the pattern of data, the direction of effects is nevertheless consistent with the results found for right-handers. In the second farther line an increased use of *'this'* was found when pointing with the right hand toward the right side compared to the left side and vice versa. In the fifth farther line the results showed an increased use of *'this'* when pointing with the left-hand toward the right side compared to the left side, no difference was shown with the right-hand.

No main effect of side nor hand was found. No other significant interactions were found.

2.3.3. Conclusion

Results of left-handed participants replicated the main effect of distance, with an increased use of *'this'* for the peripersonal space. However, no interaction between hand, side and distance was found. The result could suggest that for left-handed participants the reachability of the object does not affect the use of demonstratives. On the other hand, an interaction between hand and lateral distance was found; post hoc tests revealed a significance for the second farther distance. Although, for a better understanding of the difference between left-handed and right-handed participants a combined analysis will be run in the next section. Results showed that the difference in the lateral space is particularly salient in the boundaries from the peripersonal space to the extrapersonal space. In fact, the use of the proximal demonstrative is significantly increased in the second farther distance, where participants can reach the closest position to the middle line, but not the farthest with the opposite hand. Contrary to the previous results no interaction between hand, side and distance was found, however the same tendency, to use demonstratives depending on the reachability of the object with the hand used was observed.

2.4 Experiment 1 & 2 -- Combined analysis

Both experiment 1 and experiment 2 showed the importance of distance for the use of demonstratives in the middle line and the left and right spaces. In both samples we observed an increase in the use of *'this'* for closer positions in the sagittal and lateral axes. Although, there were differences in the interactions found. To briefly recap the results of the previous experiments, a significant interaction between hand, side and distance was found for the right-handed group, whether an interaction between hand and lateral distance was found for the left-handed group. To better understand the difference in the results and to better understand the effect of handedness on the use of demonstratives a mixed-methods ANOVA will be run, combining the data from the two experiments.

2.4.1 Combined analysis

The percentage of the use of *'this'* was calculated (Table 2.3) for each of the location × pointing hand × handedness combinations.

Table 2.3 *Percentage of the use of 'this' and SD for right-handed and left-handed participants pointing with their preferred and dispreferred hand. Each cell represents a position used to place an object. Between the tables, the gradient legend of the color used, where red represents a high percentage and green a low percentage of the use of 'this'.*

RIGHT-HANDED										
LEFT HAND POINTING						**RIGHT HAND POINTING**				
29 (.23)	26 (.26)	29 (.25)	30 (.27)	26 (.26)		26 (.29)	30 (.24)	28 (.32)	30 (.27)	23 (.23)
23 (.24)	20 (.24)	40 (.32)	30 (.27)	28 (.27)		34 (.30)	32 (.21)	26 (.25)	30 (.29)	26 (.26)
23 (.23)	43 (.29)	35 (.28)	34 (.33)	36 (.30)		33 (.24)	46 (.35)	40 (.30)	37 (.22)	35 (.28)
41 (.27)	52 (.31)	50 (.29)	47 (27)	45 (.31)		44 (.28)	47 (.27)	52 (.32)	46 (.29)	40 (.28)
53 (.35)	66 (.30)	63 (.32)	60 (.31)	39 (.32)		50 (.28)	55 (.30)	69 (.25)	55 (.30)	60 (.26)
63 (.26)	71 (.27)	73 (.28)	63 (.28)	62 (.35)		63 (.29)	70 (.29)	80 (.27)	70 (.33)	63 (.28)

0% … 100%

LEFT-HANDED										
LEFT HAND POINTING						**RIGHT HAND POINTING**				
27 (.28)	21 (.24)	29 (.26)	17 (.83)	29 (.27)		20 (.28)	26 (.25)	36 (.26)	23 (.24)	27 (.23)
22 (.28)	31 (.28)	34 (.33)	31 (.28)	29 (.25)		31 (.32)	24 (.31)	33 (.33)	32 (.32)	24 (.26)
32 (.30)	35 (.26)	37 (.29)	34 (.27)	34 (.29)		29 (.28)	43 (.29)	43 (.31)	28 (.26)	28 (.29)
35 (.28)	48 (.27)	63 (.32)	48 (.34)	51 (.30)		41 (.25)	43 (.30)	53 (.27)	48 (.33)	40 (.28)
56 (.56)	64 (.29)	69 (.27)	57 (.37)	49 (.28)		46 (.30)	62 (.33)	64 (.36)	63 (.32)	52 (.33)
65 (.29)	64 (.34)	68 (.33)	65 (.29)	60 (.28)		60 (.29)	67 (.31)	70 (.29)	61 (.29)	60 (.34)

We again ran two analyses, first considering the middle locations on their own, and then the outer (lateral) locations. When running the ANOVAs Greenhouse-Geisser correction will be used and reported where sphericity has not been met. Whereas, for the post-hoc test Bonferroni correction will be used and reported in text when appropriate.

Data from the midline locations were analysed in a 6 distance × 2 pointing 2 hand × handedness ANOVA (with Greenhouse-Geisser corrections where necessary).

There was a significant main effect of distance, $F(2.880, 175.691) = 43.258$, $p < 0.00001$, $\eta p2 = 0.415$. Follow-up analyses (using LSD tests) revealed significant differences between the first two (reachable) positions (Mdist1 = 72.82, Mdist2 = 66.07) and all the others (Mdist3 = 54.43, Mdist4 = 38.69, Mdist5 = 33.13, Mdist6 = 30.56)(all $p < 0.01$). No other effects or interactions were significant (all $p > 0.16$).

Next we considered the outer lateral locations in a sagittal distance (6 distances) × lateral distance (near, far) × side (left, right) × handedness (left, right) ANOVA. Consistent with the previous sagittal distance analyses, there was a main effect of sagittal distance (Mdist1 = 64.27, Mdist2 = 55.53, Mdist3 = 44.64, Mdist4 = 34.43, Mdist5 = 28.05, Mdist6 = 25.56), $F(1.801, 109.843) = 60.779$, $p < 0.0001$, $\eta p2 = 0.499$. There was also a main effect of lateral distance, $F(1, 61) = 21.387$, $p = 0.00002$, $\eta p2 = 0.260$. *This* was used more for near locations overall ($M = 44.35$) than for far locations ($M = 39.81$) in the lateral plane. There was also a significant lateral distance × sagittal distance interaction, $F(5, 305) = 3.086$, $p = 0.010$, $\eta p2 = 0.048$; there was an effect of lateral distance for the first four locations (all $p < 0.001$) but not for the two furthest locations ($p > 0.05$).

Of most interest was a significant pointing hand × side × sagittal distance interaction, $F(5, 305) = 4.403$, $p = 0.0007$, $\eta p2 = 0.067$ (Figure 2.6). For each distance we compared possible differences between the hand used for pointing as a function of the side the object appeared on. As shown in Figure 2.6, there was no effect of pointing hand for the nearest distance or for the majority of distances clearly beyond peripersonal space (all contrasts $p > 0.05$). However, when the object appeared on the left side in location 2, *this* was used significantly more when pointing with the left hand ($M = 59.85$) compared with the right hand ($M = 53.37$) ($p = 0.012$). The opposite pattern was the case in the equivalent locations on the right side; when the object appeared on the right side in location 2, *this* was used more when pointing with the right hand ($M = 57.5$) compared with the left hand ($M = 51.38$) ($p = 0.018$). Additionally there was one other distance (location 5), but only on the left side, where *this* was used more when pointing with the right hand

($p = 0.013$). None of the other main effects or interactions were significant (all $p > 0.15$).

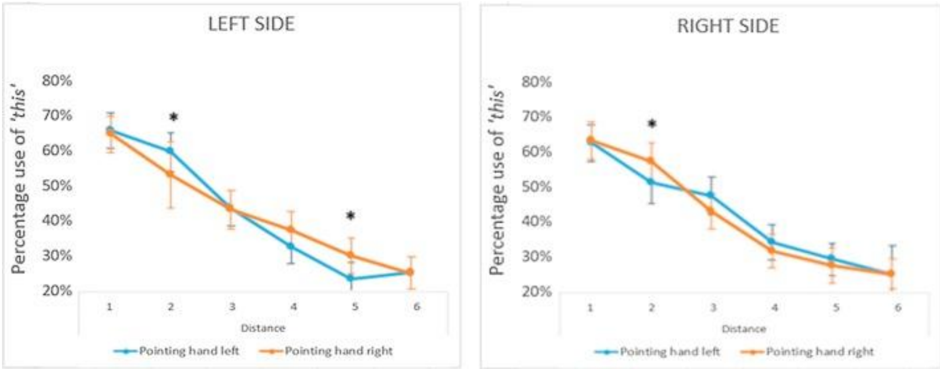


Figure 2.6 *Line graph showing the use of "this" for the 6 sagittal positions when participants pointed with their left hand and right hand on the left side (left panel) and right side (right panel). Error bars show 95% confidence intervals. *p < 0.05.*

2.4.2. Discussion

Our goals were threefold. First we set out to test the mapping between peripersonal/extrapersonal space and spatial demonstratives through manipulation of objects on both the sagittal and lateral axes. Second, we tested whether handedness might play a part in determining demonstrative choice. Third, we examined potential visual field influences on demonstrative choice.

Taking the second and third goals together, we found no evidence for the effects of handedness or visual field on demonstrative choice, save for an isolated effect of pointing hand at one location in extrapersonal space on the left side. Despite previous evidence for a mapping between left and right and visual attention on the one hand, (see for example Bergen & Lau, 2012), and handedness and language on the other (see for example Casasanto, 2011), limited evidence for the predicted mappings materialised in our data (see also Griffiths, Bester, & Coventry, 2019). It is possible that contrastive use of demonstratives would reveal a different pattern, especially with respect to visual attention (with *this* used before *that* in the contrastive pair). Moreover, the use of other paradigms might be more sensitive to such manipulations, for example, one can ask if people are more likely to gesture with their preferred hand when using *this*, consistent with the previous data for valence in the analyses of gesture (e.g. Casasanto & Jasmin, 2010).

In contrast, the results strongly support the mapping between perceptual space and demonstrative choice. Consistent with previous studies (e,g, Coventry et al., 2008, Coventry et al., 2014), '*this'* is used more in PPS in the sagittal plane, with reliable differences between reachable and non-reachable locations. In addition, the experiment has produced two new findings that strengthen the evidence for the mapping. First, *this* is used more in near lateral positions compared to far lateral positions, showing the effects of distance do not only operate on the sagittal plane. Second – and most compellingly – the use of the proximal term in the same locations is affected by the hand used to point at those locations, and critically whether the object is within or outside of reachable distance.

Overall the results offer the strongest evidence yet for a mapping between spatial demonstratives and PPS. However, some remarks are in order. It is also the case that a range of other parameters affect demonstrative use, and among these the position of a hearer and the setting in which language occurs seem paramount. Far from negating the importance of perceptual space for demonstrative use, the very flexible nature of PPS may help to explain these and other findings. For example, it has been established that the size of PPS is modulated by social interaction. Specifically, Teneggi, Canzonieri, di Pellegrino, and Serino (2013) found that the PPS representation is contracted when a participant is faced by someone else, and is expanded when working collaboratively in a space with a partner. Notions of shared space in the linguistic literature on demonstratives may be enriched with consideration of how the perceptual system processes space as a function of social interaction. It remains to be tested whether changes in PPS provides the mechanism by which more interactive factors affect demonstrative choice in context.

2.5. Experiment 3- The effect of tool use on demonstratives production in right-handed participants

Experiments 1 & 2 showed a mapping between language and space. The combined analyses between experiment 1 and experiment 2 showed the importance of reaching for the use of demonstratives, regardless of the handedness of the participant or the side where the object was placed. Tool use has been shown to extend the peripersonal space and therefore to extend the use of demonstratives farther (Coventry et al., 2008). In this experiment we tested the use of a tool in the lateral space and the hand used to manipulate the tool. If the use of a tool can extend the peripersonal space and if the use of *'this'* decreases when an object is placed increasingly further away in the lateral space, pointing with a stick should extend the peripersonal space of the participants, producing an increased use of *'this'* for the farther positions (not reachable with the hand) in the sagittal and lateral planes. Previous results showed an increased use of *'that'* as we go farther in the lateral space, we would, therefore, expect an effect of tool use in both the sagittal and lateral space. In the previous experiments, no main effect of handedness was found, and the effect of the hand used was only relevant based on the reachability of the object. Hence, in this experiment we only considered right-handed participants. As we said before, the use of *'this'* decreased when pointing with the right hand in the left space in the reachable position and vice versa. However, tool use requires finer hand abilities than mere pointing gestures. Therefore, we should expect a drop in the use of *'this'* when participants are pointing with their left hand (dispreferred hand). The same setting was used, however, less positions were tested. First of all the first farther distance is very close to the participant and using a tool to point at the object might be difficult and unnatural, in fact the distance between the first distance and the participant is much shorter than the tool length. Second, we tested only the farther lateral lines (on the left and right side).

2.5.1 Methods

2.5.1.1Participants

32 right-handed participants (10 males) took part. The age range was 18–26 (M=20.15; SD=1.76). All were English native speakers receiving payment or course credit for their time. The sample has been chosen based on previous literature (Coventry et al., 2014; Gudde et al., 2016) and the sample size of experiment 1 and 2.

2.5.1.2 Apparatus and procedure

The same setting of experiment 1 and 2 was used. However, fewer positions were tested. The first line (nearest participants) was not tested as it would have not been comfortable for the participant to point so close with a stick. Regarding the lateral positions, only the far-left and far-right lines were tested.

Instructions were similar to experiment 1 and 2, but this time participants were pointing with a 45 cm stick for half of the trials. A semi-randomized block design was used. All participants took part in all four conditions and the results were analysed within participants. The conditions were: 1) pointing with the right hand; 2) pointing with the left hand;3) pointing with the right hand using a stick; 4) pointing with the left hand using a stick. Between participants analyses were run to analyse order effect, indeed half of the participants were starting the study pointing with their hand (the right and the left hand) and half of them were using the tool first (with the left and right hand).

2.5.2 Results

The percentage of the use of *'this'* was calculated for each of the locations for group 1 (see Table 2.4) and group 2 (see Table 2.5). We ran two analyses, first considering the middle locations on their own, and then the outer (lateral) locations. Two groups were included in the analyses; the first group includes the participants that took part in the hand pointing condition first, group 2 includes the participants that took part in the tool use condition first. When running the ANOVAs Greenhouse-Geisser correction will be used and reported where sphericity has not been met. Whereas, for the post-hoc test Bonferroni correction will be used and reported in text when appropriate.

Table 2.4 *Percentage use of 'this' for group 1 (hand condition first). Each cell represents a position used to place an object. First the results for hand use are reposted, then the results for stick use are reported. The cells are color coded, where red represents a high percentage and green a low percentage of the use of 'this'.*

Group 1						
Hand						
Left				**Right**		
23% (.36)	12% (.21)	25% (.29)		25% (.26)	12% (.21)	21% (.27)
25% (.29)	29% (.32)	23% (.27)		19% (.21)	23% (.23)	21% (.32)
33% (.39)	25% (.26)	31% (.31)		29% (.30)	38% (.32)	31% (.29)
42% (.33)	52% (.24)	33% (.34)		42% (.33)	56% (.38)	27% (.33)
54% (.27)	61% (.33)	44% (.29)		54% (.32)	73% (.33)	58% (.40)
Stick						
Left				**Right**		
15% (.21)	23% (.32)	15% (.21)		19% (.24)	12% (.21)	8% (.15)
29% (.36)	27% (.35)	35% (.31)		19% (.27)	37% (.34)	19% (.24)
25% (.29)	38% (.36)	35% (.29)		23% (.29)	33% (.27)	23% (.23)
40% (.37)	58% (.38)	42% (.36)		38% (.38)	65% (.39)	54% (.38)

Table 2.5 *Percentage use of 'this' for group 2 (tool condition first). Each cell represents a position used to place an object. First the results for stick use are reposted, then the results for hand use are reported. The cells are color coded, where red represents a high percentage and green a low percentage of the use of 'this'.*

Group 2						
Stick						
Left				Right		
42% (.40)	40% (.33)	17% (.24)		27% (.37)	33% (.30)	19% (.32)
37% (.34)	40% (.35)	25% (.26)		27% (.33)	38% (.40)	25% (.29)
42% (.26)	54% (.30)	37% (.24)		29% (.27)	46% (.34)	52% (.30)
52% (.24)	69% (.38)	38% (.32)		50% (.30)	71% (.32)	50% (.30)
62% (.34)	81% (.27)	48% (.37)		50% (.40)	73% (.30)	67% (.32)
Hand						
Left				Right		
15% (.40)	25% (.40)	25% (.40)		25% (.38)	37% (.36)	29% (.38)
27% (.40)	31% (.40)	17% (.40)		25% (.38)	42% (.43)	37% (.34)
48% (.40)	40% (.40)	38% (.40)		33% (.40)	44% (.42)	46% (.36)
69% (.40)	71% (.40)	54% (.40)		61% (.41)	56% (.40)	63% (.40)
73% (.40)	71% (.40)	58% (.40)		58% (.36)	83% (.30)	69% (.38)

Firstly a 3-way ANOVA (5 distance X 2 hand & tool use X 2 groups) was run for the middle line in the sagittal plane. The assumption of sphericity for the distance variable was violated, therefore Greenhouse-Geisser correction was used. Results showed a main effect of distance $F(2.180, 65.411) = 40.082$, $p < .001$, $\eta p^2 =$

.572, with a decreased use of *'this'* for further distances (Figure 2.7). Follow up analyses (LSD) showed significant differences between the first 2 positions and the other positions (all p<.01) (reachable positions with the hand), no significant difference was found between positions 3 and 4 (p=.086), between positions 3 and 5 a significant difference was found (p=.001), and between positions 4 and 5 (p=.012). A marginally significant main effect of tool use was also found F(1, 30)=4.260, p=.048, ηp^2 = .124, with an increased use of *'this'* when participants were pointing with the stick. No significant interactions were found and no effect of the hand used nor of the group was found.

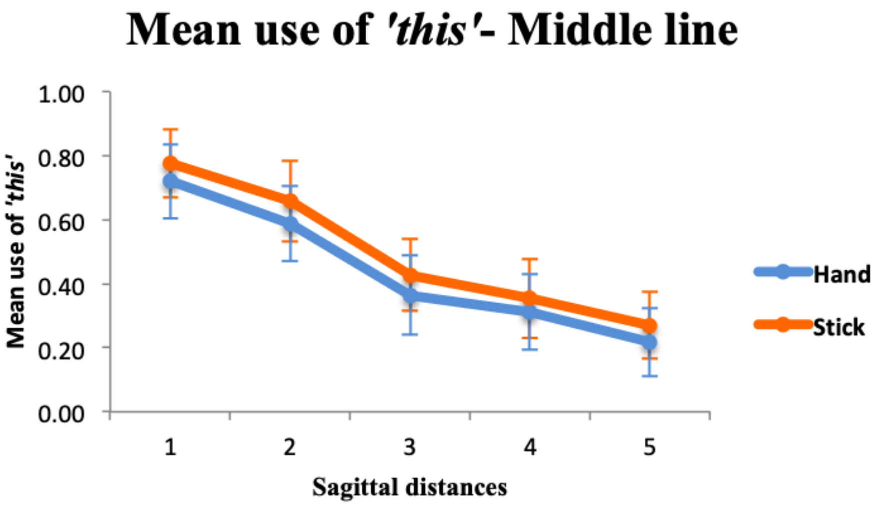


Figure 2.7 *Line graph showing the mean use of 'this' for the 6 positions in the middle line when pointing with the hand or the tool. Error bars show 95% confidence intervals.*

Secondly the percentage use of *'this'* for the lateral positions was analysed. The assumption of sphericity for the distance variable was violated, therefore Greenhouse-Geisser correction was used. Results showed a main effect of distance F(1.875, 56.259)= 26.799, p< .001, ηp^2 = .472 , with a decreased use of *'this'* for further distances. Follow up analyses (LSD) showed significant differences between the first 3 positions and the other positions (all p<.05), no significant difference was found between positions 4 and 5 (p=.109). No other significant main effects were found. A significant interaction was found between the hand used and the side where the object was placed $F(1, 30)= 7.960$, $p= .008$, $\eta p^2= .210$. *'This'* was used more when pointing with the right hand toward the right side compared to when pointing to the left side toward the right side and vice versa.

There were several interactions involving the group variable (i.e. the order in which participants completed the stick/no stick conditions). A significant interaction between hand used, side and group was found, $F(1, 30)= 7.237$, $p= .012$, $\eta p^2 = .194$ (Figure 2.8). *'This'* was used more when pointing with the right hand toward the right side compared to when pointing to the left side toward the right side and vice versa in the second group. This effect was not present in group 1. A significant interaction between the tool use condition, the sagittal position and the group was found, $F(4, 120)= 3.429$, $p= .011$, ηp^2=.103. Follow up analysis revealed a significant difference (p=.028) in the first position with a higher use of *'this'* when pointing with the stick compared to when pointing with the hand in the first group, the opposite effect was found in the second group (increased use of *'this'* when pointing with the hand). For the second position a significant interaction was found (p=.018) with an increased use of *'this'* when pointing with the tool for the first group compared to when pointing with the hand, the opposite effect was found in the second group. An increased use of *'this'* was found in the second group compared to the first group. No significant difference was found for positions 3, 4 and 5.

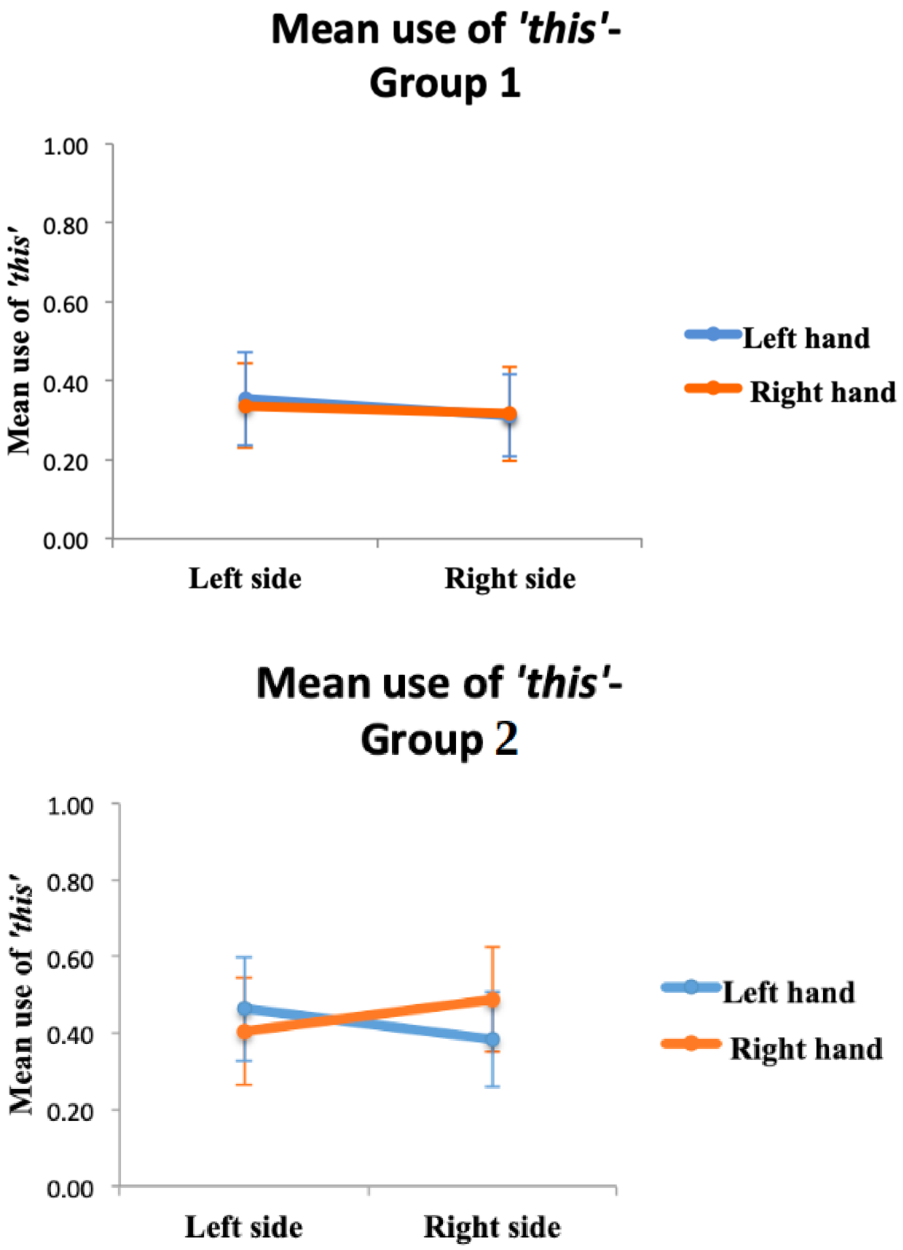


Figure 2.8 *Line graph showing the mean use of 'this' for the left and the right side when using the left and the right hand in group 1 (hand first) and group 2 (stick first). Error bars show 95% confidence intervals.*

2.5.3 Conclusion

Results confirmed the previous findings of a distance-based use of demonstratives, with an increased use of *'this'* for the peripersonal space, and the effect was still present when pointing with a tool. In the middle line, we found a main effect of tool-use, however contrary to Coventry et al. (2008), no interaction between sagittal position and tool use was found, but we instead found an increased use of *'this'* across distances. In the current study participants were instructed to not touch the object with the tool, contrary to the original paper (2008) where the tool was constructed with a hook at the end, making it easy for the participants to touch the object. This might explain the different results between studies. In addition, in the current study the farther position was much closer than in the previous experiment, making it more difficult to contrast the extrapersonal space with the peripersonal space during tool use, as the last position could have been reached by participants with a tool if they stood up and stretched across the table. The choice of placing the farther distances closer to the participant, compared to the previous experiments, was due to the fact that we needed to keep the distances closer in a way that they were reachable with one hand, but not with the opposite hand and we wanted the sagittal positions to be equally distant (except for the first line) so that there was no clear distinction between peripersonal and extrapersonal space. In addition, the current study included 240 stimuli for a total duration of 60 minutes of testing and it would not have been possible to add more stimuli in the same session. Lastly, no effect of the tool was found in the lateral positions. That might be explained by the gesture being unnatural; it is not easy and natural to use a tool in the lateral space. However, a significant interaction between tool use condition, sagittal position and the group was found. The effect of tool use was present in the first two positions (the reachable positions) and a difference between groups was found as well. It could be possible that in the second group, the group that pointed with the tool first, the fact that the object could be reached and picked up with the hand, became more salient and resulted in an increased use of the proximal demonstrative. In particular, a significant interaction between hand and side was found, showing a decreased use of *'this'* when pointing with the right hand toward the right side and vice versa, proving it to be easier to point with the hand and tool toward the side corresponding to the hand used.

This experiment provides evidence once again for a link between perceptual space and demonstrative use and that the boundary of peripersonal space can be extended by using a tool.

2.6. General discussion

In a series of three studies, we tried to further test the mapping between language and space. Lateral space and the hand used to point at the objects were manipulated to test whether people use demonstratives in a different way when the object cannot be reached with the hand they are using to point. Second, we tested whether handedness has an effect on the use of demonstratives. Third, the use of a tool was tested.

The set of three experiments add support to the theory of the use of demonstratives based on a division between peripersonal and extrapersonal space. In particular the first experiment and the combined analyses between experiment 1 and 2 showed the importance of the reaching distance for the use of demonstratives.

No evidence of a main effect of side, and therefore of attention was found in experiment 1 and 2; in addition, no effect of handedness was found. This reveals that the handedness of the person is not important for the use of demonstratives. This result contradicts the findings of Casasanto (2011) who found a link between actions and language depending on the handedness of the participants. However, participants were asked to point at the object and not to manipulate it nor to use it. Therefore, the pointing gesture might not be strong enough to produce an effect of handedness as no manipulation is involved in the pointing gesture. Further research can be conducted integrating the *'memory game'* paradigm with new technology such as motion tracking. With a motion tracking system we might be able to find differences in the pointing movement when using the preferred or dispreferred hand, and as a result, an effect of handedness. In addition, the participants were instructed to point with their right or left hand, and therefore a natural use of the preferred/dispreferred hand was not tested: results could be different and an effect of handedness may be found when participants are instinctively pointing with their preferred hand. Future studies would do well to explore these possibilities.

Both experiments 1 and 2, showed a main effect of distance, not only on the sagittal plane, but also on the lateral space. Consistent with previous literature *'this'* was used more for the near space compared to the far space supporting the theory of a mapping between perceptual space and demonstratives use. These two experiments added new findings to the literature, showing that the distance effect can be extended to the lateral space with an increased use of *'this'* for the line closer to the middle line compared to the line farther away from the middle line.

More interestingly in experiment 1 a significant higher use of *'this'* was found when participants were pointing with their right hand toward the left side compared to when participant were pointing with their right hand toward the right space (and vice versa) in the second farther positions where the far left position was not reachable with the right hand and vice versa (a finding that remained in the combined analyses of Experiments 1 and 2). Another significant difference was found in the fifth farther positions (extrapersonal space) when participants were pointing with their right toward the left, where we observed an increased use of *'this'*. No other significant differences were found in any other location. It is difficult to give a convincing explanation for this latter result as it is an isolated location, but previous research has demonstrated an increased use of *'this'* for the left space in the extrapersonal space (Griffiths et al., 2019).

With regards to experiment 2 similar results to the right-hand study were found. A main effect of distance in the sagittal and later space was found comparable to experiment 1. The only difference found was that no three-way interaction between side, hand and distance was present, however a two-way interaction between lateral and sagittal distance was found, with an increased use of the proximal demonstrative for the nearer position to the middle line compared to the farther position. The fact that no effect of hand was found might be explained with the hand used being less salient for the left-handed participants, as left-handed are usually more used to using both hands to perform actions as the majority of the objects in the real world are constructed to be used with the right-hand. In addition, the combined analysis between experiment 1 and experiment 2 replicated the results found in experiment 1 with a main effect of sagittal and lateral distance and a significant three-way interaction between hand, side and distance in the same direction previously reported.

The last experiment showed a main effect of distance in the middle line and a main effect of tool use, with an increased use of *'this'* when the tool was used. Contrary to previous literature (Coventry et al., 2008) an interaction between tool use and distance was not found. Nevertheless, the method used was different from the previous study. The main difference was that the table used was much shorter in the current study, and consequently, the number of positions used was different between studies. In fact, in the previous study 12 positions were used and in the current experiment only 6 positions were used. Also, looking at the results of Coventry and colleagues (2008) we can see that an extension of *'this'* could be found up to the position number 7. Therefore, we cannot compare the two results as it could be possible that the table was not long enough to produce an effect for the tool use based on the distance. Participants were instructed to point at the object without actually touching it, in the previous study the stick was constructed with a hook at the end making it easy for the participant to touch the object when pointing at it. Although participants were not instructed to touch the object, they were primed to do so due to the characteristics of the tool. Touching the object might create a continuity between the participant and the object, increasing the use of *'this'*, in addition it is clearer to understand if an object is reachable when a contact is made, making it easier to separate the reachable positions from the non-reachable ones. Thus, we can conclude that for the middle line the tool use is increasing the use of the proximal demonstrative, but the method used is not strong enough to prove that an extension of the peripersonal space is present. Analysis of the lateral space showed a main effect of distance consistent with the findings of experiment 1 and experiment 2. No main effect of tool use was found, this result could be explained by the positions being too close and not having enough room to extend the peripersonal space in the lateral space. More positions in the lateral space and the sagittal space could be used to better test the tool use and the effect of the extension of the peripersonal space in the sagittal and lateral plane. More interestingly, a significant interaction has been found, between hand and side. '*This'* was used more when pointing with the right hand toward the right side compared to when pointing with the left hand toward the right side and vice versa. Pointing toward the right side with the left hand and vice versa, in addition using a tool for half of the time can be seen as unnatural and result in an increased use of *'that'*, this result was not found in the previous experiments.

In conclusion, this chapter adds new and compelling findings to the literature, showing strong evidence of a mapping between the peripersonal space and the use of demonstratives, showing that an effect of distance is present also in the lateral space and that reaching distance has a role in the choice of the demonstrative on both planes. The last experiment showed that tool use can have an effect in increasing the use of the proximal demonstrative in the sagittal plane. No effect of handedness and side have been found, but more research is needed in the use of language and object manipulation in left-handed and right-handed participants and the differences between the pointing gesture in the two groups.

In the next chapter we will investigate the use of demonstratives for 3D objects and 2D images and the effect of the use of demonstratives for 2D images of objects and the link between language and affordances.

Chapter 3

Use of demonstratives for 2D images and 3D objects

3.1 Introduction

In chapter 2, we explored the effect of handedness and the hand used to point on the use of demonstratives in lateral space. Using a modified version of the *'memory game'* task devised by Coventry and colleagues (2008), we tested the use of demonstratives in lateral space in right-handed and left-handed participants pointing with their preferred and dispreferred hand. The results show, for the first time, the importance of the hand used to point on the choice of demonstratives to describe object location as a function of whether the object is reachable or not. For example, the use of *'this'* decreases when pointing with the right hand to an object located on the participant's far left compared to pointing with the left hand to the object at the same location even when the object is in the near space. No effects of handedness were found as well as no main effect of the hand used to point (i.e. pointing with one's preferred or dispreferred hand). This work demonstrates that object reachability is an important factor in demonstrative choice. Building on this finding, in the current chapter we will explore the use of demonstratives for 3D objects (manipulable) and 2D images (not manipulable) of those same objects to see if object manipulability/affordance affects the use of demonstratives to describe the locations of those objects.

Irrespective of the side on which an object is placed, or which hand is used (preferred or dispreferred hand), object reachability and distance are important factors in the use of demonstratives (Caldano & Coventry, 2019; Coventry et al., 2008); but other additional variables also affect the choice of demonstratives. For example, Coventry et al. (2014), tested whether various object properties affected both demonstrative choice and object-location memory, and the results of their studies showed an increase in the use of *this* for owned objects, for visible objects and for familiar shapes (compared to not owned, occluded and unfamiliar objects). Not only did these variables influence language, but they also affected memory for where those objects were placed. Objects that were not owned by participants, were unfamiliar, or were occluded were misremembered as further away than they actually were compared to objects they owned, were familiar, or were visible.

One property that has as yet not been considered is whether an object is a *'real'* object that can be manipulated, or whether that object is merely an image. In this contest, we consider an object 'manipulable' when this object can be held in the participants' hand. Nowadays we spend a lot of our time in front of a PC screen and we deal with images of objects all the time, but our vision system did not evolve to see images of objects, but rather real objects. Many research studies now take place on a screen assuming that the image of an object is perceived in the same way as a 3D object, but little is known about the difference in the visual perception of 3D objects compared to 2D images. Humans are equipped with two eyes placed frontally, with each eye sending a slightly different image to the brain and this binocular disparity is the basis of depth perception (Purves et al., 2009) (Figure 3.1).

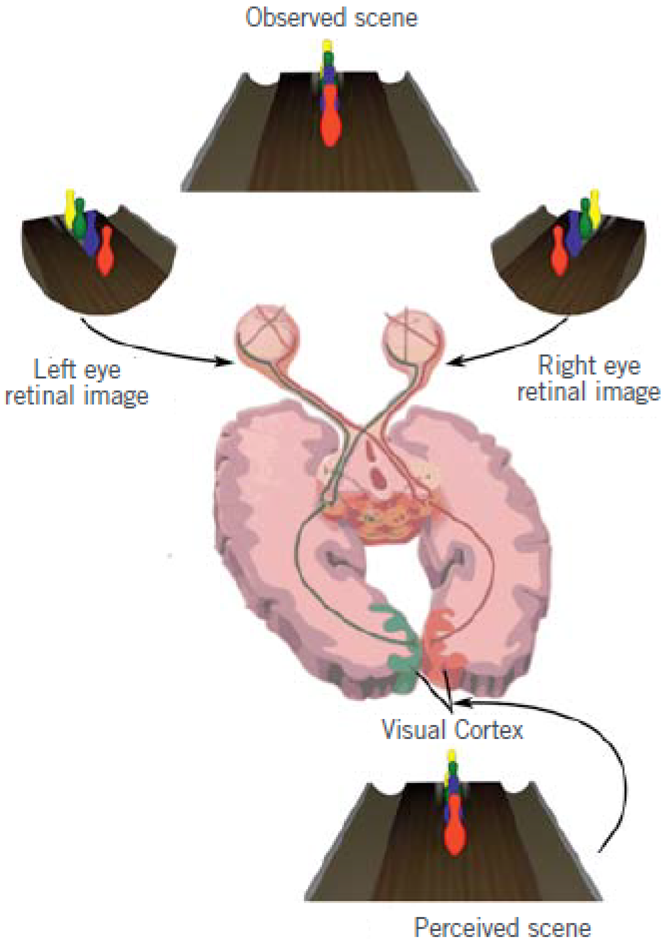


Figure 3.1 *Figure taken from De Rossi et al. (2013). The image illustrates the observed scene and the slightly different image projected to each eye, followed by the path the image follows in our brain to arrive in the visual cortex to be integrated to give the perceived 'single' image.*

As reviewed earlier in the thesis, perception comes through two different pathways: *'what-pathway'* (ventral) and the *'where-pathway'* (dorsal)(Ungerleider and Mishkin, 1982) (Figure 3.2). The first pathway is dedicated to object recognition. The second pathway processes spatial information. The *'what-pathway'* runs dorsally into the inferior temporal lobe. In contrast, the *'where-pathway'* proceeds dorsally through the posterior parietal lobe. In stroke patients, depending on the injured area it is possible to observe disorders in object recognition (visual agnosia), or in object spatial processing (unilateral neglect, optic ataxia) (Ungerleider and Mishkin, 1982; Deubel et al., 1998). However, the difference between the two pathways is not so neat; the ventral path does not work alone in object recognition, but it integrates with the ventral path and the basic features of an object (such as shape and size) are represented in a similar way in the two pathways (Konen & Kastner, 2008).

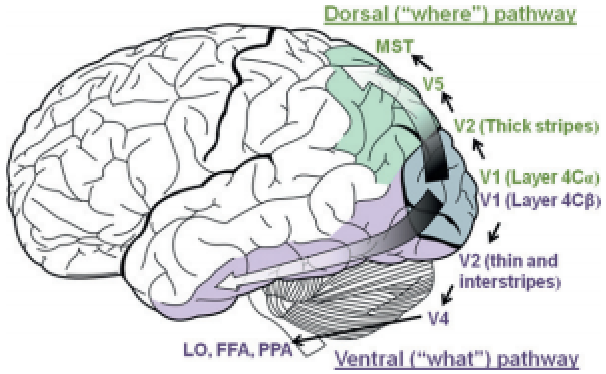


Figure 3.2. *A schematic representation of the 'what' and 'where' pathways. The dorsal pathway connects the occipital areas (V1,V2) to the medial superior temporal area (MST), the ventral path connect the occipital areas to the lateral occipital (LO), the fusiform face area (FFA) and the parahippocampal place area (PPA) (Prasad & Galletta, 2011).*

3D features can be extrapolated also from 2D images. In fact, we can transform a 2D image into a 3D image applying different features to it, such as shadows, perspective, symmetry and surface texture (Vishwanath & Kowler, 2004). Those features are important cues for object recognition; there is evidence of loss in the ability of line drawing recognition in patients with agnosia due to a stroke. Hiraoka and colleagues (2009) described the case of an agnosic patient who was not able to recognise line drawings of objects and silhouettes, but the ability to recognise the real object or a (photographic) picture of it was preserved. Due to the different brain regions involved in object recognition (2D Vs 3D) we can also assume that a healthy brain will elaborate the two objects in a different way.

Infants show a strong preference for real objects compared to pictures (Gerhard et al., 2016). Gerhard's study was divided into a habituation phase and a test phase. During the habituation phase, infants (from 7-to-9 months old) were exposed to different toys in different formats (real objects or pictures) (Figure 3.3) and the experimenter calculated the fixation time to study the difference in the habituation between the real object condition and the picture condition. This stage was followed by the test phase; during the test phase two objects were presented to the babies to test their visual recognition memory, one novel stimulus and one of the objects (real objects or pictures) used during the habituation stage. In contrast with previous literature (e.g., Ruff et al., 1976), the same objects were presented in a different format (real object vs. the picture of the object). Also, at this stage the fixation times were acquired. Results showed that during the first phase infants spent more time looking at real objects compared to pictures. In addition, they habituated faster to real objects. Lastly, during the test condition (when the real object and the picture were both present at the same time) they preferred to look at the real object.

Figure 3.3. *Stimuli used by Gerhard et al. (2016). On the left the real object, on the right the matched photograph.*

A similar tendency has also been shown in adults; Bushong et al., 2010 studied the willingness to pay for real vs. pictures of food. Three tasks were performed by each participant: a liking-rating task, a familiarity-rating task and a bidding task. Each participant received an allocation of $3 to use during the test to purchase food. On each trial participants were bidding for the food; stimuli were the name of the food, an image of the food or the real food (a between-subjects design was used). At the end of the experiment an urn was used to randomly extract one trial and the bid of the participant determined if they were getting the food or not. Results showed that the average bid for the text or the image of the food were quite similar and they were both significantly smaller compared to the real food condition. However, this effect disappeared when a plexiglass barrier was inserted between the participant and the object, suggesting that the effect is due to accessibility and graspability of the object and not to 3D features per se. Similarly Romero et al. (2018) found higher willingness-to-pay for real food compared to images. With a wallet of $3, participants were bidding on well-known snack images or real food. The food was presented on a turn-table in front of the participant. For the image condition the stimuli were created by taking images of the real food on the turntable. The stimuli were then presented on a screen that the experimenter was sliding in front of the participant each trial, and the same setting was used for both conditions (Figure 3.4). Participants were asked to not have any food for 3 hours before the experiment, and on each trial they had to rate the familiarity and how much they liked the product shown. Then the bidding task started: the real food or the image of it was shown; after that, they had to indicate how much they would bid for it; lastly, they were shown if their bid was higher than the computer bid and therefore if they won the food. Results showed that the participants were willing to pay more for the real food compared to the 2D image.

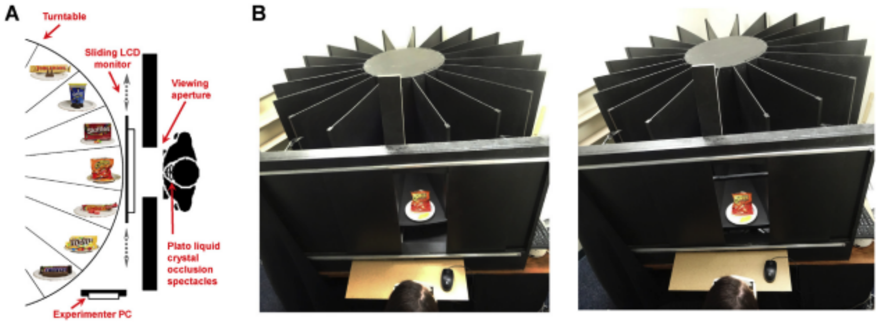


Figure 3.4. *The setting used by Romero et al., 2018. A) A schematic draw of the setting. 60 different snacks were placed on the turntable, half of the dime they were presented as real objects, for the other half the experimenter was sliding a screen with the picture of the object in front of the participant. B) The left panel shows the real food, the right panel the image on the screen.*

The biggest difference between a 2D image and a 3D object is the graspability of the object. Neurons that respond selectively for the perception of 3D objects have been located in the monkey brain in the inferior temporal cortex (IT) (Verhoef et al., 2010), in the anterior intraparietal area (AIP) (Janssen et al., 2000; Sakata et al, 1999) and in the lateral intraparietal area (Janssen et al., 2018). Sakata et al. (1999) showed that the AIP fulfills an essential role in the adjustment of the handgrip for the grasping of 3D objects. Differences in attention for 2D and 3D stimuli were also found by Gomez and colleagues (2017), with slower reaction times for 3D objects and greater flanker interference effects compared to 2D objects, but only in the near space; no differences were found in the far space. This study proves not only that we elaborate differently 2D images and 3D objects, but the difference becomes more salient when they are in the peripersonal space (Gomez et al., 2017). Object-selective neurons have been recognised in the Lateral Occipital Complex (LOC), ventral occipito-temporal regions and the intraparietal sulcus (Grill-Spector & Malach, 2004). LOC is activated by both familiar and unfamiliar objects, but not for non-objects (e.g. scrambled lines drawings) (see Grill-Spector & Malach, 2004).

Snow et al. (2014) found better performance in recall and recognition of real objects compared to coloured pictures or line drawings. Snow et al. (2011) studied brain activation during the viewing of 3D objects and 2D images. Participants were laying in the MRI scanner and objects were placed in front of the participant (see Figure 3.5). Results showed strong repetition-related changes in the BOLD response when the 2D objects were presented, but the same changes were weak in the 3D condition. Contrary to the hypotheses no changes in the BOLD responses in the LOC area (the LOC area is involved in shape processing) were found for the 3D objects manipulation. Interestingly, no difference in activation was found in eye-movement and attention-related areas in the two conditions. The increased activity in the LOC area for the 2D pictures is explained by the authors with the additional processing necessary to recognise 2D pictures compared to 3D objects.

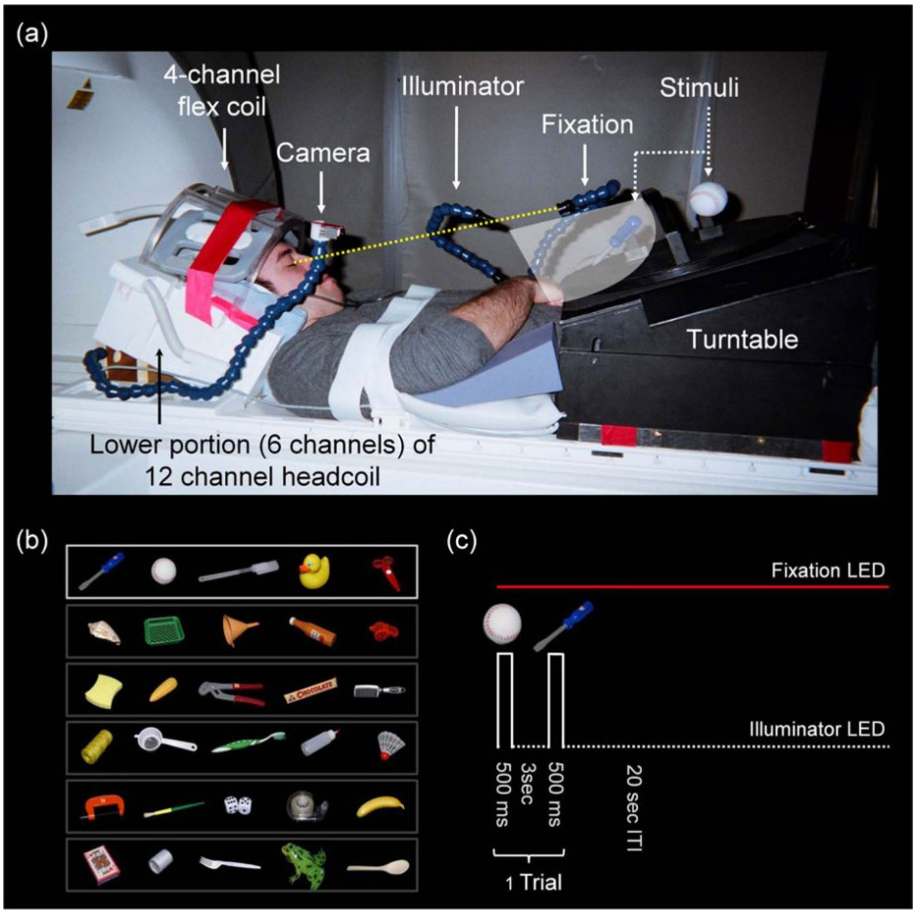


Figure 3.5 *A) The setting used by Snow et al., (2011) showing the participant in the scanner seeing the stimuli. B) The stimuli used by Snow et al., (2011) c) The trial sequence used by Snow et al., (2011) each stimulus was presented for 500ms within a 3sec inter-stimulus interval.*

Object perception is not only related to memory, but also to language use. Bara and Kaminski (2019) showed that the learning of foreign vocabulary is facilitated with real objects; they taught new words associating the word to a real object or to a picture of it, and found facilitation in the recalling of the word associated to the real object compared to the image of it (Bara & Kaminski, 2019). Not only is there a difference between real objects and images, but also between images with different degrees of realism. Saryazdi and Chambers (2018) studied the mapping between language and depictions of objects (Figure 3.6) with different gradients of realism. Participants heard a recorded sentence with a neutral noun and verb (e.g. *Sam will move the cigarette*) while 4 pictures (a cigarette, a banana, an earring and an apple) were presented, and they had to click on the object named in the sentence they heard. Results of the first experiment showed that the fixation times were shorter for the photograph condition compared to the clipart condition, with an increased consideration of the target in both conditions, after it was named, and the tendency to identify the target quicker in the clipart condition. In a second experiment, they varied also the verb, which was compatible only with two images out of four (e.g. *Jamie will peel the banana,* the verb *'peel'* is narrowing down the target to two possibilities: the apple or the banana). Fixation increased for the restrictive verb (can refer to all four objects) compared to the non-restrictive verb (can refer only to two objects), but no effect of image type was found. This study shows some evidence for an effect of language on visual processing, but no effect was found in the verb-driven condition. We can argue that both conditions were shown as images and maybe the 'verb-effect' could be found showing a 3D real object instead of a picture of it.

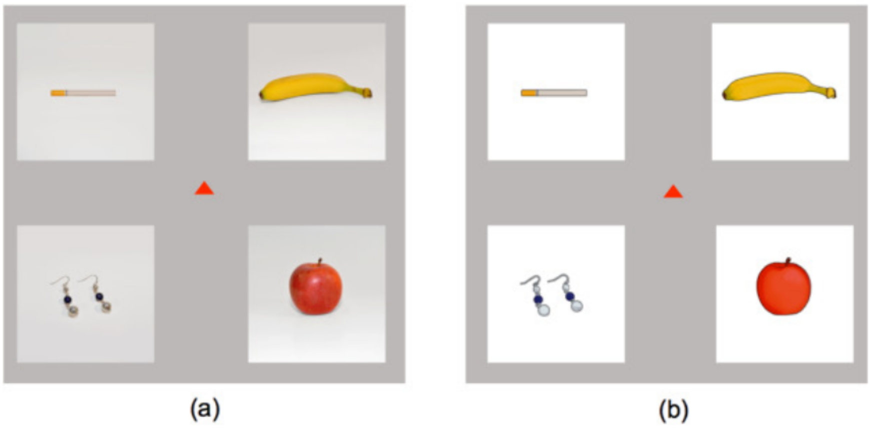


Figure 3.6 *a) Example of the photographs used by Saryazdi and Chambers (2018) b) Example of the clipart images used by Saryazdi and Chambers (2018).*

In summary, so far, the literature previously reviewed identified differences in the processing of 2D images and 3D objects. However, no clear connection between the differences in the use of language for real objects or virtual images has been found. In two experiments we will try to better understand the use of demonstratives for 2D images and 3D objects. The *'memory game'* paradigm will again be used to elicit the production of demonstratives; a large touchscreen table will be used to show the 2D images and to place the 3D objects.

In a second experiment we will explore the use of demonstratives for pictures of real objects. The aim of the study is to investigate the use of demonstratives depending on the nature of the object. Graspable objects (e.g. a mug) and not graspable objects (e.g. a cactus will be used). We define graspable objects as objects that are harmless to grasp, and as not graspable, objects that cannot be grasped because they could harm the participant if grasped. In this study we will use a mug and a glass as graspable objects and a cactus as a dangerous/not graspable object. In the previous experiments (Experiment 1,2, and 3) and in the literature (Caldano & Coventry, 2019; Coventry et al., 2014; Coventry et al., 2008; Gudde et al., 2016) geometric shapes were used, therefore a shape will be used (a star in this case) to make sure there is no difference in the use of demonstratives between geometric shapes and real objects that hold a function. Perception and action are strictly connected, when we see an object we also perceive how we can interact with the object (Garbarini and Adenzato, 2004;). For example, when we see a mug we think that we can reach for it, hold it and drink from it. Although, when we see a geometric shape, like for example a start, the object does not hold any function and therefore the object does not trigger any action. Thus, it is necessary to compare the use of demonstratives for artifacts and shapes, as we could expect that a participant can be facilitated in the use of demonstratives when an object holds a function.

3.2 Experiment 4 - use of demonstratives for images and real objects

The main goal of this experiment is to investigate the use of demonstratives for 2D images and 3D objects. Based on the literature previously reviewed it is clear that there are differences in the perception of 2D images and 3D objects and some cognitive processes are sensitive to the degree of realism, but it is not clear how the differences are processed and what is the influence of 2D images and 3D objects perception on language. Building on these findings, we next test whether the use of demonstratives is different for 3D objects compared to 2D images of those same objects. Recalling previous literature on the perception of 2D and 3D objects, we would expect to find a difference in the use of demonstratives in the peripersonal space (reachable), but no difference in the extrapersonal space (non-reachable).

Almost all past studies using the *'memory game'* paradigm have used real objects, (usually plastic disks printed with coloured shapes). One exception is a series of studies using the *'memory game'* paradigm in a virtual reality environment, therefore using virtual objects (created similar to the objects used in the previous experiments) (Griffiths et al., 2019). However, as the world 'reality' suggests, the objects presented in the virtual reality environment have different features than the images of objects appearing on a screen. First of all, in the virtual reality environment, although the entire setting is made in 2D, the different images sent to each eye gives the impression of 3D, and it is possible to interact with the objects using a virtual reality glove. So although the objects were not 'real', they were nevertheless 3D objects that could be interacted with virtually. Not surprisingly, the results of these studies were similar to those found with real objects.

In the current experiment, the setting is 3D, and the experiment takes place in the real world, but the objects are presented on a screen and the participants are not able to manipulate, nor to interact with the objects. If the manipulability of the object has an effect on the use of demonstratives one might predict an increased use of *'this'* for the 3D object as it could potentially be picked up and manipulated by the participant when an object is presented in peripersonal space.

3.2.1. Methods

The method used the *'memory game'* previously used to elicit demonstratives without participants being aware that language data are being collected (Coventry et al., 2008, 2014; please refer to chapter 1). The goal of this study was to investigate the use of demonstratives to describe the location of 3D objects compared to 2D images of those same objects. Stimuli were three 3D disks with different shapes printed on them (orange triangle, green circle and blue square) and 2D circles with the same features of the 3D images (Figure 3.7). 3D objects were placed by the experimenter on one of the six positions (25cm apart) marked in front of the participant; the 2D images appeared in the same positions of the 3D objects. Every participant was able to reach the first two positions without stretching (25 and 50cm from the participant), the third position was reachable if the participant was stretching their arm (75cm, only 2 participants were able to reach this position without stretching), the last 3 positions (100, 125, 150 cm) were not reachable. Each position was tested 3 times for each condition, with a total of 36 trials. A within participants design was used, all participants took part in both conditions; the order of the two blocks was counterbalanced between participants.

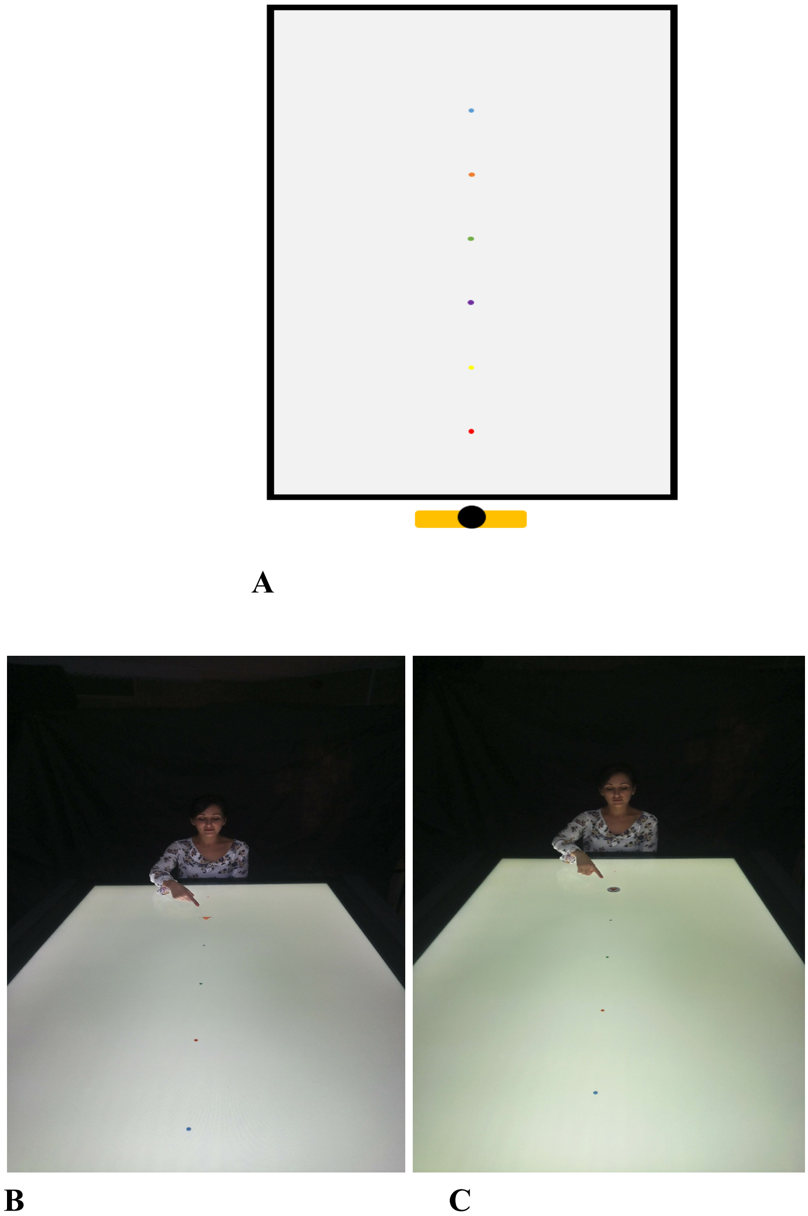


Figure 3.7 *A) The positions used on the table 25cm apart. B) An example of a participant pointing at the 2D image C) An example of a participant pointing at the 3D object.*

3.2.1.1 Participants

24 participants took part in the experiment, 12 males (2 left handed) and 12 females (all right handed), age range 19-43 (M_{age}=21.21; SD_{age}=4.99). All were English native speakers and received course credit or monetary compensation for their time. The sample has been chosen based on previous literature (Coventry et al., 2014; Gudde et al., 2016).

3.2.1.2 Procedure

Participants were asked to sit at a touch-screen table. They were told their spatial memory was to be tested and that they were in the language condition, hence they would use language to memorise object location. Participants heard a beep sound (A_4 note) that was the signal for them to close their eyes. Whilst their eyes were closed the experimenter placed the 3D object/the 2D image appeared on the screen. After 7 seconds another beep (E_4 note) was sounded and the participant was instructed to open their eyes. They were then instructed to point at the object and name it using a combination of three words: a demonstrative (either the word '*this'* or '*that')* and the colour and the shape of the object/image (e.g. '*this/that blue square'*). They were told that this was necessary to keep the language condition as similar as possible between participants. After 7 seconds the beep sounded again and the object was removed to be replaced by the next one. To keep the *'memory game'* cover plausible, after a few placement trials participants were asked where a specific shape had been most recently placed.

3.2.2 Results

The percentage use of *'this'* was calculated for each position for each condition. Data were analysed in a condition (2D Vs. 3D) x sagittal (6 positions) x group (depending on the condition administered first) ANOVA. When running the ANOVA Greenhouse-Geisser correction will be used and reported where sphericity has not been met. Whereas, for the post-hoc test Bonferroni correction will be used and reported in text when appropriate.

There was a significant main effect of distance, $F(1.862, 40.956) = 25.950$, $p < .001$, $\eta p^2 = .541$. Follow-up analyses (using LSD tests) revealed significant differences between the reachable positions (position 1,2 and 3) and the non-reachable positions (positions 4,5 and 6), (p=.026 between position 3 and 4, between position 3 and 5, p=.005, between position 3 and 4 p= .0.24, all other positions p<.001) . No significant difference was found between the reachable positions. No significant main effect of object type was found (p=.187). However, a significant interaction was found between the type of object and the group; a significant effect of object type was found in the group that underwent the 2D condition first ($F(1, 22)=10.029$, $p=.004$, $\eta p^2 = .313$) with a higher use of *'this'* for the 2D objects overall, but no difference between object types was found in the group that underwent the 3D condition first (p=.152).

A significant interaction was found between sagittal distance and condition (2D Vs 3D), $F(3.422,75.274) = 3.248$, $p = .022$, $\eta p^2 = .129$ (Figure 3.8) . However, follow up analysis revealed no significant differences (corrected Bonferroni, p=.033 for position 2) between the two conditions in any of the six positions, however an increased use of *'this'* was found for the first two positions in the virtual condition.

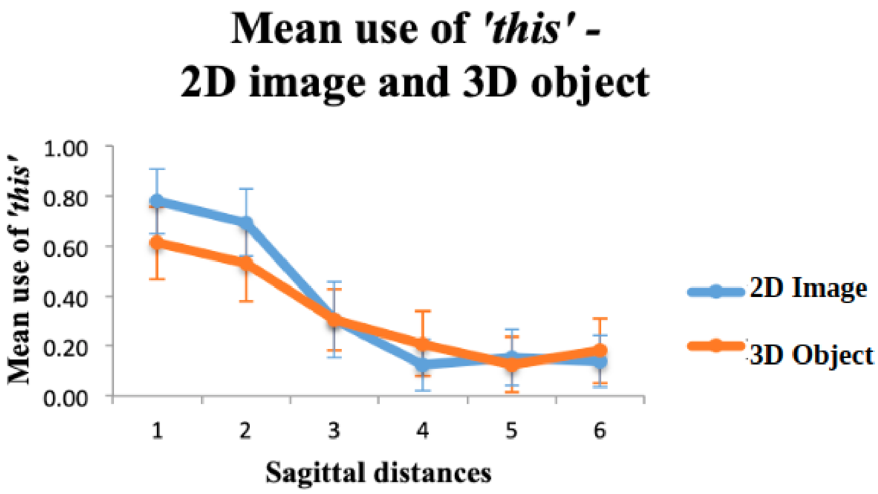


Figure 3.8 *Line graph showing the mean use of 'this' for each of the 6 positions for the 2D image (blue) and the 3D object (orange). Error bars show 95% confidence intervals.*

3.2.3 Conclusion

Results showed a main effect of distance with an increased use of *'this'* for the peripersonal space compared to the extrapersonal space, consistent with previous literature. No main effect of object was found suggesting that demonstratives are used in the same way for an image or a real object; the distance effect is still present when the object cannot be manipulated. However, a difference in the two groups (real first or virtual first) was found, with an increased use of *'this'* for the 2D objects in the group that underwent the 2D condition first. The real object has more salient features than a virtual object, therefore the passage from the virtual to the real object can be more salient for the participant, increasing the use of *'this'* in the group that took part in the virtual condition first. Despite this result, the experiment used a counterbalanced design and no main effect of object type was found, suggesting that no real effect is present, hence we can conclude that demonstratives for the

2D images are used based on distance and that the effect is equivalent to the 3D object, if not superior.

3. 3 Experiment 5 - Use of demonstratives for images of graspable and not graspable objects

3.3.1 Introduction

In the first experiment, we found effects of distance on demonstrative choice for both 3D and 2D objects. In a second experiment we further explore the use of demonstratives for images of objects. Any object we observe has a property and a function; a strong association between the object and the action is usually present (Tucker & Ellis, 1998). Tucker & Ellis presented the participants with photographs of graspable objects (Figure 3.9). Participants were instructed to press a button with the left or right hand, depending if the object was upright or upside-down. The left/right orientation was manipulated as well; e.g. a photograph of a pan was shown in its canonical orientation (for a right-handed user, the handle toward the right-side) or in the non-canonical orientation (with the handle toward the left-side). Results showed a faster reaction time when the object grasp was facing the right-side for right-handed participants and a faster reaction time for the left-grasping for left-handed participants. This experiment showed an effect of the object orientation on the reaction times, and that people do not need to see the 3D object to elicit affordances, but also a photograph can have an effect.

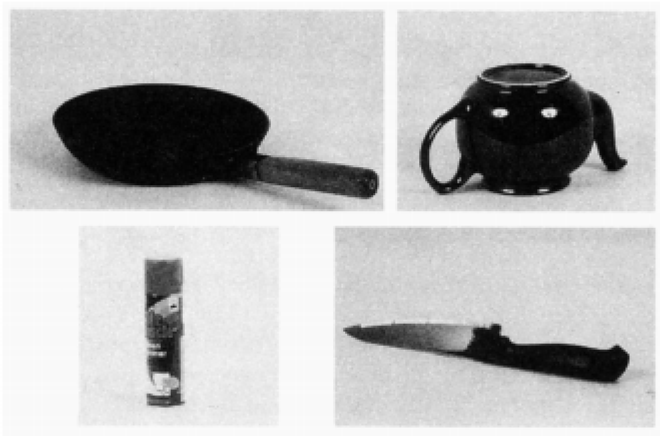


Figure 3.9 *Example of the stimuli used by Tucker & Ellis (1998). Top left: pan in a right, upright orientation; top right: teapot in a left, inverted orientation; bottom left: aerosol can in a clockwise wrist rotation compatibility, upright; bottom right: knife in an anticlockwise wrist rotation compatibility, inverted.*

Gentilucci and colleagues (2000) in a series of 7 experiments studied the effect of language on grasping and reaching movements. They asked participants to grasp and reach an object with Italian translation of near and far printed on them (*'vicino'* and *'lontan'* respectively). In further experiments more conditions were tested: the effect of the words '*big'* and *'small'* (*'grande'* and *'piccolo'*); a Stroop effect, where the objects were green and red on which the Italian word for red and green was written (*'rosso'* and *'verde'*); the effect of the words *'high'* and *'low'* (*'alto'* and *'basso'*); the effect of the words *'up'* and *'down'* (*'sopra'* and *'sotto'*). Results showed that reading a word can affect movement control. A link between the word and the motor planning is present; slower movements were executed when an incongruence was present. For example, when the object with the word *'far'* was presented in the near space the movement was slower when compared to the object printed with the word *'far'* placed in the far space. This effect has been further studied by Gentilucci (2003), finding an effect of the word on the movements for verbs (e.g. *sposta 'move'*), but not for adjectives (eg. *alto 'high')*. These results strengthen the connection between affordances and language and the representation of the words and the affordances in the brain. Similarly, Costantini and colleagues (2011) tested how 3D objects activate motor information and how this information is affected by the location of the objects. Participants were presented with 3D stereo pictures of common objects placed in a room in peripersonal and extrapersonal space. Verb stimuli (in Italian, using the imperative form of the verb) matching with only one object were also presented. Participants were asked to respond if there was a correspondence between the object and the verb or to not respond if there was no correspondence between the two stimuli. Results revealed a difference in RTs for manipulation and functions verbs depending on the location of the object, with higher RTs for the extrapersonal space, no difference was found for observation verbs. These results show that a motor activation is present only for the image placed in the peripersonal space, and therefore reachable.

It is clear that affordances are necessary to interact with objects and that a link to handedness and language is present. As we demonstrated in the previous chapter grasping and reaching are fundamental for the use of demonstratives, and in the previous experiment we demonstrated that no difference in the use of demonstratives is shown when comparing a 3D object to a 2D object. Hence, we might expect an increased use of *'this'* for the graspable objects (e.g. glass) and a decreased use of *'this'* for a the non graspable object (e.g. a spiky object such as a cactus). In addition, when showing a mug with the handle toward the right (for right-handed participants) we might expect an increased use of *'this'* when compared to pointing at a mug with the handle facing to the left-side. Moreover, this effect might only be present in the peripersonal space as the graspability of the object is not salient for the extrapersonal space, hence a significant interaction between object type and distance is predicted.

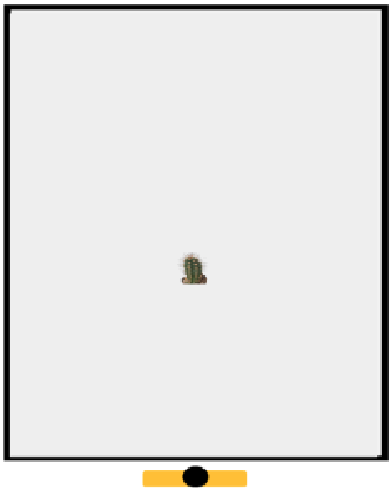
3.3.2 Methods

3.3.2.1 Participants:

26 participants (21 females) took part in the experiment. All the participants were naïve to the purpose of the experiment, right-handed and English native speakers. The age range was 19-27 (Mage= 19.88, SD=1.87). Participants received course credits as compensation for their time. Additionally, two participants were tested and eliminated from the analyses, one because they were not naïve to the purpose of the experiment and one because they were left-handed. The sample size has been chosen based on the number of participants used in experiment 4 (pag. 104).

3.3.1.2.Stimuli and procedure:

Participants were asked to sit at a large touch-screen table (see Figure 3.10A). They were told that they were taking part in a spatial memory task and that they had to remember the location of some objects that will appear on the screen. The participants were instructed to point at the object with their right-hand and to name the object. They were told that they were in the language condition and they had to use a combination of three words to name the object (a demonstrative: either the word '*this'* or *'that'* and the colour and name of the object, e.g. *'this green mug'*), the use of those three words was explained as a necessity to get the condition as similar as possible between participants in a way that all the participants were using the same amount of words when naming the object. Five objects were created: a green cactus (spiky object, not graspable), a green star (2D shape), a green mug with the handle facing to the right side and a green mug with the handle facing the left side and, finally, a green glass (Figure 3.10B). Each object was presented for 5 seconds. After a few placement trials, participants were asked to recall the position of an object, the target object was appearing on the screen with a box with the question: ‘where was the...?’ and after a few seconds a line with numbers was appearing in front of the participant, which was instructed to tell the experimenter in correspondence of which number the target object was placed.



A

B

***Figure 3.10 A**. Example of the setting used for experiment 5 showing one of the objects used (cactus). **B**. The 5 objects used in experiment 5.*

3.3.2 Results

The average use of *'this'* was calculated for each object on each location. When running the ANOVA Greenhouse-Geisser correction will be used and reported where sphericity has not been met. Whereas, for the post-hoc test Bonferroni correction will be used and reported in text when appropriate.

A main effect of sagittal position was found $F(1.670, 41.756) = 15.33$, $p<.001$, $\eta p^2 = .380$ (Greenhouse-Geisser correction), with a decreased use of *'this'* as we get farther. LSD pairwise comparisons showed a non-significant difference between the first two positions ($p=.096$), the first three positions (reachable) showed a significant difference between them and the other positions (third and fourth location $p=.014$, all other $p<.01$). No significant difference was found between the last three positions (non-reachable).

No main effect of object was found $F(3.007, 75.178)= 15.33$, $p=.130$, $\eta p^2 = .072$, Greenhouse-Geisser correction) and no significant interaction between object and location was found $F(4.918, 122.959)=1.622$ $p=.160$, $\eta p^2 = .061$, Greenhouse-Geisser correction).

Table 3.1 *Percentage use of 'this' for each object and position, standard deviation into brackets.*

		Objects				
		Cactus	**Glass**	**Mug (left)**	**Mug (right)**	**Shape**
Position	**1**	53% (.48)	60% (.49)	59% (.44)	53% (.41)	53% (.45)
	2	45% (.41)	41% (.44)	49% (.41)	54% (.42)	49% (.43)
	3	22% (.34)	31% (.40)	22% (.38)	13% (.27)	36% (.36)
	4	13% (.28)	23% (.41)	5% (.12)	24% (.38)	14% (.32)
	5	8% (.24)	22% (.41)	8% (.27)	9% (.28)	8% (.24)
	6	19% (.38)	15% (.34)	10% (.29)	5% (.20)	6% (.21)

3.3.3 Conclusion

Consistent with previous literature (Coventry et al, 2008; 2014, Gudde et al., 2016; Caldano & Coventry, 2019) and with the results of the first set of experiments a strong effect of distance was found, with an increased use of *'this'* for the reachable position and an increased use of *'that'* moving farther from the participants. Surprisingly no effect of object type was found, nor a significant interaction between object type and distance. However, only five objects were tested and only one of them was not graspable (the cactus) due to its spiky nature. In addition, participants, after the experiment, were asked if they considered the objects in any different way and the majority answered that their attention was dragged more to the cactus due to the fact that it standed out more with respect to the other objects and/or because they like plants. Therefore, more sharp and non-graspable objects should be used to find an effect of the object. Lastly, a difference between the handle facing the left and right side was expected. However, the difference might not be salient enough to increase the use of the proximal, since the cup is not always grasped by its handle, and it can be grasped anyway on the opposite side of the handle.

In conclusion, more research is needed for a better understanding of the difference in the use of demonstratives for 2D images of different types of objects, although the experiment shows, once again, the importance of distance in the use of demonstratives.

3.4 General discussion

In two experiments we studied the use of demonstratives for 2D objects and the difference between 2D images and 3D objects.

In the first experiment, we found a main effect of distance with an increased use of *'this'* for the near space compared to the far space compatible to results previously found (Coventry et al., 2008, 2014; Gudde et al., 2016; Caldano & Coventry, 2019). Following on from previous studies, and consistent with the results of Chapter 2, the data support a strong mapping between choice of demonstratives and distance as a function of reach (peripersonal versus extrapersoanl space). No overall main effect of 2D images compared to 3D objects was found. However, the results show a significant interaction between distance and 2D Vs. 3D objects. Literature shows that reaching is an important variable in the perception of the real and virtual objects, and it is an important feature for the use of demonstratives. Hence, we would have expected that the increased use of the proximal demonstrative for the real object compared to the image of the object. However, besides the object being graspable the participant had to name the shape printed on it that is a 2D image. Further testing should be run with a three-dimensional version of the named object to better compare the two conditions. For example one object was a round coaster with an orange triangle on a white background. Therefore, the coaster was graspable, but not the triangle named by the participants. To better test the difference between 2D (non-graspable) images and 3D (graspable) a real 3D triangle could be placed on the screen instead of a printed object on a 3D object. In addition, 6 dots were appearing on the screen and they were 'virtual' in both conditions. Due to touchscreen features (a protective glass is applied on top of the screen, creating a disparity between the image projected and the top of the screen) it might be that participants were perceiving the real object farther with respect to the dots compared to the virtual image and, therefore, using more the distal demonstrative. However, when asked some participants reported the real object appearing to be closer and easier to remember, others reported not to have perceived any differences between the two conditions, and finally some participants reported the real object to be more memorable. These information were not recorded and therefore not analysed. Questions were only asked to make sure the participants were not aware of the real purpose of the study and to make sure they were using demonstratives in a natural way. In addition, as this was one of the first experiments run using the touch screen we wanted to have feedback from the participants about the appearance of the objects.

Another difference between the two conditions was that in one case the object was appearing on the screen, in the other case was the experimenter that was placing it. The fact that the object was manipulated by the experimenter before being placed might have influenced the perception of the object and the use of demonstratives. The object being manipulated by another person and being in their peripersonal space first might have resulted in the object being perceived farther from the participant. Indeed, the participants had their eyes closed during the placement and they were not seeing the experimenter placing the object, however they were not wearing any headphones, so it could be possible that they were hearing the steps, in addition they were not told, but they soon became aware and could elaborate the concept that the object was manipulated by the experimenter. Coventry et al. (2008) showed an effect of the person placing the object on the use of demonstratives, with an increased use of *'that'* was found when the experimenter was placing the object compared to when the participant was placing it. On the other hand, the experimenter was never interacting with the screen, nor were they touching a PC to deliver the stimuli, this could have got the manipulation of the object by the experimenter stronger.

Lastly, an effect of group was found; no effect of object type was found in the group that started with the real object first. It is possible that people in the second block (the 2D image) continued to use the demonstratives in the same way as the first block, as they assigned a demonstrative to a determinate position. In the other group, however, participants used demonstratives differently in the second part. It is possible that it is more difficult to switch from the 2D image to the 3D object and the difference is more salient, resulting in an increased use of *'that'*.

More investigation is needed for this phenomenon to better understand the implications. To better study this it will be necessary to further reduce the differences in perception of the two objects by removing the screen misalignment between the 2D stimuli and the 3D object, in addition the use of real objects, with a practical function (e.g. a cup), could give us more precise results. Lastly, a 'pure memory' experiment should be run to see if the same results can be found in cognitive processes other than language.

In the second experiment results showed a main effect of distance consistent with the previous findings present in the literature (Coventry et al, 2008; 2014; Gudde et al., 2016; Griffiths et al., 2019; Caldano & Coventry, 2019) and with the results of experiment 1. Again, the results supported a strong mapping between peripersonal and extrapersonal space and the use of demonstratives, with an enhanced use of the proximal demonstrative (*'this'*) for the peripersonal space compared to the extrapersonal space. Contrary to the hypotheses no main effect of object type was found, nor a significant interaction between distance and object type was found. Indeed, experiment 1 showed no difference in the use of demonstratives for the 2D images compared to the 3D objects, however the objects used in that case were shapes and not objects used in everyday life. Geometric shapes might not carry affordances contrary to the objects shown in the second experiment (e.g. the mug). As a matter of fact, when we see a mug we link it to a holding and a drinking movement, but when we see a geometric shape less actions come to mind with only a grasping movement being possible. Therefore, it might be possible that a difference in the elaboration of the real and virtual object is indeed present for objects that have clear functions. Further research should be run to investigate the use of demonstratives for objects with 3-dimensional everyday objects using the *'memory game'* paradigm. In particular, we were expecting differences between the spiky object (the cactus) and the other graspable objects, if the grasping is important for the use of demonstratives (as demonstrated by Caldano & Coventry (2019)) a drop in the use of *'this'* was expected for the cactus, however it could be possible that the cactus is not considered 'dangerous' enough in a 2D format. In addition, some participants reported to be more attracted by the cactus as it stood out more with respect to the other objects and/or because they like cactuses as ornamental plants. We were also expecting an increased use of *'this'* for the mug with the handle toward the right side compared to the mug with the handle facing toward the left side (due to the fact that all participants were right-handed). The handle should facilitate grasping and therefore the motor planning when the object is seen and we were expecting participants to be facilitated in the use of *'this'* when the mug was easier to grasp. Yet, the mug can be grasped anyway with the right-hand when the handle is facing the other side. Future testing can be run with left-handed participants to see if the handle direction could become an important variable in the use of demonstratives when the handedness of the participant is manipulated. Lastly, we were expecting an increased use of *'this'* for the graspable objects compared to the shape, however it could be possible that no difference was encountered as both the objects were images and the same grasping affordance have sprung. One last possibility is that the nature of the object is not important for the use of demonstratives and that the dangerousness of the grasp and the handle orientation are not variables that affect the use of demonstratives.

In conclusion, these two experiments proved that a strong effect of distance is present for the use of demonstratives for 2D images of objects. No main difference has been found between 2D images and 3D objects suggesting a strong mapping between the demonstrative choice and the division of the space in peripersonal and extrapersonal space and that this difference remains true also for a 2D representation and that it is not affected by the affordances, nor the characteristics of the objects.

Chapter 4

The use of spatial language in patients with and without Unilateral Spatial Neglect

4.1. Introduction

In chapter 2 we explored how people use demonstratives in the left and right space, and no effect of hemi-field was found. Results show that in healthy participants the side where the object is placed does not affect how people use demonstratives. But, what about stroke patients? Some patients after a stroke lose the ability to interact with objects in the left space, and are no longer aware of what is happening in that side of the space. This syndrome, called Unilateral Spatial Neglect (USN), usually develops after a right-brain stroke. This syndrome usually develops after a stroke in the right-brain, in particular (but not only) the posterior parietal cortex, and it is rare to experience space perception deficits after a left-brain injury. Whereas, it is common to experience deficit in language production and comprehension after an injury in the left-brain (where the Broca's area and the Wernicke's area are located). Thus, there is a tendency to divide and rehabilitate patients on the basis of the side of the lesion. The combined analysis in chapter 2 revealed a strong mapping between space perception and demonstratives use, it is therefore important to test patients with issues in spatial perception to better understand this mapping and the implication of spatial perception and spatial awareness in the use of demonstratives. The connection between spatial and speech problems have not been studied in depth, therefore, in this chapter, we will further investigate the use of demonstratives and prepositions (words that are connected to space perception) in a sample of Italian patients with USN.

Different systems of demonstratives and prepositions are used in different languages (e.g. in Italian the toast is *in* the plate and not *on* the plate), hence we cannot apply the previously collected data in the English language to Italian. It was first necessary to collect data in Italian with the '*Memory game*' method (Coventry et al., 2008) to study the use of demonstratives as a baseline prior to testing patients. The Spatial Naming Test (SNT) (Markostamou et al., 2020a; Markostamou et al., 2020b; Markostamou et al., 2015; Markostamou, 2017) was used to test the use of spatial prepositions. The SNT tests the ability of naming spatial relations. The test is divided in two parts, first the use of static spatial relations is assessed, secondly it is assessed the use of dynamic spatial relations. The stimuli consist in drawings of geometrical shapes that are presented to the participant on a A4 paper (for more details see page 129). The SNT has been developed for the English language and in experiment 6 we adapted it for the Italian language. In the next section we present the Italian data from a healthy sample of participants prior to exploring spatial language in a group of USN patients.

Please note that the study with USN patients is exploratory and due to COVID-19 it was not possible to continue with the data collection, therefore the number of participants is very limited. In addition, due to the lack of CT or MRI scan available no lesion analysis will be run.

4.2 Experiment 6- The use of spatial language in the Italian language

4.2.1 Introduction

Demonstratives are present in all languages and they are also among the most frequent words used in a language (Diessel et al., 2006, Deutscher et al., 2005). However, demonstrative systems vary across languages. The most common system is the 2-ways system,as in English followed by a 3-ways demonstratives system, like Spanish (with proximal and distal terms like English, plus a medial term). Other languages can also have more than 5 demonstratives. In some systems, like Spanish and Italian, demonstratives also mark gender and number.

4.2.1.1 Demonstratives in Italian

Modern Italian uses a two-way demonstrative system with a term usually assumed to indicate an object/subject close to the speaker (*'questo'*) and a term to indicate something/someone far from the hearer and the speaker (*'quello'*) (see Table 4.1). In ancient Italian the demonstratives system was a three-way system with *'codesto'* used to refer to something/someone close to the hearer and far from the speaker. In the region of Tuscany (in the center of Italy) and in particular in the city of Florence, the term *'codesto'* is currently used in spoken language, but in other parts of Italy, the term is known but the use is confined to grammars and to bureaucratic writing. In addition, the demonstrative changes in accordance with number and gender of the subject in the sentence (see Table 4.1.).

Table 4.1 *Demonstratives in the Italian language*

	Singular		***Plural***	
	Masculine	***Feminine***	***Masculine***	***Feminine***
Proximal	*Questo/ Quest'*	*Questa / Quest'*	*Questi*	*Queste*
Medial (ancient Italian)	*Codesto*	*Codesta*	*Codesti*	*Codeste*
Distal	*Quello/ Quell'/ Quel*	*Quella/ Quell'*	*Quei/ Quegli*	*Quelle*

The comprehension of Italian demonstratives have been studied by Bonfiglioli and colleagues (2009) in a reach-to-grasp task. Participants were hearing the instruction to take the object and a demonstrative, either *'take this'* (*'prendi questo'*) or *'take that'* (*'prendi quello'*) or a neutral condition (*'prendilo'*/ *'take it'*), both objects were placed in reachable space. Then the PLATO spectacles were allowing the view of the object and the participant had to make a judgment if the gender of the pronoun heard in the instruction matched the gender of the object. If it matched they had to reach and grasp the object. The results revealed faster reaction times for the closer object when they heard the word *'this'* compared to the farther location. The authors argue that the key distinction between proximal and distal demonstrative is not based on the strict distinction between peripersonal and extrapersonal space.

In the current experiment we tested the use of demonstratives in Italian native speakers using the *'memory game'* paradigm. The use of *'questo'* and *'quello'* (*'this'* and *'that'*) was tested. In addition to examining the effects of distance of an object from a speaker, the effect of the position of the hearer was also tested. Coventry et al. (2008) showed that the addressee position is important in the use of demonstratives in Spanish (but not in English) with an increased use of the proximal demonstrative for the farther space when the experimenter was sitting opposite to the participants, compared to when they were sitting near the participant. Ancient Italian, as Spanish, had three demonstratives and their use was based on the hearer position (as you can recall from earlier, the middle term was used to indicate something close to the hearer and far from the speaker). It could be possible that such a 'hearer- based' distinction is still used in the modern 2-way system. If the hearer position has an effect on the use of demonstratives, we can hypothesize an increased use of *'questo'* for the middle position when the hearer is in front of the participant. On the other hand, if the use of demonstratives is distance-based, and no value is given to the hearer position, the proximal demonstrative (*'questo'*) will be used for the reachable objects and the distal demonstrative (*'quello'*) will be used for the non-reachable space, with no difference between when the experimenter is sitting beside the participant or opposite and facing the participant.

4.2.1.2 Describing spatial locations in Italian

Humans from around the world have developed in the same way and have the same basic perceptual apparatus. We would therefore expect that all languages would describe spatial prepositions in the same way. However, spatial language exhibits much cross-linguistic variability. For example, in English we can say: *the man is on the bus/train/plane* (but if the vehicle is smaller *the man is in the car*). However, in other languages, such as Polish, we cannot say that *the man is on the bus*, but for every vehicle the preposition *in* is used. Spatial adpositions are an example of words widely used to describe spatial locations that exhibit such a variation. They have the function of describing where one object is located in relation to a reference object, the connection between objects/subjects, they describe the location and the time. Prepositions are one of the most difficult categories to master when learning a foreign language, as no specific translations can be applied and prepositions need to be learned in situation-specific contexts (Coventry & Garrod, 2004). Taylor (1988) compared the use of three common prepositions (*on, over, above*) in English and Italian, underlining the different uses we can make of the prepositions in the two languages. For example, the use of *'on'* is comparable to the use of the preposition *'su'* in Italian, but in Italian *'su'* can also be used to describe something placed on a superior level to another object without contact. On the other hand, the word *'sopra'* (*'over'*) can be used if there is contact between the objects, making it difficult to distinguish between *'su'* and *'sopra'*. Let's now see three sentences in Italian, and their English translation of the use of *'su'* and *'sopra'* as reported by Taylor (1988):

1) La lampada pende <u>sul</u> tavolo

The lamp hangs <u>*on</u> the table

2) Appoggiò la mano <u>sul</u> mio braccio

He put his hand <u>on (*over)</u> my arm

3) Si costruì la casa mattone <u>sopra</u> mattone

He built the house brick <u>on (*over)</u> brick

'*Su'* and *'sopra'* do not have exactly the same meaning, but the variation is minimal and finding a rule for the interchangeability of the two is not easy. As Evans and Levinson (2009) have argued, one cannot assume that findings in English are representative of all languages; it is necessary to test in a wide range of varied languages to avoid ethnocentrism. Hence, we adapted the Spatial Naming Test, test developed by Markostamou and Colleagues (Markostamou et al., 2015; Markostamou, 2017; Markostamou & Coventry, 2020a; Markostamou & Coventry, 2020b) as an analog of the Boston Naming Test (Kaplan et al., 2001) to better understand how Italian healthy native speakers use spatial language to describe the location of geometrical shapes and to better understand the differences between the two languages.

4.2.2.Method

The study was composed of two parts, the first aimed to investigate the use of demonstratives in the Italian language; the second part aimed to investigate the use of language to describe spatial relations in Italian. All participants took part in both parts, the entire study was a duration of about 30 minutes.

The study used the *'memory game'* method (Coventry et al., 2008; Gudde et al., 2018) to elicit the use of demonstratives without the participant being aware that language is being tested. In this study we wanted to test how people use demonstratives in Italian when the hearer is sitting near the participant or at the other end of the table facing the participant.

In the second part, we used the Spatial Naming Test to better understand how spatial relations are described in Italian by healthy subjects, and to develop/adapt the test for use with a clinical sample.

4.2.2.1 Participants

24 Italian native speakers were tested (16 females), age range 19-39 (M_{age}= 25.71, SD_{age}=6.18). One participant was not included in the *'memory game'* analysis as they guessed the purpose of the experiment, but their data for the Spatial Naming Test were analyzed. The sample size was chosen based on previous literature (Coventry et al., 2014; Caldano & Coventry, 2019) and based on experiments 1,2,3,4, and 5.

4.2.2.2.Stimuli and Procedure

Testing the use of demonstratives – The 'memory game' paradigm

After consent was gained, participants were asked to sit at a table 320cm long and 120cm wide. They were told they were taking part in a spatial memory experiment and that they would use language to memorise object location. On the table 12 distances were marked 25cm apart, but only 6 distances were used in this study: the first two, 25cm and 50cm from the participant; the middle positions, 150 and 175cm; and the last two positions, 275 and 300cm (Figure 4.1). On each trial, one of the 6 objects was placed on one of the 6 positions. Objects were plastic disks on which coloured shapes were printed (3 feminine nouns and 3 males nouns) (Figure 4.2). Once the object was placed, the experimenter sat down, half of the time on a chair next to the participant, and half of the time on a chair at the other end of the table. When the experimenter was sitting the participant was instructed to point and name the object. To name the object they were told that they were allowed to use only a combination of three words (to get the condition as similar as possible between participants): a demonstrative, either '*questo'* (*this)* or '*quello'* (*that)* (or their feminine version '*questa*' or '*quella*') and the shape and color of the object (e.g. *'questa luna rossa', 'this *moon *red*', in Italian the adjective follows the subject). At the end of the test, they were asked if they had any idea about the purpose of the experiment to make sure that they did not know we were interested in studying the use of demonstratives. They were also asked questions about the Italian demonstratives system and if they would have used the third demonstrative (*'codesto'*). None of the participants reported using the third demonstrative when talking, one participant reported using the third demonstrative when writing.

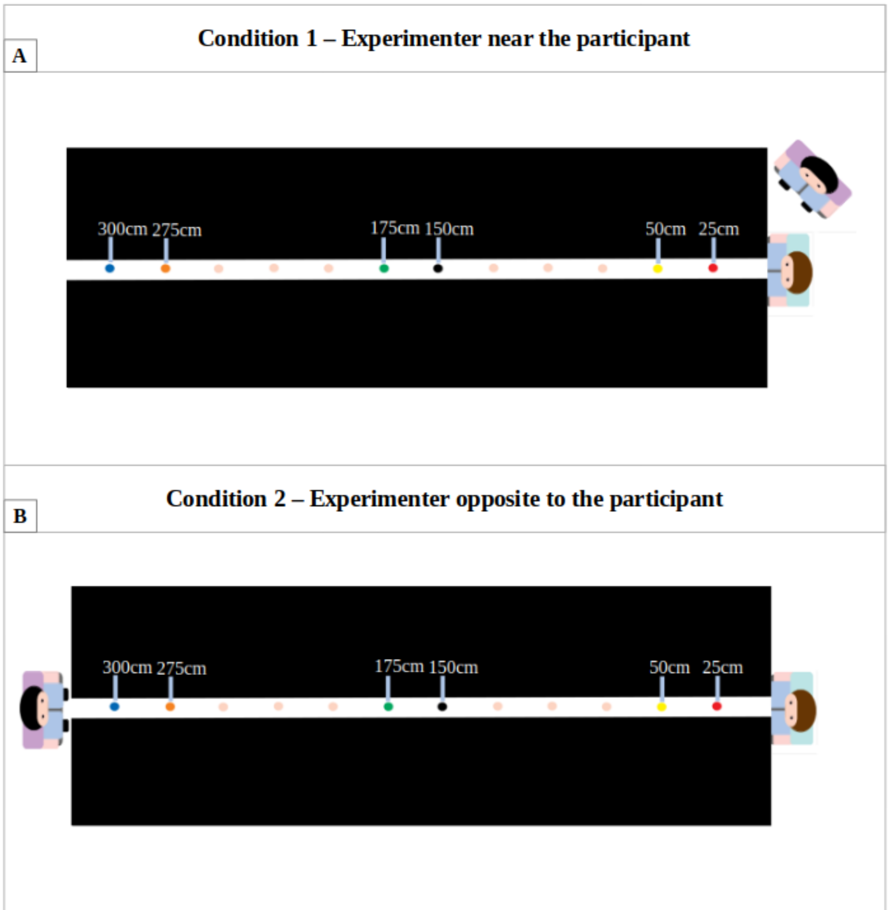


Figure 4.1 *The 'Memory game' setting representing the table used in Experiment 6 with the 12 positions marked. The red, yellow, black, orange and blue dots (25cm, 50cm, 150cm, 175cm, 275cm, 300cm respectively) were the positions used during the experiment. A. shows the participant (in green) sitting at the table with the experimenter (in purple) sitting next to the participant. B. shows the participant (in green) with the experimenter (in green) sitting opposite the participant.*

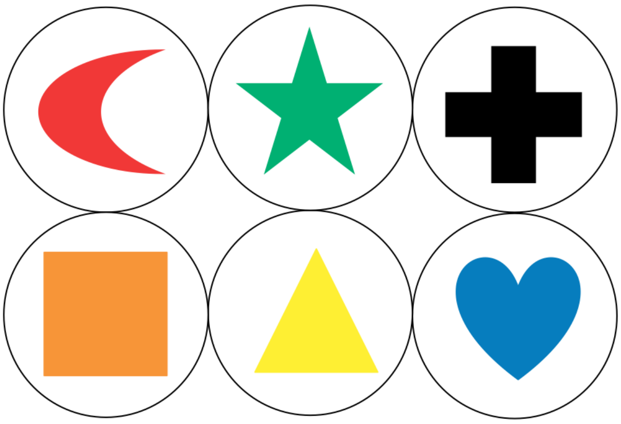


Figure 4.2 *The 6 objects used in the 'Memory game' test. Objects were plastic badges with a printed shape inserted in them. The three top shapes are the feminine nouns, from left to right: 'La luna rossa' (the red moon), 'la stella verde' (the green star), 'la croce nera' (the black cross); the three bottom shapes are the masculine nouns, from left to right 'il quadrato arancione' (the orange square), 'il triangolo giallo' (the yellow triangle), 'il cuore blu' (the blue heart).*

<u>The spatial naming test (SNT)</u>

Immediately after the *'Memory game'* experiment, participants took part in the SNT. Participants were sitting at the same table and they were shown some images printed on A4 paper. Stimuli were 30 images depicting a box, a red ball and one or more black balls. The test was divided into two parts. For the first 15 stimuli they were told they had to describe the position of the red ball with respect to the box using a preposition where possible, in a way that it is possible to identify the position of the red ball and not of the other black balls. They were asked to try to be as accurate as possible. A first picture was shown as an example: *'the ball is on the left of the box'* (Figure 4.3A). After part A, new instructions were given for part B. They were told that they would be presented with similar images, but this time they would also see some arrows indicating the movement of the red ball, and that they had to describe the movement of the red ball. A second example was presented: *'the ball is moving to the left'* (Figure 4.3B1). They were then shown 4 images picturing only the red ball moving. Later a new example illustrating the red ball moving toward the box (Figure 4.2B2), and they were instructed to describe the movement of the red ball with respect to the box.

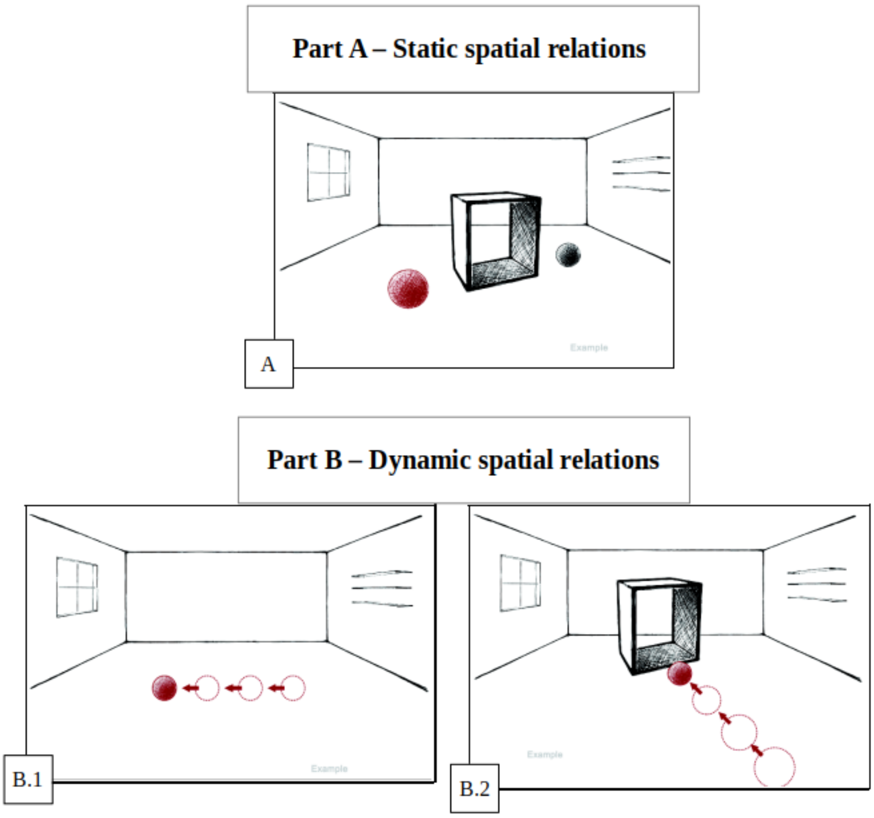


Figure 4.3 ***A.*** *An example of the stimuli used for the static spatial relations ('the ball is on the left);* ***B*** *Examples of the stimuli used for the dynamic spatial relations (B.1 'the ball is moving to the left'; B.2 'the ball is moving toward the box').*

Table 4.2 *Prepositions tested in the SNT and respective scoring.*

Stimuli	Score: 1 point	Score: ½ point	Stimuli	Score: 1 point	Score: ½ point
Part A – static spatial relations			*Part B – Dynamic spatial relations*		
Example A	left		Example B.1	left	
A1	in; inside; within		B1	down; downwards	
A2	right		B2	up; upwards	
A3	on; on top		B3	right	
A4	above; over		B4	across	right
A5	behind		Example B.2	towards; at	
A6	under; underneath;beneath; below		B5	into; towards inside	towards; at
A7	below; under; underneath; beneath		B6	out of	away from
A8	in front		B7	away from	
A9	far; far left; furthest left		B8	around; round	
A10	near; near left; nearer		B9	over	
A11	next to; beside; alongside; adjacent; by the side; touching/ attached to/ adjoining the left side	near; nearer	B10	under; underneath; beneath; below	
A12	between; in the middle		B11	through	
A13	among; amongst		B12	onto; on top	over and up
A14	in the middle; in the centre		B13	down of; off of	
A15	opposite	right in front	B14	along; past; parallel	left in front of
			B15	towards the side; to the side; next to; beside	towards, at; near

4.2.3 Results and discussion

4.2.3.1 'Memory game'

A 6 sagittal positions X 2 experimenter positions ANOVA was run. Results showed a main effect of distance $F(2.433, 53.523) = 316.268$, $p < .001$, $\eta p^2 = .935$, with and increased use of *'that'* as we go farther (Figure4.4). Follow up analyses (LSD) showed no significant difference between position 1 and 2 and between position 3 and 4 and between positions 5 and 6. A significant difference was found between position 1 and 2 and the other positions (all $p<.001$). All the other comparisons showed a significant difference (all $p<.05$). No main effect of the experimenter position was found. A marginal significant interaction was found (Greenhouse-Geisser correction applied) between sagittal position and experimenter position, $F(3.213, 2.665) = 2.665$, $p=.051$, $\eta p^2 = .108$. As we can see from the chart (Figure 4.4) an increased use of *'this'* can be observed at 150cm (middle positions) when the experimenter is facing the participant. On the contrary, a drop in the use of *'this'* can be observed in the reachable positions (25cm and 50cm) when the experimenter is facing the participant.

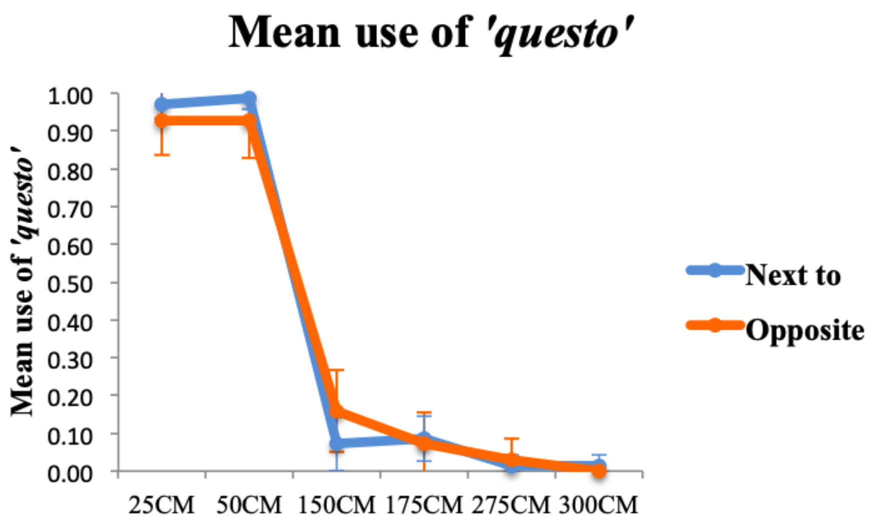


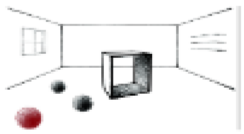
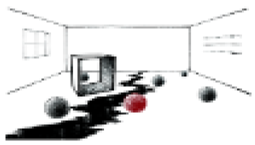
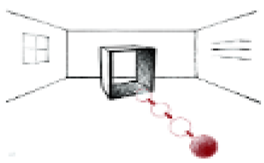
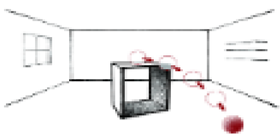
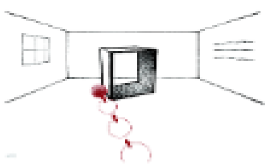
Figure 4.4 *Percentage use of 'questo'. In orange the percentage use of 'questo' when the experimenter was sitting opposite to the participant. In blue, the percentage use of 'questo' when the experimenter was sitting in next to the participant. Error bars show 95% confidence intervals.*

As we can see from the graph, there is a very strong preference for *'questo'* (the proximal demonstrative) for the first two positions, where the participant can reach and we observe an increased use of *'quello'* (the distal demonstrative) in non-reachable space. Therefore, the results are comparable to the previous findings in English (Coventry et al., 2008, 2014; Gudde et al., 2018, Caldano & Coventry, 2019).

4.2.3.2 Spatial Naming Test

The total score for each participant was first calculated. To calculate the scores the same scoring sheet previously used by Markostamou and colleagues (2015) was utilised with the exact Italian translation. The lowest score registered was 19/30 and the highest score was 26.5. The scores are much lower than the one recorded for the English native speakers (Markostamou, 2017, p. 43), where the author registered a low score of 24/30. The average score for the Italian group was 22.60/30, with an average accuracy of 75.35%. The mean score for part A, the static spatial relations description, was higher (12.67/15) than for part B, the dynamic spatial relations section (mean score of 9.74/15). We then calculated the accuracy for each stimulus and noticed that a few stimuli in particular had a much lower accuracy using the adapted English scoring system. For part A, the stimulus A9 (correct answer *'far left'*) showed an accuracy of 56.25%, a lot of participants scored only 0.5 points, answering *'on the left'*. In the Italian language there is not a precise translation and it is more natural and common to say on the left, as two sentences would be needed to describe the *'far left position'*, that is *'on the left, far away from the box'*. A very low accuracy was also found for the stimulus A15 (1 point: *'opposite'*; 0.5 points: *'right in front'*): 29.17%. Here too, it could be the case that in Italian the word *'opposite'* is not much used in everyday language and a better translation would be *'in front'*. For part B, a few stimuli in particular also had a low accuracy score. Four stimuli scored lower than 60% mean accuracy. Stimulus B4 (1 point: *'across'*; 0.5 points: *'right'*) recorded an accuracy of the 50% with all but one participant describing the ball moving toward the right, hence we can say that the correct answer in the Italian language should be set as *'right'* (only one participant scored 0 points, answering *'left'*). The average score for the stimulus B7(1point: 'away from') was 41.67%. In this case some participants did not understand the picture, describing it as *'it is going out of the box'*. Stimulus B13 (1 point:'*down off', 'off of'*) scored a very low accuracy of 8.33%. Only one participant scored 1 point using the preposition *'giù'* (*'off of'*) showing that the use of that preposition does not come naturally in that context and some people preferred to use the verb *'scende'*, that does not need a preposition and can be translated with *'it gets off'*. Lastly, the stimulus B15 (1 point: *'towards the side', 'to the side', 'next to', 'beside'*; 0.5 points: *'towards', 'at', 'near'*) has an average score of 58.33%, with a few participants scoring only half a point.

Table 4.3 *Stimuli with low accuracy where the scoring system has been adapted.*

Stimuli	Accuracy
Part A -Static spatial relations	
	56.25%
	29.17%
Part B – Dynamic spatial relations	
	50%
	41.67%
	8.33%
	58.33%

If we recalculate the accuracy without the problematic stimuli in Italian with a lower accuracy than the 60%, the mean accuracy value is 85.14%. The average score is 19.5 (sd= 1.82), the lowest score was 17 (73.91% accuracy) and the highest was 23 (100% accuracy). It is clear that not all the stimuli can be used to test the use of spatial language in the Italian language and that the images should be changed and adapted to different prepositions more appropriate to the Italian language.

4.3 Experiment 7 - The use of spatial language in patients with and without Unilateral Spatial Neglect

4.3.1 Introduction

Over 100,000 people are affected by a stroke each year in the UK, that means about a stroke every 5 minutes (State of the Nation. Stroke statistics, 2018). After a stroke, usually affecting the right-brain, approximately 50% of patients manifest a syndrome called Unilateral Spatial Neglect (USN) (Ten Brink et al., 2016). In USN patients are unaware of what is happening on the left part of the visual field: they do not interact with the world on the left side, with the consequence that they might apply their makeup only on their right side or shave only the right side of their beard (Vallar, 1993). Most patients recover within 3 months, but 40% of patients will manifest chronic neglect after one year from onset (Ten Brink et al., 2016). USN is not a unitary syndrome, as patients may manifest a number of discrete disorders independent from one another and dissociated from one another (Vallar, 2001) (see box 1). Due to this variation between patients, assessment for the condition needs to include a variety of different tests capable of identifying all the different components of the syndrome (see box 2).

Box. 1 *Type of Unilateral Spatial Neglect and related disorders*

Disorder type	Description	Example
Unilateral Spatial Neglect (USN)	It is a neuropsychological disorder characterized by the inability to detect or even respond to stimuli presented contralaterally to the lesion.	 Drawing taken from Thomas (2013)
Egocentric USN	Patients neglect the cotralesional side of the space	when we ask to copy a draw the patient neglects the left side of the image  Drawing taken from Korte & Hillis (2001)
Allocentric USN	Patients neglect the left side of the object	when we ask to copy a draw the patient neglects the left side of each object in the draw  Drawing taken from Korte & Hillis (2001)
Representational USN	Patients fails to recall contralesional details of an image from memory	In a famous experiment Bisiach asked to a patient to describe the 'Duomo square' in Milan facing the Dome, the patient gave all the details that were on their right. Then They asked him to try to describe it giving the back to the Dome, they described all the details on their right, neglect the details previously described that are now on the left 
Personal USN	Patients fail to recognise the contralesional part of their body	 The patient is not aware of their left part of the body. If asked to remove, for example, some fluff on their left hand, they would not be able to reach it and feel it.
Anosognosia	It is the refusal of recognising a disturb	For examples, the patient can be asked to comb their hair with their contralesional hand, the patient might not move their hand, nor do the action, but when asked if they accomplished it they will answer they did.
Hemiplegia	Patients are affected by movement disorders only on one half of the body	Patients are not able to move their controlesional arm and/or leg. They won't be able to walk, or they will have difficulties to walk and/or to perform actions with their controlesional hand.
Extintion	The failure to detect a contralesional stimulus in presence of a concomitant ipsilesional stimulus, even if it can be detected correctly when presented in isolation.	When touched on both hands at the same time, the patient reports that they have felt the touch only on the ispilesional hand.
Allochiria	Patients report the stimuli presented on the contralesional side in the ipsilesional side	when touched on the controlasional hand, the patient report that they have been received the stimuli on both hands.

***Box 2**. Behavioral Inattention Test (BIT) - Details about the tests used*

Behavioural Inattention Test (BIT)		
It is a widely used test to assess the presence of USN. It is divided in two parts the conventional subtests (BITC) and the behavioural subtests (BITB)		
Type	**Test**	**Description**
BITC	**Line crossing**	Patient needs to cross out all the target lines on the page
	Letter cancellation	Patient needs to cross out all the target letters on the page
	Star cancellation	A sheet with shapes and words is presented to the patients that has to cross out all the target stars
	Figure and shape copying	The patient needs to copy three different shapes placed in the left of the page
	Line bisection	The patient needs to indicate the midpoint of a line
	Representational drawing	Patient is asked to draw a clock, a person and a butterfly
BITB	**Picture scanning**	Three pictures are placed in front of the patient that has to point the three main objects of the pictures
	Telephone dialing	Patients are presented with a phone and a sequence of numbers. The patient is instructed to dial the numbers presented in the sequence
	Menu reading	A menu in the format of a 'open-out' page with 18 food items organised in 4 columns is presented. Patient is instructed to open the menu and read all the items out loud.
	Article reading	Patient is presented with 3 columns of text, and they are instructed to read the text out loud.
	Telling and setting the time	This test is made of 3 parts. First, patient is asked to read the time on photographs of a digital clock. Second, the patient is asked to read the time 3 times on a analogue clock. Third, the patient is asked to set the time on an anologue clock as instructed by the experimenter
	Coin sorting	Patient is presented with an array of coins. Patient is asked to indicate the location of the coin called out by the experimenter.
	Address and sentence copying	Patient is asked to copy an address and a sentence on two separate pages
	Map navigation	Patient is asked to follow and locate spatial points on a network of pathways located on a sheet.
	Card sorting	Patient is presented with 16 cards in a 4X4 matrix. each card is pointed out to the patient, and then hte patient is asked to point at the card called out by the experimenter.

4.3.1.1 Near and far dissociation in USN

Some patients might manifest neglect only in peripersonal space, but not in extrapersonal space, or the other way around. During neuropsychological assessment the emphasis is placed on the assessment of the presence of USN for near space, as a matter of fact, all the paper and pencil tests are usually administered in peripersonal space. The use of these tests in patients' extrapersonal space is usually confined to research. However, during assessment the patient is usually asked to describe the objects present in a room, that can give a measure of neglect for the near and far space, depending on the side and distances of the objects picked by the patient.

Halligan and Marshall (1991) describe the case of a patient that manifested neglect for near space, but not for far space. Lines of different lengths (51, 102, 152, 203 and 305mm) were presented 45cm from the participant for near space, and the patient was asked to bisect the line with a pen. For far space (2.44m), the lines presented were corrected for visual angle and the length increased based on that (27, 56, 83, 114,138 and 166 cm). The patient was asked to bisect the line with a light pointer. Line bisecting showed bias away from the centre in near space, but not in far space. On the other hand, Vuilleumier and colleagues (1998) report the case of a woman manifesting neglect only for the far space. Six different tests (star cancellation, two letter cancellations and 3 bisections) were administered to the patient in their peripersonal space (35 cm) and extrapersonal space (3.5m). In addition to these tests, perceptual tests were also carried out. A series of squares were presented to the patients and the shapes were complete or a line was missing on the right or left side The patient had to say if the figure was complete or not. The patient showed neglect in both the perceptual and the visuomotor tasks in the extrapersonal space, but not for the peripersonal space.

In addition, Berti and Frassinetti (2000) showed that patients can remap the space and that neglect bias can change depending on the tool used to complete the task.The authors asked a patient to bisect a line in near space and in far space with a stick and with a laser pointer. The participant manifested neglect only for the near space, but when they were asked to bisect the line in the far space with a stick, so actually being able to reach the line with the tool, they were remapping the far space as near space and manifested a rightward bias comparable to the bias manifested in the near space.

4.3.1.2.Brain representation of peripersonal and extrapersonal space

The dissociation between the neglect for near and far space can be explained with different anatomical bases for the processing of peripersonal and extrapersonal space. Studies on anatomical differences for space elaboration have been carried out in primates, patients and healthy subjects.

In the area F4 of the macaque (located in the macaque inferior area 6), multimodal neurons are found that discharge in reaction to tactile and visual stimuli, but they are poorly activated by a 3D object in the farther space (see Di Pellegrino & Làdavas, 2015). The encoding of peripersonal and extrapersonal space has been studied in mirror neurons. Mirror neurons are a set of neurons that discharge not only when an action is accomplished, but also when the subject is observing someone else doing that action. Those neurons were found in the macaque premotor cortex (F5) and described for the first time by Di Pellegrino, Fadiga, Fogassi, Gallesse and Rizzolatti in 1992. *'Mirror neurons'* could be involved in better understanding actions. The findings were soon extended to the human cortex (Fadiga et al., 1995). Moreover, it has been found that the neurons in F5 respond differently when an action is performed in the monkey's peripersonal (less than 37cm) or extrapersonal space (further than 37cm). Not only do those neurons elaborate space based on distances, but also in an operational manner. In fact, if the monkey is prevented from reaching the object, extrapersonal space neurons will start firing also in peripersonal space (Caggiano, Fogassi, Rizzolatti, Their & Casile, 2009). Bjoertomt and colleagues (2002) used TMS on healthy participants to study the brain activation for near and far space. Lines were presented at 50 or 150 cm on a computer screen and participants were asked to bisect them with the aid of a computer mouse. Four stimulation sites were individuated: the right posterior parietal cortex (PPC), the right dorsal occipital lobe, the right vertical occipital lobe and the left dorsal occipital lobe. Without TMS stimulation, a larger pseudoneglect bias (the tendency of healthy people to bisect a line slightly more toward the left side) for the near space compared to the far space was found. Bjoertomt's results are compatible with results previously found by Barrett and colleagues (2000), in support of the theory of a different brain path representing near space and far space. In addition to that the TMS stimulation of the right PPC produced a right bias in peripersonal space, whether the stimulation of the right ventral occipital lobe produced a right shift for lines presented in the far space. In a similar task, Weiss and colleagues (2003) found, with a PET study, activation of the left dorsal occipital cortex, left intraparietal cortex, left ventral premotor cortex and left thalamus for near space, and activation of the ventral occipital cortex bilaterally and the right medial temporal cortex for far space.

Based on the current literature, it is clear that people perceive and manifest different behaviours for stimuli shown in the far space and different brain areas intervene in these processes.

4.3.1.3 The relationship between space and communication in brain damaged patients

There are words, such as demonstratives and prepositions that not only involve speech skills, but also spatial skills. For example, if we take the sentence: "*the cat is in the box*" not only we need to understand what a cat and a box are, but also use the word '*in*' to locate it. Little is known about the neural substrates underlying spatial language and how language and space are integrated. Therefore, it is important to study more in depth the relation between prepositions and/or demonstratives and spatial deficits in stroke patients.

Göksun and colleagues (2013) studied the effect of the *'where pathway'* on naming spatial prepositions in brain injured patients and the relationship between impaired naming of spatial relations and spontaneous gesture. Pictures depicting four spatial relations (*in, on, above* and *below*) were presented to the patient. The spatial relation was illustrated by the actor's hands in the picture (Figure 4.5). Pictures were presented on a screen and the patient had to complete a sentence started by the experimenter:

E. "The cup..."

P. "The cup is on the book".

Another task, the dynamic spatial relations task, was then administered. Short movie clips were presented to the patient representing different spatial relations (*put in, put on, move over, move* *under* and *move across*). As in the previous task, movie clips were presented on a screen and the action was illustrated by the actor's hands. The goal of the task was to describe the relation between the two objects, for example: *'the orange was put in a bowl'*.

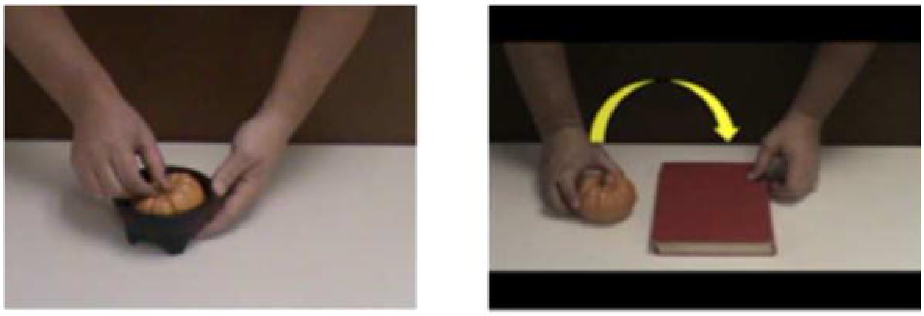


Figure 4.5 *On the left an example of a static picture representing the relation between two objects: the pumpkin is in the bowl. On the left a picture representing the dynamic relation between two objects: the pumpkin was put on the book Göksun et al. 2013).*

The left hemisphere damaged (LHD) group performed worse in naming spatial relations between objects than the right hemisphere damaged (RHD) group. Voxel-based lesion-symptom mapping (VLSM) analysis showed damage to the left posterior middle frontal gyrus, the left inferior frontal gyrus and the left anterior superior temporal gyrus. Göksun and colleagues also found a negative correlation between the extent of gesture use and naming accuracy. That suggests that gestures are used as a compensation for difficulty in the production of the locative preposition, but patients with a lesion in the left posterior middle frontal gyrus and the left inferior frontal gyrus might not gesture as much as expected to compensate for their naming impairment.

Amorapanth and colleagues (2010) studied the neural processing of categorical spatial relations in right and left-brain damaged patients. Images were shown to the patients representing two objects and a spatial relation (*above, below, in, on, left, right, in front of*, or *behind*) (Figure 4.6). Patients were instructed to press a button to indicate whether the current image matched the previous one based on either object type (both objects are the same as the previous slide) or spatial relation. No difference in accuracy or in reaction times were found between participants. A bilateral activation across patients was found in the superior parietal lobules, the inferior parietal lobules and the middle temporal cortices for the judgment of spatial relations. Significantly greater activity in the left inferior parietal lobule was found for the spatial relations. In a second experiment participants were divided in two groups depending on the side of the brain lesion. Patients had to match a picture representing a spatial relation to one of the other four presented (Figure 4.7). Two similar tasks were presented; the first one (categorical spatial match) was aimed to study patients' ability to match pictures on the basis of categorical spatial concepts, in the second task (coordinate spatial match) the aim was to assess patients' ability to match pictures based on the metric spatial distance. Results showed that the LHD group performed relatively better in the categorical task compared to the coordinate task and the opposite pattern was found in RHD patients, with a better performance in the coordinate task compared to the categorical task. For the categorical spatial matching task in the LHD group a correlation between the impairment and the lesion in the posterior middle and inferior frontal gyri, the supra-marginal gyrus and the angular gyrus, and the white matter undercutting to the anterior temporal gyrus. In the RHD group the impairment correlates with a lesion in the superior temporal gyrus, supramargynal gyrus and the angular gyrus. For the coordinate spatial match task, in the LHD group correlation was found between task impairment and lesions in the angular gyrus and the inferior temporal gyrus; for the RHD group a correlation between impairment and damage in the middle temporal gyrus was found. This study proves that there is a bilateral network involved in the recognition of spatial relations.

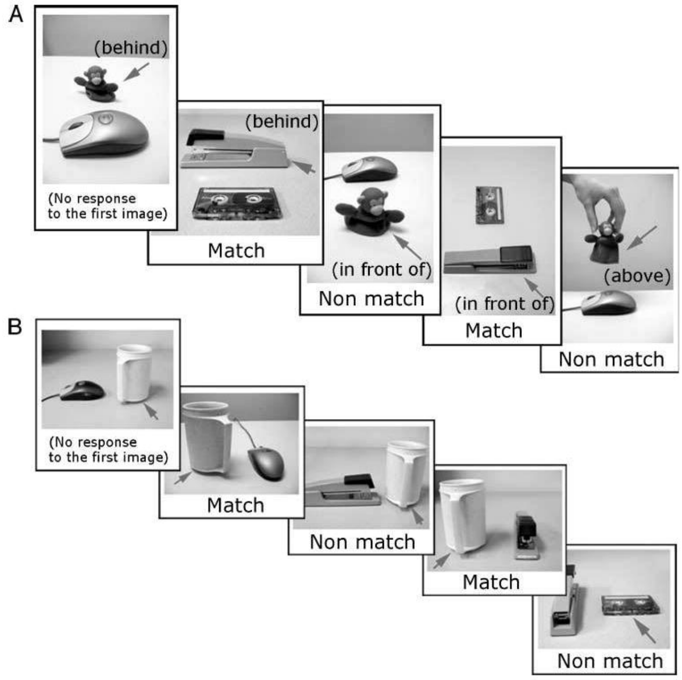


Figure 4.6 *The stimuli used by Amorapanth and colleagues (2010) in the fMRI study. A) spatial condition; B) object condition.*

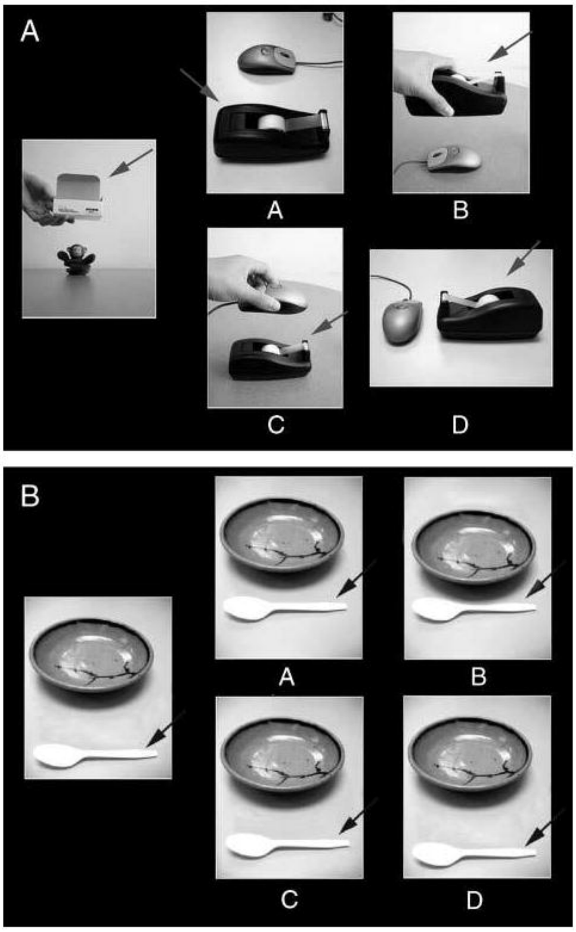


Figure 4.7 *Stimuli used by Amorapanth and colleagues (2010) in the lesion study. A) categorical match; B) coordinate matching task.*

4.3.1.4 The current study

We reviewed the brain anatomy of peripersonal and extrapersonal space, and the studies testing spatial language in brain-damaged patients. From the literature above there is no clear understanding of the implication of the right-brain in the use of spatial language. Amorapanth and colleagues' results seem to agree that both hemispheres are working together to recognise spatial relations. More recently, in a fMRI study Rocca and colleagues (2020) tested brain activation while participants were hearing spatial demonstratives. The results showed a bilateral activation of parietal areas and frontal areas. These areas are usually involved in space perception and attention orienting, and a lesion in these areas is often associated with USN. Rocca's et al. results suggest that space perception areas are involved in the understanding of spatial demonstratives. If areas involved in space perception are important for the elaboration of spatial language we could hypothesise that patients affected by USN might have issues describing spatial relations and using spatial demonstratives. To our knowledge, the use of demonstratives has never been tested in USN patients, testing stroke patients is important to better understand the brain anatomy of demonstratives use and the mapping between space perception and language.

The current study aims to further investigate the mapping between space perception and demonstratives use. If this mapping is indeed present, we would expect that patients with problems in space perception will also have problems in the production of demonstratives. In particular, patients with USN have problems in elaborating the contralesional side of space, we will therefore expect problems in the use of demonstratives in the contralesional side, but not in the ipsilesional side. In particular, we would expect a drop in the use of the proximal demonstrative compared to the right side. In addition, as we reviewed above, in some patients a dissociation between near and far USN has been found, we would therefore expect that patients that manifest neglect only in far space will not use demonstratives in a different way for the left and the right side in for near space, but we will assist to a difference for far space, and vice versa.

As we have seen before, Amorapanth and colleagues (2010) results lean toward a bilateral network that is involved in the recognition of spatial relations. On the other hand, Noordzij and colleagues (2008) in a fMRI study found that the left inferior parietal regions are fundamental for processing prepositions. If the left inferior parietal regions are the only areas used during the processing of spatial prepositions, we would not expect any issue in the production of spatial prepositions in patients with USN. However, due to the activation of the *'where pathway'* in Rocca's et al. study and the results found by Amorapanth we might expect a lower performance at the SNT in USN patients.

4.4 Methods

The study took place in Turin (North-Italy) at the San Camillo Health Care Center[1]. Patients were referred by the neuropsychologists, based on their judgement all patients were able to give consent and they were divided in two groups depending on the presence of USN based on the neuropsychological assessment run by the hospital staff (Behavioural Inattention Test, BIT used as main measure for the presence of USN). No speech disorder was recorded during the assessment and for some patients a Verbal Fluency test was performed to be sure that no issues in speech production was present. The test did not show major speech impairments, only one patient (N8) had major problems performing the test however that was due to not having understood the task correctly. The study was divided in two sessions. In the first session the patient was introduced to the research and consent was gained. After that, a semi-structured interview about their life and languages was conducted and then the use of prepositions was tested with the Spatial Naming Test (STN) was administered. In the second session the presence of neglect for the near and the far space was assessed with the bisection and the Bells' test in the near and the far space and, finally, the use of demonstratives was assessed. All the tests (apart from the bisection test

[1] The San Camillo is not an emergency hospital, therefore patients are usually transferred there for the recovery and rehabilitation and therefore there are in a sub-acute or chronic stage. CT scans of the patients were collected when possible, however the medical team did not possess the CT scans of all the patients, in addition due to COVID-19 it was not possible to ask and collect the scans of the last patients in the study. Hence, no brain analysis was run in this study.

where pictures were taken) were video recorded and patients' answers were checked from the videos. Both the sessions were a duration of less than 1 hour.

4.4.1 First session:

4.4.1.1 Semi-structured interview

As we said previously in this chapter, different languages use different types of demonstratives systems, therefore it is important to know what languages a patient is able to speak, if for example they were born in another country or if they lived in another country most of their life. In the elderly population the use of the dialect is still dominant, with people growing up in small villages. Furthermore, the dialects have different demonstratives systems and a three-way demonstratives system is still used in some parts of Italy. For example in Piemont (the region where Turin is located) the system used is close to the French system of demonstratives. A proximal term and a distal term are present, but the demonstrative needs to be used together with the adverb *'here'* or *'there'*. However, Turin is a big industrial city, and in the postwar period a lot of people from the south of Italy moved there, hence it is not difficult to find people from different parts of Italy. In addition, as we have seen earlier in Tuscany, and in particular in Florence, the third demonstrative is still used. During this interview patients were asked simple questions such as where they were born, where they lived and which languages they used to speak, or they are usually speaking with friends/ family and partner.

4.4.1.2 Spatial language assessment -- Spatial Naming Test

The same test used with the healthy subjects was used, the same instructions were given. Participants saw all the 30 stimuli of the SNT, however the scoring was adapted for the Italian language. The stimuli where a low accuracy was registered in the young healthy participants were removed after testing and not analysed (please refer to p. 134 for more details about the stimuli).

4.4.2 Second session:

4.4.2.1 Neglect assessment – Bisections and Bells test

Neglect was assessed with two tests: the bisection test and the Bells test. Ferber and Karnath (2001) showed that there is a dissociation between bisection tests and cancellation tests. Results showed that the bisection test missed 40% of the neglect patients while the cancellation tests (letter cancellation or the Bells test) missed only 6% of the patients with neglect. That might be due to the fact that some patients might manifest hemianopia (contrary to USN it is a vision problem that can arise after a stroke and entails the loss of vision in an hemifield or part of it) and this can affect the perception of the line length. Molenberghs and Sale (2011) confirmed Ferber and Karnath's results. Paper and pencil tests (bisections and cancellation tests) were linked to patients scans and although the tests underlie the same cortical deficits the cancellation task was more sensitive. Therefore, it is important to include both tests in the assessment of USN.

4.4.2.2 Bisection test

Lines were presented in near space (30cm from the patient) and in far space (120cm from the patient). Lines were presented on a A4 white panel for near space and on a A0 white panel in far space. The line length was 18cm for the near space and 72cm for far space. Panels were placed vertically in front of the patient (see Figure 4.8). Participants were instructed to point at the middle of the line either with a telescopic pointer or a laser pointer. To avoid giving cues to the patient by measuring the middle of the line, pictures were taken of the line and the pointing and afterwards the bias was measured.

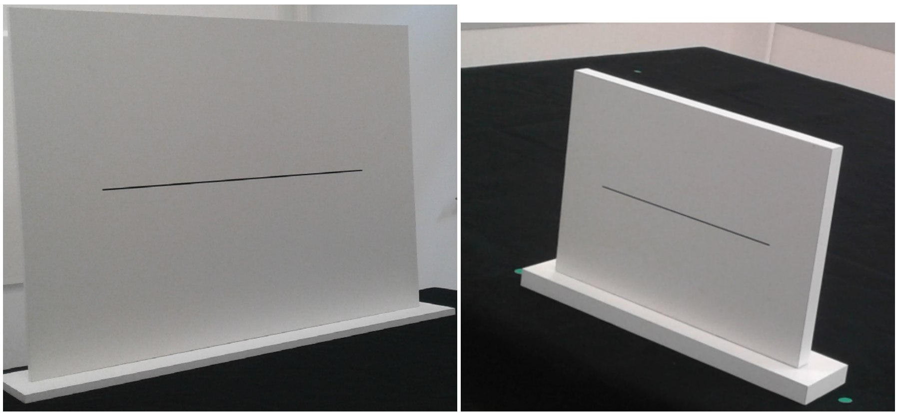


Figure 4.8 *Example of the panels used for the bisection test. On the left the panel used for far space (panel size: A0; line length: 720mm); on the right the panel used for near space (panel size: A4; length size: 180mm).*

4.4.2.3 Bells test

The Bells test was printed on two white panels (see Figure 4.9), in an A4 format for near space and an A0 format for far space. Panels were placed vertically at 30cm and 120cm from the patient. The patient was instructed to find all the bells present on the panel within the other shapes. Patients pointed either with a telescopic pointer or a laser pointer in both near and far space. The test was video-recorded.

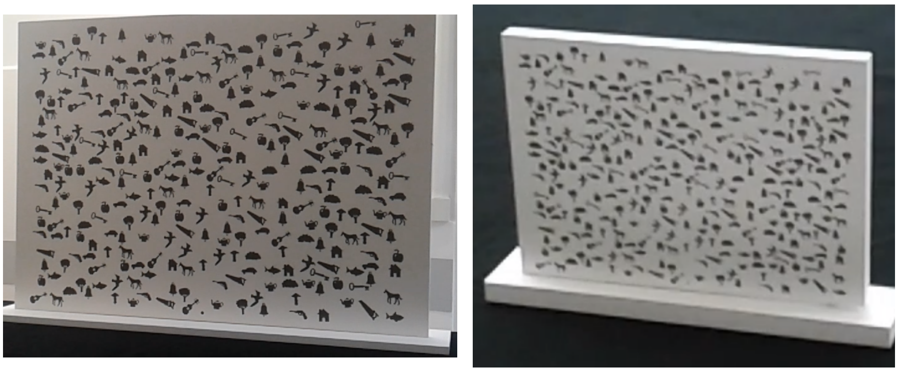


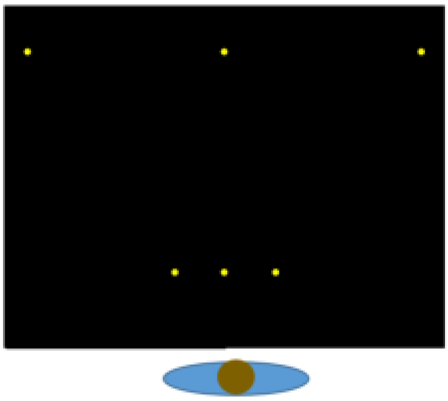
Figure 4.9 *Example of the panels used for the Bells test. On the left the panel used for far space (panel size: A0); on the right the panel used for near space (panel size: A4).*

4.4.2.4 Demonstratives test

Six positions were individuated in front of the participant: three in the near space (30cm) and three in far space (120cm). Positions were marked on the left, the middle and on the right of the patient, in near space positions and far space positions. Marked positions in far space were corrected by visual angle.

On every trial, two objects (an orange or blue star and an orange or blue triangle) were placed vertically (See Figure 4.10) on one of the six positions (see. Figure 4.11A). 7 combinations of object locations were used (Figure 4.11B). Patients were asked to close their eyes; the experimenter then placed the objects on the table and once the experimenter was out of sight, patients were asked to open their eyes again. First of all, the experimenter made sure that the patients were able to see both objects by asking them how many objects were on the table. If the answer was that there was only one object the patient was encouraged to look more on the left side (as we were supposing that the patient was neglecting the left side). The question was repeated twice, and if the patient continued to neglect the object on the left, the following trial was administered. Patients were then asked: e.g. *'which one is the orange star?'* (*'Qual è la stella arancione'*) and they were asked to point at the object and answer with *'this'* (*'questa'*) or *'that'* (*'quella'*).

Figure 4.10 *The four objects used in the testing of demonstratives.*



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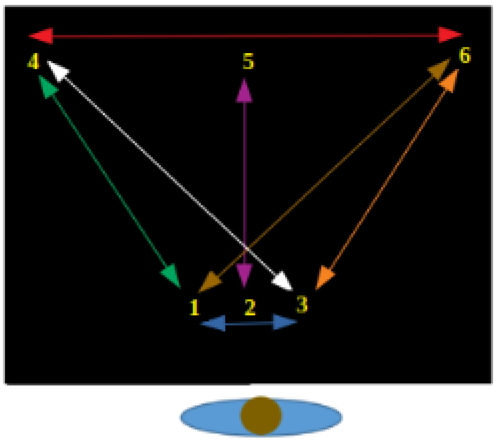


B

Figure 4.11 A.*Example of the setting used for the demonstratives test. In yellow the 6 positions used are marked.* ***B.*** *Arrows indicate the combinations used for the placement of objects. numbers indicate the positions marked on the table, arrows indicate where object 1 and object 2 were placed. For example the green arrow indicates that one object was placed on position 1 (near space left) and the other on position 4 (far space left).*

4.4.3 Participants

13 patients were tested. 10 patients with USN (based on the assessment run by the neuropsychologist in the hospital) and 3 without USN. As we said before, patients were in the care center for rehabilitation, rehabilitation and tests are done by the neuropsychological

group based on the patients needs and symptoms shown. All patients have a cognitive assessment, usually the Montreal Cognitive Assessment (MoCA) is used and for cases of USN the Behavioural Inattention Test (BIT) test is used. In case there is no suspect of neglect the BIT test is not performed. One patient was not able to complete the Bells test (R26), and one patient did not take part in the demonstrative test. As assessed in the semi structured interview all the participants were Italian native speakers, and no speaking problems were reported by the neuropsychologists.

Table 4.4[2]*List of patientients with (N) and without USN (NN), age, gender and the scores of the BIT are reported.*

			BIT	
Patient	**Age**	**Gender**	**Conventional**	**Non-conventional**
N1	68	F	44	98
N2	79	M	NA	NA
N3	66	M	122	56
N4	70	M	102	70
N5	71	F	127	81
N6	75	F	25	9
N7	NA	NA	NA	NA
N8	NA	NA	NA	NA
N9	NA	NA	NA	NA
N10	NA	NA	NA	NA
NN1	79	M	NA	NA
NN2	NA	NA	NA	NA
NN3	NA	NA	NA	NA

[2] Please note that for the last patients no data is available due to the impossibility in entering the hospital and retrive the data due to the COVID-19 emergency.

4.5 Results and discussion

4.5.1 USN tests assessment

4.5.1.1 Bisections

The average bias was calculated for each patient for the two conditions (far and near stimuli). In the table below (Table 4.4) we can see the bias for near and far space using the pointer and the laser.

Table 4.5 *Average error in mm for each participant, SD into brackets. Errors higher than 6mm (for near space) and 24mm (for far space) are marked in red for a bias toward the right side and in blue for a bias toward the left side.*

	Near		Far	
Participant	**Pointer**	**Laser**	**Pointer**	**Laser**
N1	-1.52 (11.21)	1.95 (11.74)	2.8 (51.34)	-52.94 (16.72)
N2	13.5 (22.92)	24.33 (31.80)	120.57 (16.39)	115.96 (48.87)
N3	-3.19 (1.21)	-3.42 (2.17)	-4.32 (9.66)	-14.4 (8.44)
N4	-6.61 (14.94)	-2.7 (13.03)	-4.41 (8.38)	1.82 (3.64)
N5	-0.41 (1.73)	-5.38 (2.78)	-10.48 (13.15)	-25.95 (29.15)
N6	-5.71 (10.61)	-7.87 (6.19)	-72.07 (41.38)	-52.99 (25.80)
N7	6.79 (3.40)	-19.72 (4.38)	105.24 (10.38)	36.28 (22.33)
N8	30.6 (24.32)	27.9 (8.05)	121.34 (98.54)	134.28 (138.73)
N9	10.21 (4.14)	2.25 (11.58)	73.38 (22.58)	64.64 (62.28)
N10	-0.67 (9.55)	-32.67 (28.62)	-7.09 (24.65)	-42.22 (71.22)
NN1	-7.56 (1.02)	-4.44 (5.89)	-30.97 (7.71)	-24.34 (6.88)
NN2	-5.75 (3.32)	-3.86 (10.01)	2.32 (12.58)	-21.83 (13.30)
NN3	0.4 (4.91)	-6.56 (3.58)	3.51 (19.97)	20.32 (16.99)

Patients N2, N8 and N9 manifest a large bias toward the right side in near and far space. Patient N7 manifests neglect only when the test was run in far space.

4.5.1.2 Bells test

The number of omissions for each section was calculated for both conditions (Table 4.5). In the table below we can see the number of omissions for the left and right side of the test for near and far space.

Table 4.6 *Omissions for the left and right space for each condition.*

	Near				**Far**			
	Pointer		**Laser**		**Pointer**		**Laser**	
Patient	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
N1	17	13	17	13	17	9	17	7
N2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
N3	6	2	8	1	9	6	8	1
N4	7	4	10	7	14	3	10	11
N5	14	9	7	1	13	9	N/A	N/A
N6	17	14	17	9	17	12	17	12
N7	16	9	16	14	17	11	17	7
N8	17	14	17	15	17	14	17	13
N9	16	6	13	10	14	11	14	12
N10	9	2	10	1	9	1	13	4
NN1	0	0	0	1	1	0	0	1
NN2	2	4	2	3	1	2	2	1
NN3	6	7	5	5	4	5	5	7

All the patients in the USN group showed a high number of omissions, in particular in the right space, and they had a tendency to explore the right space more. Participant NN1 and NN2 showed very few omissions and explored the panels from left to the right side. Patient NN3 missed more bells, suggesting an attentional problem, however no big difference was found between the left and the right space and no USN symptoms were present.

In conclusion, taking the results of the bisection test and the Bells test together, the Bells test resulted in a better predictor of USN. A dissociation between near and far neglect was found only in patient N7 that manifested a right bias only when asked to bisect the line in the far space, however no space remapping was found, in fact the bias was recorded also when pointing with the pointer in the far space. In addition, the Bells test did not show a clear USN for the far and near space.

4.5.2 Spatial language assessment

4.5.2.1 Demonstrative test

Results of the demonstrative test were analysed with a mixed 3-way ANOVA, 2 sagittal distances X 3 lateral positions (within participants) X 2 groups (between participants). The variable *'group'* (USN group = patients with USN; NN group= patients without USN) was added to analyse if any difference in the use of demonstratives was present in the two groups, however we need to underlie that the NN group was very small, therefore there is a high chance of type II error.

The table below (Table 4.6) shows the percentage use of *'this'* for each position and for each group (USN group, N=8; NN group, N= 3). Please note that data of two participants in the USN group are not available. Patient N2 could not see the objects placed on the left side, therefore he could not be added to the sample and patient N8 did not take part in the test due to technical difficulties.

Table 4.7 *Percentage use of 'questo' ('this').*

	USN group		
	Left	**Middle**	**Right**
Far	10.00%	12.50%	8.25%
Near	91.25%	100.00%	93.38%

	NN group		
	Left	**Middle**	**Right**
Far	0.00%	16.67%	0.00%
Near	83.33%	100.00%	94.44%

A sagittal (near x far) X lateral (left x middle x right) X group ANOVA was run. The results showed an increased use of *'questo'* (*'this'*) for the reachable positions and an increased use of *'quello'* for the far space, $F(1, 9)=91.270$, $p< .001$, $\eta p^2 = .910$. A significant effect of lateral position was found, $F(2, 18) = 5{,}993$, $p= .010$, $\eta p^2 =.400$. LSD post-hoc tests revealed a significant difference between the left and the middle position ($p=.028$) and between the middle and the right position ($p=.036$); no significant difference was found between the left and the right positions ($p=.199$). No significant difference of group nor significant interactions were found.

4.5.2.2 Spatial Naming Test

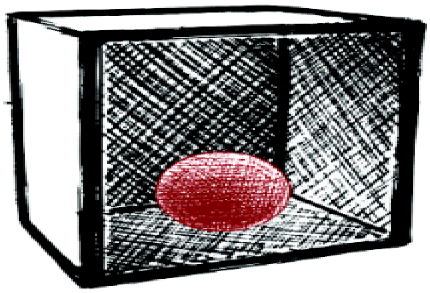
The total score was calculated for each participant removing the stimuli where a low accuracy was registered in the testing with healthy participants, leaving 13 stimuli for the static spatial relations part and 10 for the dynamic spatial relation part. In the table below you can see the scores for the static and dynamic test (Table 4.7), the total score and the percentage of accuracy for each participant.

Table 4.8 *Results of the SNT. The total score, the accuracy and the scores for the static and dynamic parts are reported.*

Patient	Total	Accuracy	Static score	Dynamic
N1	11.5	50.00%	9	2.5
N2	4.5	19.57%	0.5	4
N3	14.5	63.04%	7	7.5
N4	13	56.52%	8	5
N5	9	39.13%	6	3
N6	8	34.78%	5	3
N7	12	52.17%	7	5
N8	10	43.48%	7	3
N9	16	69.57%	10	6
N10	11.5	50.00%	7	4.5
Average	11	47.83%	6.65	4.35
NN1	20.5	89.13%	13	7.5
NN2	20.5	89.13%	12	8.5
NN3	18.5	80.43%	11	7.5
Average	19.83	86.23%	12	7.83

After removing the low accuracy stimuli in the healthy participants an accuracy of 85% with the lowest score found at 17. In the USN group the average score was 11, with an accuracy of 48%. Patient N2 produced the lowest score in the group (total score= 4.5) with an accuracy close to the 20%. Patient N2 is also the patient that manifested the most severe neglect. The highest score was registered for patient N9 (a score of 9), with an accuracy close to the 70%. This result is only 1 point lower than the lowest score recorded in healthy participants. On the other hand, the three patients without USN had scores comparable to the scores of healthy subjects. Both patient NN1 and patient NN2 scored 20.5 (89% accuracy) and patient NN3 scored 18.5 (accuracy of 86%).

When analysing the answers of some patients it was difficult to understand what they were describing, for example patient N2 described the figure representing the *'ball in the box'* with the words: *'sotto nella biforcazione'* (*'under in the bifurcation'*), the world *'bifurcation'* has been repeated more times by the patient for different stimuli. We could think that the patient was not able to perceive the entire picture, therefore the box was not complete and the ball appeared between two lines instead of surrounded by 4 lines composing a square (Figure 4.12).



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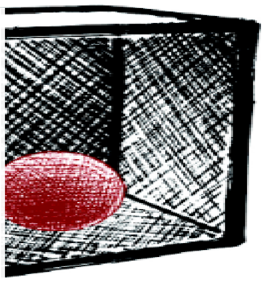

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Figure 4.12 ***A.*** *Example of the box shown to the patient.* ***B.*** *An example of how the patient might have perceived the box, if they are not able to see the left half of the stimulus they are not aware of the object being a box, the two lines that connect to create the bottom corner might be the 'bifurcation' the patient is talking about.*

Some stimuli had a lower level of accuracy in average, stimuli with a value of accuracy lower than the 60% are reported below (Table 4.8 & Table 4.9).

Table 4.9A *Stimuli with a low accuracy for part A.*

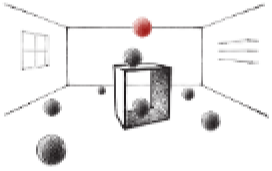
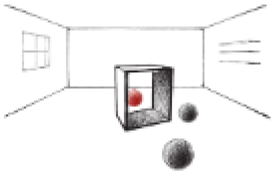
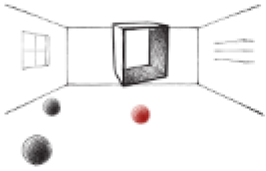
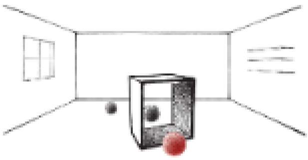
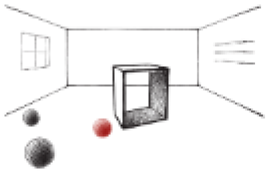
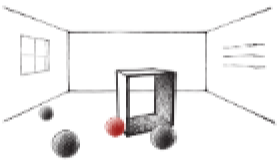
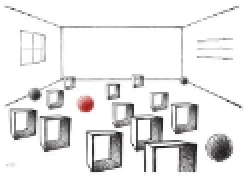
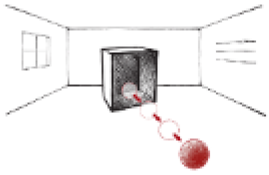
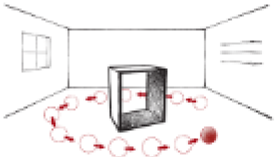
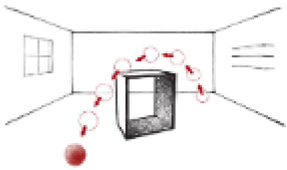
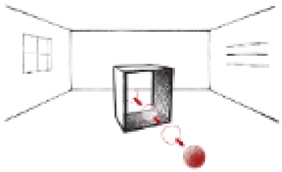
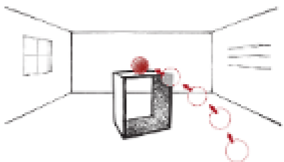
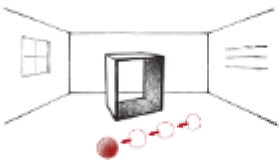
	Stimulus	Accuracy
A4		50%
A5		20%
A7		45%
A8		30%
A10		55%
A11		50%
A13		10%

Table 4.9B *Stimuli with a low accuracy for part B.*

	Stimulus	Accuracy
B6		50%
B8		40%
B9		15%
B11		20%
B12		40%
B14		0%

4.6 Discussion

In this chapter we studied the use of spatial language in patients with and without Unilateral Spatial Neglect. Due to the experiment being run in an Italian hospital and therefore the patients being Italian native speakers, we first tested the use of spatial language in healthy Italian native speakers. We first tested the use of demonstratives with the *'memory game'* paradigm. Results showed an increased use of *'this'* for the reachable positions, and an increased use of *'that'* as objects were placed at increasing distance in extrapersonal space. Hence, we can conclude that the Italian demonstratives system is distance based and the results are comparable to the previous data collected with the *'memory game'* paradigm in English and Spanish (Coventry et. al, 2008; Coventry et al., 2014, Gudde et al., 2016, Griffiths et al., 2019, Caldano & Coventry). The Spatial Naming Test was then used to test the use of spatial language to describe spatial locations. The same test used for the English language was used, however some differences were found in Italian. The scores for the Italian participants were lower than the English group (Markostamou, 2017). However, after removing the stimuli with low accuracy from the sample the average accuracy was comparable to that found with English participants. The difference between the two samples can be attributed to the fact that no precise translation of some English prepositions can be found in Italian, for example in some cases a verb is used instead of a preposition. As a result, the SNT was modified accordingly for use in Italian.

The use of spatial language was then tested in right-brain stroke patients. This was an exploratory study to better understand if patients that have problems with space perception also have issues using spatial language.

In the first session the SNT was used to test the use of spatial language, and spatial prepositions in particular. Some differences were found between participants. The average accuracy in the USN group was lower than in the Non-USN group. Due to the difference in the samples and the very low number of participants in the non-USN group no reliable statistical analysis can be run to determine if there are statistically significant differences in performance between the two groups. However, we can see that the average accuracy of the USN group is under the 50% whereas the accuracy for the non-USN group is higher than 80% (and comparable to the results found with healthy subjects). Looking at the results of singular patients the highest score found was close to 70% accuracy and the lowest score in non-neglect patients was 80%. We can therefore see that a difference is indeed present in the two groups, but of course further testing needs to be carried out to increase the control sample to a comparable size.

In the second session, the presence of USN for the near and far space was assessed and the demonstratives test was carried out. However, the test, contrary to the previously reviewed papers, used a contrastive use of demonstratives. The contrastive use of demonstratives has previously been tested in Danish (Rocca et al., 2018). The results showed an increased use of the proximal demonstrative when the object was closer to the speaker and far away from the other object. In the current study, only 3 positions per peripersonal space and extrapersonal space were tested, therefore the methodology might not have been powerful enough to show a deficit in the use of demonstratives. Better and more precise results could be obtained with more positions in particular in the lateral space. However, the test was already 20 minutes long and most of the patients would not be able to take part in a longer test. In addition, no patient showed a clear dissociation between far and near USN, as we hypothesized a difference in the use of demonstratives might be present in patients who manifest a dissociation between far and near USN, this hypothesis could not be tested, and therefore a deficit in the use of demonstratives might be indeed present in those patients. However, the dissociation is very rare and it has been described in few cases in literature.

In conclusion, demonstratives in Italian follow the mapping between perceptual space and demonstratives use. The presence of Unilateral Spatial Neglect does not affect the use of demonstratives, however issues in the use of spatial language have been found in patients with USN via differences in performance on the SNT. Further testing needs to be carried out to better understand how USN affects the use of spatial language, and in particular larger sample sizes are needed to compare the results in the two groups.

Chapter 5

General discussion

In this thesis a total of 7 experiments were conducted. The link between spatial perception and language was explored in both healthy participants across two languages - English and Italian - and in an exploratory study with right-brain stroke patients. In this chapter we will first summarise the results of each experiment and then we will explore the implications of the results, limitations of the methodologies used, and future directions for research.

5.1 Experiments 1,2 & 3

5.1.1. Summary of findings

In chapter 2 we tested the effect of lateral distances, hand and side on the use of demonstratives in right-handed and left-handed participants. In addition, in right-handed participants the use of a tool was also tested. A modified version of the *'memory game'* test devised by Coventry and colleagues (2008) was used to extend the testing to the lateral plane.

The results of combined analyses showed an increased use of *'that'* for the farther positions. This result replicated the previous findings of experiments using the *'memory game'* paradigm (Coventry et al., 2008; Coventry et al., 2014; Gudde et al., 2016; Griffiths et al., 2019). The novelty of this study was the use of lateral distances as well of sagittal distances and the use of the preferred and the dispreferred hand to point at the placed objects. Results revealed an increased use of *'that'* for the farther positions in the lateral space, proving that distance is an important feature in the use of demonstratives also in the lateral space. No main effects of hand and side were found, however a more interesting interaction between distance and hand and side was found. When pointing with the left hand toward the right side we assisted to a drop in the use of *'this'* compared to when the participant was pointing with the right hand toward the right side, and vice versa. This effect was found in the second further distance, where the farther position on the right could be reached with the right hand, but not with the left hand (and vice versa), underlining the importance of distance and reaching in the use of demonstratives. This result strengthened the mapping between perceptual space and language. In the third experiment a main effect of tool use was found in the middle line, suggesting that peripersonal space can be extended in the sagittal plane and that the use of the proximal demonstrative is increased when reach is increased.

Results of the three experiments strongly support the mapping between space perception and demonstrative choice. Consistent with previous studies (e,g, Coventry et al., 2008, Coventry et al., 2014), '*this'* is used more in PPS in the sagittal plane, with reliable differences between reachable and non-reachable locations.The novelty of this study was the use of lateral positions and the findings showed that the effect of distance operates also in the lateral space. A particular interesting result found was the interaction between hand, side and sagittal distance. This finding strengthened the evidence for the mapping. The use of the proximal term in the same locations is affected by the hand used to point at those locations, and critically whether the object is within or outside of reachable distance.

Lastly, an effect of tool use was found underlining the effect of distance in the use of demonstratives, however a main effect of tool use was found only in the middle line. This could be because it is actually difficult to operate a tool in the lateral space, in particular because participants were asked not to move and stretch. We could think that a major body movement needs to be done operating a stick in the lateral space, in particular in the opposite space. Nevertheless, contrary to experiments 1 and 2, an interaction between side and hand used was found, underlining that acting in the contralateral space becomes more difficult when using a tool and that the differences between the two spaces become more salient when a tool is involved in the experiment.

5.1.2. Methodological concerns and future directions

The *'memory game'* paradigm is a well established methodology to test the use of demonstratives. However, the non natural setting can be criticised, and in particular the method requires the participant to use one of the two demonstratives when pointing at the object.The laboratory is a controlled environment, and affords testing distances with precision that would be hard to achieve in a more naturalistic setting. Nonetheless, the memory game paradigm involves limited interaction between participant and experimenter, and therefore the absence of dyadic interaction may limit the generalizability of the results. In some variants on the memory game paradigm, the setting has been manipulated such that it approaches more naturalistic interaction. For example, Coventry et al. (2008) manipulated the position of an interlocutor (the experimenter), as we did for the Italian version of the task in experimenter 6, such that half the time communication took place within a more dyadic (face-to-face) setting. The paradigm could be further developed to further increase the nature of interaction between participants. For example more conditions can be added where the position of an interlocutor can be varied throughout the experiment. For example, if an interlocutor is sitting on the right side in a middle position (Figure 5.1) and the object is placed on the right side we could expect an increased use of *'this'* compared to when the object is placed at the same distance from the participant but on the left side, and vice versa. In this way we can test whether demonstratives are used in a different way when the participant is able to reach the object, when both, the participant and the interlocutor are able to reach the object, when only the interlocutor is able to reach the object, and when none of them can reach it in the lateral space. In addition, the distances, both on the lateral and sagittal plane should be increased to make sure that all conditions can be easily tested.

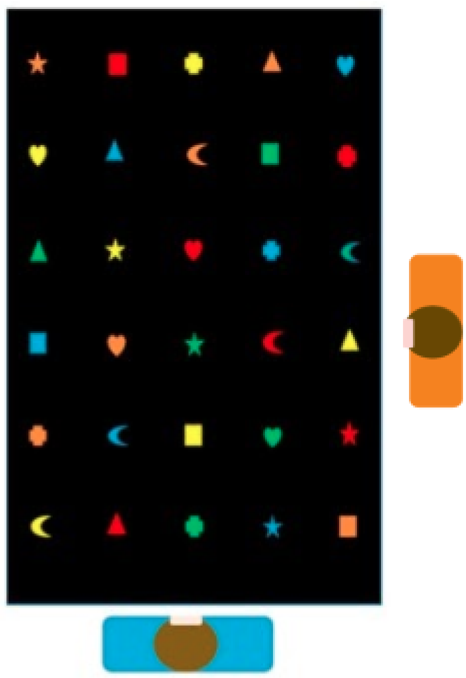


Figure 5.1 *Example of a set up to test the effect of the hearer on the use of demonstratives in the sagittal and lateral space. In this case, both participants are able to reach the green heart, but only the experimenter (orange) is able to reach the green square.*

In all three experiments, the positions were modified for each participant based on reaching distance. The positions were painted on a tablecloth that could be moved back and forward, in this way we could have more precise results based on participants' reach. However, the method is not perfect. Reaching can be influenced by a lot of variables such as arm length, shoulder width and body composition. Hence, our measurements were not perfect, but the need to physically mark the positions meant it was not possible to change the distances between the positions for each participant. Technology may help us improve the methods. Precise measurements of participant's reach can be taken with a touch screen table, if we ask a participant to reach as far as they can, without stretching, on the table the measure can then be translated into the farthest reachable position and the other locations can be calculated accordingly. In this way the proportion between the reaching and each position will be the same for each participant, giving us a much more precise measurement.

Only two distances were tested in the lateral space for each side. In further experiments more positions could be added to have more non reachable positions in the lateral space for each side. For example in the first line all the positions were reachable. It would be interesting to have not reachable distances in the first line and compare the use of demonstratives between an object placed in the far right (or left) and an object placed in front of the participant at the same distance. This will help us to better understand how people perceive distances and reaching in the lateral space and how language is used accordingly. In particular, adding more positions can help better understand the effect of a tool in the lateral space, as we can better test if the tool use is increasing the use of *'this'* in the same way in the lateral space if positions reachable with a tool but not with the hand are added.

Lastly, no main effect of handedness and of hand was found. However, the objects were flat plastic disks, that therefore did not possess any inherent affordances, and participants were asked only to point at the object without interacting with it (through touch). It could be possible that different results could be obtained when an object, for example a mug, is used as people are used to grasping such an object and seeing the object can therefore activate affordances that relate to a specific action accomplished with a specific hand (the preferred hand).

5.2 Experiments 4 & 5

5.2.1 Summary of findings

In chapter 3 we tested the use of demonstratives for 2D images. A PC screen table was used to show the images and to place real objects.

In the first experiment pictures of objects and real objects were shown, and the *'memory game'* paradigm was used to test the use of demonstratives. Congruent with the results of previous experiments a main effect of distance was found, with an increased use of *'this'* for peripersonal space relative to extrapersonal space. The effect was present in both the image and real object conditions, no main effect of the object was found. A significant interaction between the condition and the group was found. Groups were created depending on what condition the participant underwent first (group 1- image first, group 2- 3D object first). An increased use of *'this'* for the 2D objects in the group that underwent the 2D condition first. This result reveals that there is a difference in the use of demonstratives when the 2D image is shown first, however no main effect of object type has been found in the full sample. This interaction suggests that future studies should consider the order effect and how it can possibly affect the results.

In the second experiment, the use of demonstratives for images of objects (a mug with the handle facing the left side, a mug with the handle facing the right ride, a glass, a cactus and a star shape) was tested. The same PC screen table of experiment 4 was used. As before an effect of distance was found. But no main effect of object type was found, nor a significant interaction between distance and object type.

5.2.2 Methodological concerns and future directions

Some methodological issues can be identified for the two experiments delineated in chapter 3. First of all, the 'real' objects used in the first experiment were disks with a shape printed on them and the participant was asked to name the shape, therefore the difference between the real object and the 2D image may not have been salient enough. The objects were created in that way to be consistent with the objects used in the previous studies. To better test the difference between the 2D and the real objects, the actual shape should have 3 dimensional features.

Another problem was related to the construction of the table. The screen was not built to be placed flat on a table, but to hang on a wall, and to be looked at from a frontal position and not from the side. Looking at the screen from a lateral point of view creates a disparity in the real position of the object, looked from the front, and the position of the object seen from the side. This effect follows a curved pattern, in the half size of the screen closer to the participants the image was appearing closer than the real position, and in the other half it was appearing farther away. This optic effect was bigger farther from the middle line. The experimenter was placing the real object on top of the image (that was then disappearing), therefore the objects were in the same positions, however for the optic effect created by the screen, from the participant's point of view the image was appearing closer (for the near half of the screen) and farther (for the far half of the screen). Nonetheless, the variation in distance was very small.

Furthermore, the screen has a protective glass on top. When the real object was shown, the virtual dots marking the positions where appearing (only the one marking the position where the object was appearing was not shown). Because of the protective glass, the real object was appearing on a higher level than the dots, and also of the 2D images shown in the other trials. However, as no main effect of object type was found, we could assume that this should not be considered a problem and it did not impact in the results, as if the different level had an impact on the use of demonstratives, we would have expected a higher difference in the use of demonstratives between the two conditions.

In the second experiment we tested the use of demonstratives for images of graspable and not graspable objects. 5 objects were tested: a mug with the handle facing toward the left side, a mug with the handle facing toward the right side, a glass, a cactus and the shape of a star. In this experiment we wanted to see if the affordances of the objects have an effect on the use of demonstratives, in particular in the peripersonal space. However no effect of object type was found. We need to underline that this was an exploratory study and only a few objects were used. In further studies more objects should be tested. In fact, three of the objects were graspable (the mugs and the glass), one was not graspable due to the thorns (the cactus) and one was a control object showing a shape used in the previous studies. In particular, no difference was found for the graspable objects, we were expecting a difference in the use of demonstratives for the mug facing the left side compared to the mug facing the right side, however we can argue that we do not always use the handle to pick up a mug and that it is still graspable when the handle is facing the opposite side. Different objects that can only be grasped from one side should be used in future studies, for example a knife or a hammer. Furthermore, the flat nature of the images might not create strong enough affordances and to affect the use of demonstratives. Lastly, we were expecting an increased use of *'that'* for the cactus, some participants said that their attention was dragged more to the cactus because it was different from the other objects and/or because they like cactuses as plants. Valdés-Conroy and colleagues (2012) showed that affective value of objects influence perceived reaching. Therefore, if participants positively evaluate the cactus we would expect them to perceive it being closer, thus increasing the use of the proximal demonstrative for that object. Although that was not the case, however not every participant referred to like cactuses. Further studies should take into consideration the likeability of an object and participants' personal preferences. More spiky objects should be used in further experiments to better test the use of demonstratives for non graspable objects. Lastly, a version of the *'memory game'* with real objects such as mugs and other objects with a function and non graspable objects and the images of the same objects should be run. Experiment 4 did not show a difference in the use of demonstratives for 3D objects and images of objects. However, as we said before the participants were naming the shape printed. It is possible that a difference in the use of demonstratives for 3D objects and images is indeed present for objects that have an intrinsic function. In addition, a cactus or another spiky object might not be considered as dangerous when it is an image of it.

In conclusion, for the first time the *'memory game'* paradigm was run on a PC screen table showing images of the objects. No difference between type of object was found, however only few objects were tested in the current study, and only one 'spiky' object was used, therefore more research is needed and more objects need to be tested.

5.3 Chapter 4- Experiment 6 & 7

5.3.1 Summary of findings

In chapter 5 we explored the use of spatial language in patients with and without USN. The experiment was run in Italy, and therefore we first ran a pretest with healthy participants to understand how people use demonstratives in the Italian language. Results strongly support the mapping between space perception and language in Italian with an increased use of *'this'* ('questo') for the reachable positions. In addition no significant effect of addressee position was found. No difference was found in patients with and without neglect in the use of demonstratives. However, at the SNT low scores have been recorded for the USN group, suggesting that participants affected by USN have difficulties describing spatial relations. More research is needed to better understand this phenomenon.

5.3.2. Methodological concerns and future directions

For the pre-test no new paradigms were used, nor have they been modified. With regards to the test of demonstratives the *'memory game'* paradigm was used, this paradigm as we said before is a well established protocol to test the use of demonstratives that has been used across a range of different languages other than English (e.g. Spanish: Coventry et al., 2008; Japanese: Gudde et al., 2017; Estonian: Reile et al., 2020) and it proved to be effective for the Italian language as well.

Although, some differences between the English testing and the Italian testing were found for the Spatial Naming Test (testing spatial relations), this was to be expected given the considerable cross-linguistic variation in spatial adpositional systems. In particular, some problems have been noticed in the use of the Spatial Naming Test in Italian, participants were prompted to use prepositions, however for some tables no perfect translation is present in Italian (e.g. the same word can be used for *'on'* and *'above'*) and in some cases verbs are used and not prepositions (e.g. *'uscire': 'to get out'* to describe *'out of'*). The test has been adapted by dropping the stimuli with a low accuracy and where no perfect translation was possible. That left 24 stimuli compared to 30 stimuli of the English test. To Improve the test for the Italian language more stimuli could be created specifically to test Italian prepositions.

Regarding the experiment involving stroke patients a few issues arose. First of all, this was an exploratory study to better understand if the use of spatial language is intact in right-brain patients. Due to COVID-19 for safety of the patients and the experimenters the testing had to be suspended, therefore the sample was not complete and the control group had far fewer patients than the USN group making it difficult to compare the two samples. In addition to the issues found for the SNT used in the test with healthy participants, more problems specific to USN patients emerged. For some stimuli the target was located in the left space. To better test how impaired perception affects the use of prepositions specular stimuli (with the target object placed in the left and the right side) should be used. Showing the same stimulus with the target in the same position but on the left and then on the right part of the space can help us better understand the difference in the use of prepositions depending on space perception. In addition in some cases the answers given by participants were not clear and complete. To better understand why a determinate preposition was used, patients could be asked to describe the picture shown, and in that way we could better understand how many boxes and balls the patients can see and where they think the targets are located. For example one patient used the preposition *'on the left of the box'* instead of the preposition *'among the boxes'.* This could be because they could simply not see the boxes on the left, but another possibility is that when a picture involves many elements, it is more difficult for people with spatial perception difficulties to describe the spatial relation, and they may have considered only one box instead of all the boxes presented. Bochynska and colleagues (2020) used the SNT to test the use of spatial language in participants with autism. They found a significant difference in the score between autistic participants and typical developing participants, with lower scores in the autism group. In particular, lower scores were found for stimuli where more elements were presented in the scene. We might think that the same effect is present in USN patients and the more elements are inserted in the picture the more difficulties they have to process the image and describe the spatial relations correctly. In addition, more questions could be asked about the stimuli shown to the patients to better understand the types of errors made.

In the demonstrative test a main effect of distance was found in the sagittal and lateral space, comparable to the results found with healthy subjects. However, the test had some differences. First of all, the use of demonstratives tested was a contrastive use. In addition only six positions were tested, three in peripersonal space and three in extrapersonal space. Therefore, the difference between the near and far space was very clear, and it was easier to divide the space into near and far than into left and right. Hence, we should use more reachable and not reachable positions in the sagittal and lateral space, affording more power and therefore reducing the likelihood of type II errors. However, for some patients the length of the task was already demanding and patient groups may not be able to tolerate a longer study. We must also say that they took part in the bisection and bells test immediate before the test, so they were already fatigued from the previous tasks, nonetheless for some patients it is more difficult to repeat the same task than to take part in a one hour long session, therefore having one entire session with more trials for the demonstrative task might not solve the problem. One alternative could be to show the stimuli on a computer screen. In the current study the experimenter was manually placing the objects, checking what object to place, placing them and sign the answer can take a few seconds. The duration of the study can be decreased using a computer to show the stimuli. In that way the object can be shown in less than a few seconds, and more trials can be added in a short amount of time. This method can also help keeping the patient active, less bored and the patient would not be distracted nor oriented by the experimenter walking around them. On the same topic, the patient was instructed to close their eyes while the experimenter was placing the objects. Two problems come with this method: first, the patient is getting more sleepy and bored to not be active for a while and second, some patients were not actually able to close their eyes for so long and they were seeing the experimenter placing the object. To solve this problem PLATO goggles can be used to prevent the patient from seeing the experiment placing the objects and, as we said before, shortening the placement time can also tone down the trouble of having their eyes closed while someone is walking around them.

In the USN assessment not all the patients (in the USN group) showed USN at the bisection test and more than average bells were missed also by the non-USN group. The patients tested were following personalised stroke rehabilitation plans, thus they knew what the bisection test was, they were used to the test and they might also know that they have a tendency to bisect the line toward the right side and how to correct it. For example at the Bells test one patient, as soon as we started the test, stated: '*I need to go on the left because I cannot see things on the left'*, it was clear that instinctively they started the search from the right side of the panel, although they then corrected themselves. Usually the patients are asked to cancel all the bells on the sheet with a pencil, in this experiment they were asked to indicate them but no mark was applied on the bell when it was found, making the task much harder. That was due to the fact that no easy way was found for the experimenter to mark them without directing the patient in the far space and when the laser was found. To improve the method a PC screen can be used. For example the test can be shown on the screen and the experimenter can easily mark the bells shown by the participant. Alternatively, a touch screen can be used to indicate the bells with the pointer and a mouse can be used to check the bells instead of the laser. However, the fact that they are using the mouse and they can actively cancel the bell can be less effective. In fact, it has been shown that the use of a mouse can extend the peripersonal space (Bassolino et al., 2010).

Future studies should increase the positions in the lateral space with technology. In particular, Bisiach in 1996 explained the bias observed in USN patients at the bisection test with a theory based on the anisometry of the space. The representational space, from the left to the right is progressively compressed in the mind of the subject. Hence, at the bisection task the segment on the left is longer than the segment on the right, because the mental space occupied by the two segments is different (Berti et al., 2007). If we apply this theory to the lateral space used in the demonstrative task, if we add more positions on the lateral axis we might assist to an increased use of *'this'* for the position on the right side compared to the equidistant position from the middle line. This is because the patient is perceiving the left position being farther away than the right position. A difference in the use of demonstratives, between the left and the right side, was expected in this experiment with the two marked positions, however we need to agree that probably one position per side is not enough to produce an effect and that better results can be used with more positions. Due to the interesting results found with the SNT further testing needs to be carried out in USN patients, better adapting the tests used. Finally, an analysis of the brain lesion should be carried out. Due to the lack of CT scans available, it was not possible to run a conclusive analysis on the brain lesion. More information can be obtained with a MRI scan taken before the testing and/or using fMRI methods to analyse the brain activation of the patient during the use and comprehension of spatial language.

In conclusion, the exploratory study with USN patients showed that patients with USN might manifest issues in the use of spatial language and that further research is needed, in the directions previously outlined in this chapter.

5.4. Conclusion and theoretical implications

The work presented in this thesis provided evidence as a whole for a strengthening of the mapping between space perception and demonstratives use, emphasising the importance of reaching for the use of spatial demonstratives. Moreover, for the first time, to our knowledge, patients affected by right-brain lesions were assessed in the use of spatial language,revealing deficits in the description of spatial relations. While there have been challenges to the view that spatial language maps onto the perception and action systems (e.g. Kemmerer, 1999; Peeters et al., 2015), the body of studies we have presented suggests that such a mapping indeed exists, which changes in the processing or interaction with space affects how one talks about object location. As reviewed in the introduction some author propend for a mapping between space perception and demonstratives use (Diessel, 1999; Diessel, 2006; Coventry et al., 2014, Coventry et al., 2014; Gudde et al., 2016) and other authors argue that this mapping does not exist (Kemmerer, 1999; Peeters et al., 2015; Peeters & Özyürek, 2016). In particular Kemmerer (1999; 2006) argues that distance does not influence the use of demonstratives, but demonstratives have abstract meanings and they are modulated by the context. The studies conducted in this thesis all contradict Kemmerer's thesis. In fact, in the first series of experiments we proved that not only demonstratives are linked to space perception and they are used based on distance, but also that reaching distance is the principal variable that influences the choice of demonstratives.

However, we think that the two theories, Kemmerer's theory and Coventry and Diessel's theory, are not necessarily antithetical. The results of the first series of experiments show that the use of demonstratives is distance based, but distance is not the only variable that intervenes in the choice of demonstratives. Therefore, we can say that the use of demonstratives indeed depends on the context in which they are used, but also that distance is fundamental in this choice (at least for the English language).

The second set of experiments also support the theory that the use of demonstratives is distance based, in particular the two studies proved that demonstratives are not only used based on distance to indicate real objects, but a distance effect has been found also for 2D images.

The results of the first series of experiments have implications for embodied cognition too. Embodied cognition is the theory for which cognition depends on the body that the actor possesses and that body parts are actively involved in action and cognition. In addition, language can also be considered a form of action, and therefore language is embodied (see Borghi & Cimatti, 2010 for a review). Multiple studies support the theory that language affects the motor system (Scorolli & Borghi., 2007; Borghi & Scorolli, 2009; see Fisher and Zwaan, 2008 for a review). The results of the combined analysis (experiment 1 and 2) supports the theory of the link between the action system and language; as well as strengthen the theory of embodied cognition for language. In fact, our first two experiments show that the production of demonstratives is affected by body parts, notably reaching distance, and therefore by arm length. Although we need to underline that not only arm length affects reaching distance, but also shoulder weight and other body parts, besides the ability to move. Thus, as we highlighted in the previous paragraphs, more precise results can be obtained adding more controlled distances modifiables depending on the participants.

Lastly, experiments 6 and 7 were run in Italian. In experiment 6 we proved that also in the Italian language a mapping between space perception and demonstratives use is indeed present. These results contradict Bonfiglioli's and colleagues (2009) paper, where the authors argue that the key distinction between proximal and distal demonstrative is not based on the strict distinction between peripersonal and extrapersonal space. However, our results strongly support the division between peripersonal and extrapersonal space as the main variable implied in the choice of demonstrative. In fact, no effect of addressee position was found. Lastly, in experiment 7 right-brain stroke patients were tested. Although no problem in the use of demonstratives was found, a deficit in the use of spatial language was found at the Spatial Naming Test. These preliminary tests seem to suggest that deficits in the visuo-spatial functioning affect spatial language, and therefore, once again our results are consistent with the link between spatial language and the processing of space. In addition, the results of experiment 7 identify communication problems in right-brain stroke patients. Usually patients with a right-brain lesion go through neuropsychological testing and rehabilitation for spatial perception problems, and little or no attention is given to problems they encounter with communication. Our results underline the necessity to further research this phenomenon to improve patients rehabilitation and their quality of life.

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Appendix

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Brief article

Spatial demonstratives and perceptual space: To reach or not to reach?

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ABSTRACT

There is much debate regarding the relationship between spatial demonstratives (*'this'* or *'that'*) and perceptual space. While some have argued for a close mapping between the use of demonstratives and the peripersonal/extrapersonal space distinction (Coventry et al., 2008, 2014; Diessel, 2014), others have argued that distance from a speaker does not affect demonstrative choice (e.g. Kemmerer, 1999; Peeters, Hagoort, & Özyürek, 2015). We investigated the mapping between demonstratives and perceptual space across sagittal and lateral planes. Manipulation of object location on the lateral plane, and the hand used to point at objects (left, right) afforded a critical test of the the mapping between demonstratives and the reachability of objects. Indeed, we found that objects positioned at the same locations were described using *this* when the hand pointing at the object could reach it. Furthermore, we found no overall effects of handedness or visual field on demonstratives choice. This provides strong support for a mapping between perceptual space and the use of demonstratives. Such a mapping may help explain the influence of other variables on demonstrative choice, including interactive factors.

1. Introduction

Spatial demonstratives, including the words *this* and *that* in English, constitute an important class of lexical items across all languages. Not only are they present in all languages and are among the highest frequency words within a language (Deutscher, 2005; Diessel, 1999, 2006), but they are also among the earliest words to be acquired (Clark, 1978, 2003). Moreover, they are closely linked with the action system – demonstratives often involve pointing at objects (Clark, 1996; Diessel, 2006), and in some languages it is obligatory to point when using such terms (*Goemai*, Hellwig, 2003; *Kilivili*, Senft, 2004).

Typologically, the most common demonstrative system across languages is a binary system, as in English (Diessel, 1999, 2005). This has prompted many linguists to assume that the binary distinction is distance based, with one term, the proximal term, used for near distances and the other (distal) term for far distances. More precisely, this distance distinction in the case of demonstratives has been mapped onto the peripersonal (near) space and extrapersonal (far) space distinction made by the vision and action systems (Coventry, Valdés, Castillo, & Guijarro-Fuentes, 2008; Kemmerer, 1999). Peripersonal space (PPS) may be defined as "a network of body-part-centred representations responsible for the coordination of actions toward, and avoidance of, objects and other living entities." (Hunley & Lourenco, 2018, p14; see also Di Pellegrino & Làdavas, 2015). More specifically, the distinction between PPS and extrapersonal space is assumed to map onto different brain systems (Berti & Rizzolatti, 2002; Legrand, Brozzoli, Rossetti, & Farné, 2007; Làdavas, 2002) with recent evidence suggesting that processing of objects within reachable/manipulable space is associated with dorsal stream activation, and in particular the reach-related area of the superior parieto-occipital cortex (SPOC) and the intraparietal sulcus (IP) (Gallivan, McLean, & Culham, 2011; Makin, Holmes, & Zohary, 2007). Moreover, there is much evidence that PPS is flexible and graded. For example, extending one's reach using a tool extends PPS (Berti & Frassinetti, 2000; Farné, Bonifazi, & Làdavas, 2005; Longo & Lourenco, 2006; Maravita, Spence, & Driver, 2003) and PPS is contracted when the arm is weighted (Lourenco & Longo, 2009).

Experimental work on demonstratives has provided support for a link between the PPS/extrapersonal space distinction and the use of proximal versus distal demonstratives. In a series of studies, Coventry and colleagues (Coventry, Griffiths, & Hamilton, 2014; Coventry et al., 2008) found a rapid graded drop off in the use of *this* in English and *este* in Spanish to describe object locations in egocentric space when the object moves across the graded boundary to extrapersonal space (see also Maes & De Rooij, 2007; Stevens & Zhang, 2013). Moreover, when participants point at objects with a stick, the area in which *this* and *este* are used extends to the area reachable with the end of the stick, consistent with the extension of near-space neglect reported by Berti & Frasinetti (2000).

It is important to note that a mapping between perceptual space and demonstratives is not the only factor that determines their use. Other

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factors have been identified empirically, including object properties such us visibility, ownership, familiarity (Coventry et al., 2014), the position of a hearer (Coventry et al., 2008; Rocca, Wallentin, Vesper, & Tylén, 2018), and joint attention (see for example Diessel, 2014; Küntay & Özyürek, 2006). However, although demonstratives seem determined by multiple factors, with perceptual space among them, the role of the mapping between demonstratives and perceptual space has been challenged on two grounds.

First, a possibility that might still be consistent with the experimental data on demonstratives to date is that the proximal-distal contrast may have to do with a more general distance contrast rather than a direct mapping between peripersonal-extrapersonal space and demonstratives. For example, it is possible that the stick manipulation simply rescaled space in some way, extending the proximal scope that supplied a new artificial proximal-distal boundary. Such a possibility might be consistent with a point made by Kemmerer (1999) that one can use *this* and *that* (e.g. *this* planet and *that* planet) when objects are clearly not in peripersonal space (although one needs to be cautious extrapolating from contrastive to non-contrastive uses of closed class terms), and in a similar vein, the distal term can also be used in peripersonal space (see for example Bonfiglioli, Finocchiaro, Gesierich, Rositano, & Vescovi, 2009).

Second, it has been argued that the joint attentional function of demonstratives is the primary function, and that use is not affected by egocentric distance (Peeters & Özyürek, 2016; Peeters et al., 2015). For example, Peeters et al. (2015) challenge the very notion that there is any kind of mapping between perceptual space and demonstratives, citing EEG evidence from matches/mismatches between heard demonstratives and locations when participants viewed photographs varying object location with reference to a pictured speaker faced outwards from behind a photographed table. While the EEG data supports the view that people in face-to-face communication do not seem to differentiate between (egocentric) peripersonal and extrapersonal space (preferring *this* at any distance between speaker and hearer), the pretest data reported by Peeters *et al.* where participants were asked to indicate the appropriate demonstrative to use for each position did support the importance of distance as a determinant of demonstrative choice when people were face-to-face. It is therefore rather hard to know what to make of the Peeters *et al.* findings, especially since they used pictures rather than physical distances in three-dimensional space.

Here our main goal was to further test the mapping between demonstratives and perceptual space. In order to do so, we manipulated the location of objects in both the sagittal and lateral planes. This allows us to precisely test the mapping between peripersonal/extrapersonal space by manipulating when an object is reachable and when it is not, depending on the hand used to point at the object. If the PPS-extrapersonal space distinction is indeed important for demonstrative choice, one should find a drop off in the use of *this* in lateral locations dependent on the hand used to point at the object when naming it (see Fig. 1B). Specifically, pointing at an object on the far left should be associated with increased use of *this* when pointing with the left hand (as the object can be reached) compared to the same location when pointing with the right hand (where the object cannot be reached). And the reverse should be the case for an object positioned at an equivalent contralateral location. Therefore, the lateral axes affords a strong test of the mapping between perceptual space and the use of demonstratives.

We also consider two other potential variables that may affect demonstrative use: the hemifield in which an object appears (left versus right visual field of the speaker) and the handedness of the speaker. First, demonstratives can be used temporally to denote objects and events in current focus of attention/temporal proximity (*this month*) versus objects and events that appeared in the past (*that was a particularly good year*), and the proximal term usually occurs first when referring to two objects (e.g. '*this cup and that cup*'). Moreover, there is a general processing bias in the left visual field (Marzoli, Prete, & Tommasi, 2014), for example, manifest in facial asymmetries in face processing and visual attention to faces (see for example Burt & Perrett, 1997). Given the processing biases from left to right, often also associated with writing direction (Bergen & Lau, 2012; Shaki, Fischer & Petrustic, 2009) or the dominance of right handers (Marzoli et al., 2014), one can postulate that *this* might be used more in the left visual field than in the right (and vice versa for *that*).

Regarding handedness, it is generally easier to manipulate objects with one's preferred hand, so one can also predict that pointing with the preferred or dispreferred hand potentially could affect the language one uses to describe object location, with *this* being used more when pointing with the preferred hand. This would be consistent with results showing mappings between preferred hand and other categories of language (see Casasanto, 2011), and how such mappings can be disrupted changing manipulability of objects (Casasanto & Chrysikou, 2011). Furthermore, there is evidence for differences in the representation of body space as a function of handedness and of lateralized mental imagery of actions (Willems, Hagoort, & Casasanto, 2010). Neurologically healthy subjects have the tendency on line bisection tasks to bisect with a bias toward the left (a phenomenon labelled 'pseudoneglect'). Pseudoneglect is influenced by a range of variables included handedness, with dextrals manifesting a slightly bigger bias toward the left side than sinistrals (Jewell & McCourt, 2000; Luh, 1995).

In summary, we manipulated the location of objects on the sagittal and lateral axes, handedness, and the hand used to point at objects when describing object location in order to further test (1) the mapping between PPS/extrapersonal space and demonstrative use, (2) and the possible influence of visual attention and handedness on demonstrative use.

2. Method

The method employed the 'memory game' previously used to elicit demonstratives without participants being aware that language data are being collected (Coventry et al., 2008, 2014; Gudde, Griffiths, & Coventry, 2018). Objects (6 coloured disks) were placed in front of participants in 30 different positions (25 cm apart) on a table, resulting in a 6 sagittal X 5 lateral grid (Fig. 1A).

2.1. Participants

31 left-handed (8 males) and 32 right-handed participants (16 males) took part. The age range was 18–30 (left-handed: $M = 21.32$, $SD = 2.7$; right-handed: $M = 19.83$; $SD = 1.29$). All were English native speakers receiving payment or course credit for their time.

2.2. Procedure

Handedness was assessed with the Edinburgh Handedness inventory (Cohen, 2008 version adapted from Oldfield, 1971) and Stereo acuity was tested using the Randot Stereo Test (Stereo Optical Inc. Chicago, USA) (all participants had a threshold of at least 40 arcseconds). Participants were then asked to sit at the table where the 30 different positions were marked on a tablecloth. Participants were instructed to touch several key locations on the tablecloth so reaching distances to locations were strictly controlled (moving the tablecloth according to reach ensured participants were able to reach the second far right position with their right hand, but not with their left hand and vice versa, to test our main hypothesis: Fig. 1B).

Participants were then instructed they were taking part in a 'memory game' task assessing the possible impact of language on memory for object location (based on Coventry et al., 2008, 2014). On each trial, the experimenter placed an object (one of 6 coloured plastic disks) on one of the 30 marked positions. When the experimenter was behind the participant, they were instructed to point at the object, half of the time with their preferred hand and half of the time with their

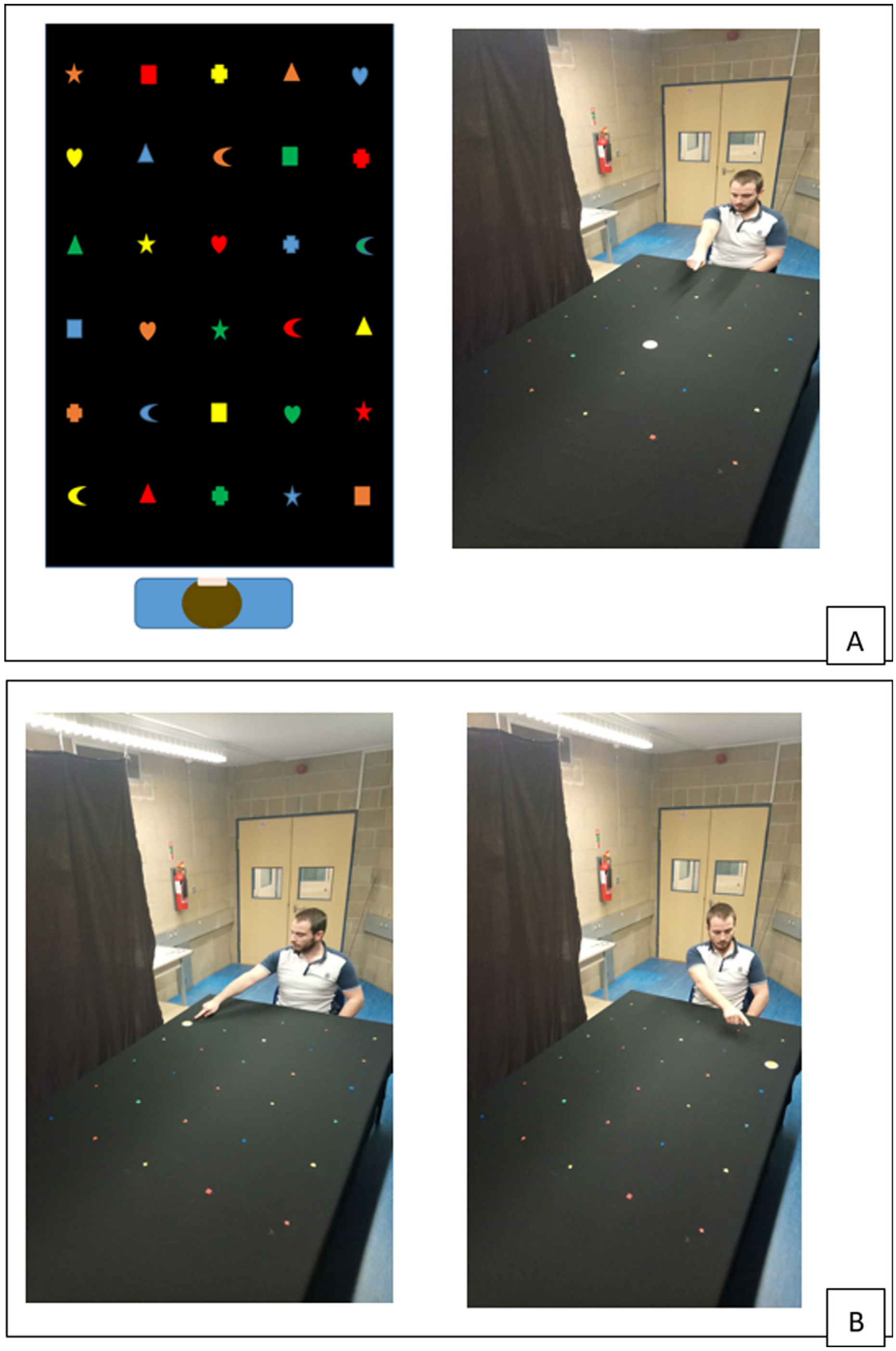

Fig. 1. A. Left panel: a schematic representation of the table used for the study, with all the placement positions marked. Right panel: a picture of a participant pointing at an object placed on one of the midline locations. **B.** An example of a participant able to reach the object on their right with their right hand but not at the equivalent contralateral location.

dispreferred hand, and to name the object using a combination of three words (so all particiants used the same amount of language on each trial): a demonstrative (the word *'this'* or *'that'*), the object colour and the word *disk*, e.g. ***this*** *red disk* or ***that*** *red disk.* To maintain the memory cover, after a random number of trials, participants were asked to recall the position of an object previously placed. At the end of the experiment, the experimenter ensured that the 'memory game' cover persisted during the entire experiment by checking that the participant was not aware the experiment was testing demonstrative use (for detailed instructions see the supplemetary materials in the Appendix).

3. Results

The percentage of the use of *'this'* was calculated (see Table 1) for each of the location × pointing hand × handedness combinations. We ran two analyses, first considering the middle locations on their own, and then the outer (lateral) locations (see Appendix for raw data).

Data from the midline locations were analysed in a distance × pointing hand × handedness ANOVA (with Greenhouse-Geisser corrections where necessary). There was a significant main effect of distance, $F(2.880,\ 175.691) = 43.258$, $p < 0.00001$, $\eta p^2 = 0.415$. Follow-up analyses (using LSD tests) revealed significant

Table 1
Mean % use of *this* (and SDs) by distance, pointing hand and handedness. (Sagittal distances are labelled from closest (1) to furthest (6) from participants.)

		RIGHT-HANDED									
Sagittal position		Left hand pointing					Right hand pointing				
		Far left	Near left	Middle	Near right	Far right	Far left	Near left	Middle	Near right	Far right
6	**Mean**	29%	26%	29%	30%	26%	26%	30%	28%	30%	23%
	(SD)	(0.23)	(0.26)	(0.25)	(0.27)	(0.26)	(0.29)	(0.24)	(0.32)	(0.27)	(0.23)
5	**Mean**	23%	20%	40%	30%	28%	34%	32%	26%	30%	26%
	(SD)	(0.24)	(0.24)	(0.32)	(0.27)	(0.27)	(0.30)	(0.21)	(0.25)	(0.29)	(0.26)
4	**Mean**	23%	43%	35%	34%	36%	33%	46%	40%	37%	35%
	(SD)	(0.23)	(0.29)	(0.28)	(0.33)	(0.30)	(0.24)	(0.35)	(0.30)	(0.22)	(0.28)
3	**Mean**	41%	52%	50%	47%	45%	44%	47%	52%	46%	40%
	(SD)	(0.27)	(0.31)	(0.29)	(0.27)	(0.31)	(0.28)	(0.30)	(0.25)	(0.30)	(0.26)
2	**Mean**	53%	66%	63%	60%	39%	50%	55%	69%	55%	60%
	(SD)	(0.35)	(0.30)	(0.32)	(0.31)	(0.32)	(0.28)	(0.30)	(0.25)	(0.30)	(0.26)
1	**Mean**	63%	71%	73%	63%	62%	63%	70%	80%	70%	63%
	(SD)	(0.26)	(0.27)	(0.28)	(0.28)	(0.35)	(0.29)	(0.29)	(0.27)	(0.33)	(0.28)
		LEFT-HANDED									
Sagittal position		**Left hand pointing**					**Right hand pointing**				
		Far left	**Near left**	**Middle**	**Near right**	**Far right**	**Far left**	**Near left**	**Middle**	**Near right**	**Far right**
6	**Mean**	27%	21%	29%	17%	29%	20%	26%	36%	23%	27%
	(SD)	(0.28)	(0.24)	(0.26)	(0.83)	(0.27)	(0.28)	(0.25)	(0.26)	(0.24)	(0.23)
5	**Mean**	22%	31%	34%	31%	29%	31%	24%	33%	32%	24%
	(SD)	(0.28)	(0.28)	(0.33)	(0.28)	(0.25)	(0.32)	(0.31)	(0.33)	(0.32)	(0.26)
4	**Mean**	32%	35%	37%	34%	34%	29%	43%	43%	28%	28%
	(SD)	(0.30)	(0.26)	(0.29)	(0.27)	(0.29)	(0.28)	(0.29)	(0.31)	(0.26)	(0.29)
3	**Mean**	35%	48%	63%	48%	51%	41%	43%	53%	48%	40%
	(SD)	(0.28)	(0.27)	(0.32)	(0.34)	(0.30)	(0.25)	(0.30)	(0.27)	(0.33)	(0.28)
2	**Mean**	56%	64%	69%	57%	49%	46%	62%	64%	63%	52%
	(SD)	(0.56)	(0.29)	(0.27)	(0.37)	(0.28)	(0.30)	(0.33)	(0.36)	(0.32)	(0.33)
1	**Mean**	65%	64%	68%	65%	60%	60%	67%	70%	61%	60%
	(SD)	(0.29)	(0.34)	(0.33)	(0.29)	(0.28)	(0.29)	(0.31)	(0.29)	(0.29)	(0.34)

differences between the first two (reachable) positions ($M_{dist1} = 72.82$, $M_{dist2} = 66.07$)and all the others ($M_{dist3} = 54.43$, $M_{dist4} = 38.69$, $M_{dist5} = 33.13$, $M_{dist6} = 30.56$)(all $p < 0.01$). No other effects or interactions were significant (all $p > 0.16$).

Next we considered the outer lateral locations in a sagittal distance (6 distances) × lateral distance (near, far) × side (left, right) × handedness (left, right) ANOVA. Consistent with the previous sagittal distance analyses, there was a main effect of sagittal distance ($M_{dist1} = 64.27$, $M_{dist2} = 55.53$, $M_{dist3} = 44.64$, $M_{dist4} = 34.43$, $M_{dist5} = 28.05$, $M_{dist6} = 25.56$), $F(1.801, 109.843) = 60.779$, $p < 0.0001$, $\eta p^2 = 0.499$. There was also a main effect of lateral distance, $F(1, 61) = 21.387$, $p = 0.00002$, $\eta p^2 = 0.260$. *This* was used more for near locations overall ($M = 44.35$) than for far locations ($M = 39.81$) in the lateral plane. There was also a significant lateral distance × sagittal distance interaction, $F(5, 305) = 3.086$, $p = 0.010$, $\eta p^2 = 0.048$; there was an effect of lateral distance for the first four locations (all $p < 0.001$) but not for the two furthest locations ($p > 0.05$).

Of most interest was a significant pointing hand × side × sagittal distance interaction, $F(5, 305) = 4.403$, $p = 0.0007$, $\eta p^2 = 0.067$, displayed in Fig. 2. For each distance we compared possible differences between the hand used for pointing as a function of the side the object appeared on. As shown in Fig. 2, there was no effect of pointing hand for the nearest distance or for the majority of distances clearly beyond peripersonal space (all contrasts $p > 0.05$). However, when the object appeared on the left side in location 2, *this* was used significantly more when pointing with the left hand ($M = 59.85$) compared with the right hand ($M = 53.37$) ($p = 0.012$). The opposite pattern was the case in the equivalent locations on the right side; when the object appeared on the right side in location 2, *this* was used more when pointing with the right hand ($M = 57.5$) compared with the left hand ($M = 51.38$) ($p = 0.018$). Additionally there was one other distance (location 5), but only on the left side, where *this* was used more when pointing with the right hand ($p = 0.013$). None of the other main effects or interactions were significant (all $p > 0.15$).

4. Discussion

Our goals were threefold. First we set out to test the mapping between peripersonal/extrapersonal space and spatial demonstratives through manipulation of objects on both the sagittal and lateral axes. Second we tested whether handedness might play a part in determining demonstrative choice. Third, we examined potential visual field influences on demonstrative choice.

Taking the second and third goals together, we found no evidence for the effects of handedness or visual field on demonstrative choice, save for an isolated effect of pointing hand at one location in extrapersonal space on the left side. Despite previous evidence for a mapping between left and right and visual attention on the one hand, (see for example Bergen & Lau, 2012), and handedness and language on the other (see for example Casasanto, 2011), limited evidence for the predicted mappings materialised in our data (see also Griffiths, Bester, & Coventry, 2019). It is possible that contrastive use of demonstratives would reveal a different pattern, especially with respect to visual attention (with *this* used before *that* in the contrastive pair). Moreover, the use of other paradigms might be more sensitive to such manipulations, for example, one can ask if people are more likely to gesture with their preferred hand when using *this*, consistent with the previous data for valence in the analyses of gesture (e.g. Casasanto & Jasmin, 2010).

In contrast, the results strongly support the mapping between perceptual space and demonstrative choice. Consistent with previous studies (e,g, Coventry et al., 2008, 2014), *this* is used more in PPS in the

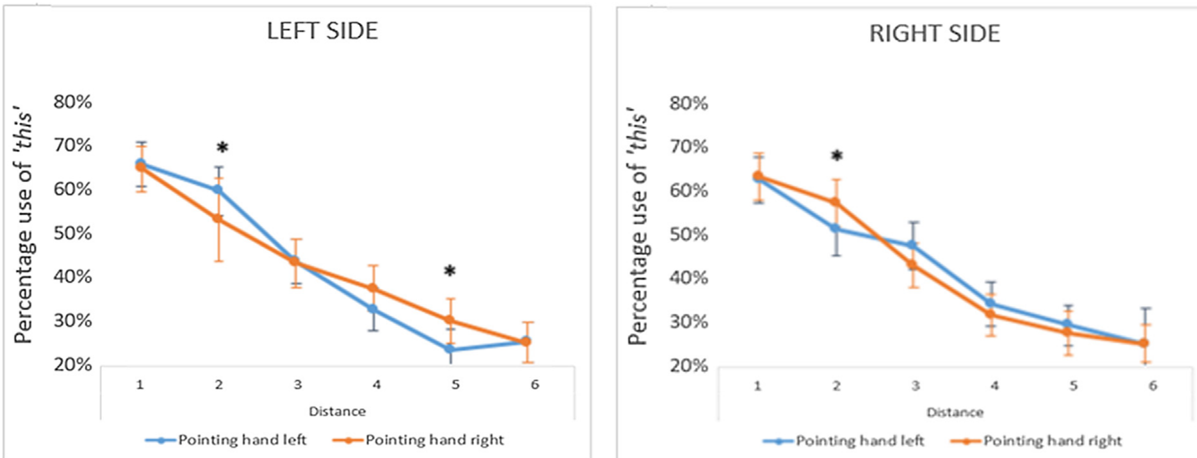

Fig. 2. Line graph showing the use of "this" for the 6 sagittal positions when participants pointed with their left hand and right hand on the left side (left panel) and right side (right panel). Error bars show 95% confidential intervals. *$p < 0.05$.

sagittal plane, with reliable differences between reachable and non-reachable locations. In addition, the experiment has produced two new findings that strengthen evidence for the mapping. First, *this* is used more in near lateral positions compared to far lateral positions, showing the effects of distance don't only operate on the sagittal plane. Second – and most compellingly – the use of the proximal term in the same locations is affected by the hand used to point at those locations, and critically whether the object is within or outside of reachable distance.

Overall the results offer the strongest evidence yet for a mapping between spatial demonstratives and PPS. However, some remarks are in order. It is also the case that a range of other parameters affect demonstrative use, and among these the position of a hearer and the setting in which language occurs seem paramount. Far from negating the importance of perceptual space for demonstrative use, the very flexible nature of PPS may help to explain these and other findings. For example, it has been established that the size of PPS is modulated by social interaction. Specifically, Teneggi, Canzonieri, di Pellegrino, and Serino (2013) found that the PPS representation is contracted when a participant is faced by someone else, and is expanded when working collaboratively in a space with a partner. Notions of shared space in the linguistic literature on demonstratives may be enriched with consideration of how the perceptual system processes space as a function of social interaction. It remains to be tested whether changes in PPS provides the mechanism by which more interactive factors affect demonstrative choice in context.

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Declaration of Competing Interest

Authors report no disclosures.

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Appendix. Supplementary material

Supplementary data for this article are available at: https://doi.org/10.17632/ywt6rm83fr.1.

The archive contains an excel sheet with the mean percentage use of *this* for each participant for all combinations of pointing hand and distances in the lateral and saggital planes (also noting handedness as measured by the Edinburgh Handedness Questionnaire). The dataset also contains detailed instructions to participants.

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