AN EMBODIED APPROACH TO LANGUAGE COMPREHENSION IN PROBABLE ALZHEIMER'S DISEASE: COULD PERCEPTUO-MOTOR PROCESSING BE A KEY TO BETTER UNDERSTANDING?

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Statement

I hereby declare that this thesis has not been, and will not be, submitted in whole or in part to another University for the award of any other degree.

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25th April 2013

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An embodied approach to language comprehension in probable Alzheimer's Disease: Could perceptuo-motor processing be a key to better understanding?

Summary

One of the central tenets of the embodied theory of language comprehension is that the process of understanding prompts the same perceptuo-motor activity involved in actual perception and action. This activity is a component of comprehension that is not memory–dependent and is hypothesized to be intact in Alzheimer's Disease (AD). Each article in this thesis is aimed at answering the question whether individuals with probable AD, healthy older adults and younger adults show differences in their performance on tests where perceptual and motoric priming take place during language comprehension. The second question each article asks is whether language comprehension in AD can be facilitated by the specific use of this perceptual and motoric priming.

Article I examines whether the way individuals with pAD represent verbs spatially matches the way healthy older and younger adults do, and how stable these representations are. It also explores in what way spatial representations may relate to verb comprehension, more specifically, whether representations matching the norms translate into a better quality of verb comprehension.

Article II tests the interaction between the verbs' spatial representations taking place during comprehension and perceptual cues - compatible and incompatible to the representations - in order to investigate whether individuals with pAD show differences in susceptibility to perceptual cues, compared to healthy older and younger participants. The second aim of this article is to explore in what way performance on a word-picture verification task can be affected, with reference to the fact that in previous studies on young participants, both priming and interference have resulted from the interaction of linguistic and perceptual processing.

Article III explores the Action Compatibility Effect (ACE) (Glenberg & Kaschak, 2002) with the aim of finding out whether the ACE exists for volunteers with pAD and whether it can facilitate language comprehension. The order of presentation of language and movement is manipulated to establish whether there is a reciprocal relationship between them. This information could be crucial in view of possible applications to individuals with pAD.

These articles test, for the first time, the effects of the manipulation of the perceptuo-motor component during language comprehension in individuals with pAD; they are intended as a methodological exploration contributing to a better understanding of the potential of embodiment principles to support language comprehension changes associated with pAD. Embodiment effects need to be studied further with a view to putting them to use in either clinical or real-life applications.

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Everything except language

knows the meaning of existence.

Trees, planets, rivers, time

know nothing else. They express it

moment by moment as the universe.

Even this fool of a body

lives it in part, and would

have full dignity within it

but for the ignorant freedom

of my talking mind.

Les Murray, "The Meaning of Existence" from Poems the Size of Photographs*, 2002,* in Burnett, R. (2005).*How images think.*MIT Press, Massachusetts, p.39.

1. Introduction & Overview

Foreword

This introductory chapter presents, in general terms, the rationale behind the work that constitutes this thesis and draws a succinct outline of the background of comprehension studies in Alzheimer's Disease (AD) and the philosophical premises underlying theories of embodiment. In order to avoid unwanted reiterations, the methodology and the literature specifically relevant to each article will appear in the Introduction and Methods' sections of that article. First of all, a few words on Alzheimer's Disease.

Were he alive today, Aloysius Alzheimer would be astonished at the attention generated by the three-page report he wrote in 1907 (Alzheimer, 1907): *Alzheimer's* has become, in the last two decades, a household term. Alzheimer's Disease accounts for sixty to seventy per cent of cases of dementia; other disorders that cause dementia include: Vascular Dementia, Parkinson's Disease, Dementia with Lewy Bodies and Fronto-temporal Dementia.

In the early stages of these diseases, there can be some clear differences between the diseases. For example, in dementia with Lewy Bodies, which is the second most common form of dementia, early symptoms include lowered attention span, visual hallucinations, fluctuation between periods of lucidity and confusion. As the specific disease advances, more parts of the brain become affected and the differences form one cause of dementia to another become subtle.

Beta-amyloid is a key component of the neuronal plaques associated with AD. Usually plaques and tangles develop in the posterior temporal lobe, more specifically in the hippocampus (Martin, Cox, Brouwers & Fedio, 1985). In AD, according to magnetic resonance imaging, signs of neurodegeneration appear first in the temporo-limbic cortex and then, gradually, spread and reach the frontal lobes at the later stages of the disease (Braak & Braak, 1991). Magnetic resonance imaging scans can show other common features, such as hippocampal atrophy, ventricular enlargement, sylvian fissure widening, while fluoro-deoxy-glucose positron emission tomography can measure amyloid deposition.

However, the progression of AD as described above is a rare scenario as it is usually associated with pre-symptomatic individuals (Martin, Brouwers, Lalonde et al., 1986; Fox, Crum, Scahill et al., 2001); reality is that individuals with AD show more widespread cortical atrophy involving frontal, parietal, temporal lobe cortices by the time a brain scan takes place. In Gonnermann, Andersen, Devlin et al. 1997, the atrophy that characterizes AD is defined as ‘diffuse and unpredictable’. On top of that, to date, no two persons have been found to be similar in how the disease has impacted them.

Because of all these reasons, Alzheimer’s Disease can be diagnosed with complete accuracy only *post mortem*, using a histologic examination of brain tissue, which checks for plaques and tangles, and so we always qualify the diagnosis of Alzheimer’s Disease as ‘probable’ (pAD).

1.2 Rationale

Embodiment is built on the premise that language is rooted in movement and perception in and of the real world (Barsalou, 1999). This thesis seeks to use recent embodiment theories and studies inspired by those theories to shed light on the possible practical uses these can be put to with respect to individuals with probable Alzheimer's Disease (pAD). Can theories that have hitherto been confined to the academic investigation of the nature of language be applied in real-life settings that might improve the lives of those with pAD? With this objective in mind, the first task for this thesis will be to produce evidence for preservation of embodiment effects in language comprehension, despite the degeneration caused by AD.

The idea of linking embodiment with AD builds on work conducted on action-based memory in AD (Hutton, Sheppard & Rusted, 1996; Senkfor, Van Petten & Kutas, 2008). This work has shown that mild to moderately impaired individuals with pAD are better able to remember events which are enacted than those communicated verbally, suggesting that structures in the brain are preserved in individuals with pAD to create an advantage when it comes to motoric or multimodal processing. The Enactment Effect is defined precisely by this advantage of enacting – either at encoding or at retrieval – over other types of processing. If the act of remembering has been shown to be improved by enacting the responses, can the understanding of language also benefit from similar processes? Supported by a number of studies cited in Chapters 2 and 3, I have hypothesized that the brain structures involved in producing embodiment effects would be preserved in the mild to moderate stages of AD, and that, like memory, language comprehension could also benefit from *embodiment.*

The work conducted in the present thesis, therefore, offers a new and intriguing opportunity to make the first steps toward using embodiment theories and testing them with the view of devising practical applications. The testing of embodiment effects on participants with pAD produces new evidence that reinforces the embodiment approach to language comprehension. This may also open up the possibility of linking some of the research in action-based memory with embodiment theories, with the latter providing an explanatory framework for the former.

1.3 Why the embodied approach to study language comprehension in AD?

Alzheimer's disease can affect any or all aspects of language comprehension, reflecting the location and progression of the particular disease. Comprehension failures in individuals with pAD impact enormously on their quality of life and that of their carers, so a greater understanding in this area would have clear benefits.

However, the study of language comprehension in AD is rendered problematic because it remains unclear how best to separate the memory and language contributions involved in the process of comprehension. Given that memory impairment is one of the primary symptoms of AD, it has been of particular interest for researchers in this field to try and tease apart the two; much research has been dedicated to trying to establish whether the comprehension deficit seen in AD is due to generalised memory impairment, or whether it should be attributed to deficits specific to language (Kemper

& Kliegl, 1999). However, results from this research have been conflicting and inconclusive, with different methodologies producing results that cannot easily be compared. In short, language and memory have been shown to be inextricably intertwined.

The use of embodiment theories of language comprehension offers us a way out of this conundrum. As explained above, embodiment posits the theory that language comprehension makes use of non-memory dependent processes such as perceptual and action-related mechanisms. Because these processes are hypothesized to be preserved in the mild and moderate stages of the disease, their role in language comprehension can then be tested. As these tests are implicit, memory is, in a sense, factored out of the equation.

More recent research has been conducted on selective comprehension deficits: Whether people with pAD find it easier to understand, for example, nouns relative to verbs, concrete words relative to abstract words, motion verbs relative to static verbs (e.g. Almor, Aronoff, MacDonald, 2009). This research, too, has proven inconclusive, as the data are failing to provide adequate results which could help identify the *loci* in the brain responsible for the hypothetical selective impairments. The idiosyncratic nature of the deficit, however, is such that this goal of identifying brain *loci* is difficult to achieve, as the trajectory of the degeneration can be determined by genes, cognitive reserves, underlying physiology etc. There is even some debate as to whether selective comprehension exists at all. The fact that there is a disproportion between the number of studies exposing, for example verb deficits than noun deficits, makes comparisons between the two kind of deficits even harder to justify.

The research into comprehension deficits in AD has to date been characterized by theoretical dilemmas and methodological difficulties. It is hoped that the tackling of comprehension failures in AD via the non memory-dependent processes at play during comprehension may provide answers that have hitherto been elusive. The use of embodiment theory has an added benefit: to date, research into AD has tended to concentrate on analysing and measuring the extent of the loss of comprehension experienced by individuals with pAD; this thesis turns this on its head, seeking to test and analyse what is retained.

1.4 A synopsis of theories of embodiment in language comprehension

Embodiment theorists do not view language as an autonomous and closed system of arbitrary symbols that bears no relation to the physical world around us, but one which, on the contrary, achieves meaning through its *embodied* connection to the real world (Barsalou, 1999). So, when we try to understand a sentence, we visualize our bodies in space, as if we need to simulate in our mind's eye our interaction with the real world to help us understand language. This "experiential" grounding to our thought processes applies to both conscious and unconscious representations. Scientists have been shown to visualize themselves physically and bodily in space in order to orientate themselves around a theoretical problem (Ochs, Gonzales, & Jacoby, 1996). We even understand abstract language about social and psychological causation in terms of the "pushes" and "pulls" based on our bodily experience (Talmy, 1988, Glenberg & Kaschak, 2002).

It is therefore argued that the comprehension of language activates the same perceptuo-motor processes that are activated when we perceive things in the real world, and when we plan and perform actions. We understand sentences about action not in terms of the meaning of the individual words in a sentence, but in terms of the motor patterns needed to perform the action. It is by thus cognitively simulating the actions implied by sentences that those sentences are imbued with meaning.

Recent evidence has shown that motor action and the processing of action-related language share common neural representations to a point that the two processes can interfere when performed concurrently. Boulenger, Silber, Roy et al. (2008) examined cross-talk between action word processing and an arm reaching movement, using words that were presented too fast to be consciously perceived (subliminally). The finding that motor processes were modulated by language processes despite the fact that words were not consciously perceived, suggests that cortical structures that subserve the preparation and execution of motor actions are indeed part of the (action) language processing network. This study supports the assumption that language-induced motor activity contributes to action word understanding.

Whilst there is a very limited amount of evidence from patient studies that could inform embodied theories, some attempts to find clinical applications for embodiment effects have begun to emerge (Pulvermuller's Intensive Language Action Aphasia Therapy, unpublished trials, 2011; Glenberg's reading intervention, reported in Glenberg, Brown, & Levin, 2007). This thesis represents one of the first attempts to apply embodied theories to groups other than a healthy young population, and is the first to explore how the embodied approach to language comprehension might help in bypassing the cognitive impairment brought about by AD. Because the embodied approach focuses on perceptual and action-related processes activated during language comprehension, the experimental paradigms based on this approach do not require the participants to make a mnemonic effort in order to perform the tasks.

1.5 Conclusion

The experimental work presented in this thesis is contained in three main articles, reported in Chapters 2,3 and 4. The first two articles deal with word-level effects, whereas the final article investigates embodiment effects at sentence-level. All experimental work was conducted on three groups: individuals with pAD, healthy older and young adults.

Article I consists of two studies: in the first, spatial representations of verbs are compared across the groups and enacted responses are compared with pen & paper responses; in the second, I assess the role of representations in the process of comprehension. Article II takes the exploration reported in Article I further: spatial representations elicited during verb comprehension are manipulated through perceptual processing to establish whether facilitation or interference occur. With the objective in mind of searching for a way of aiding comprehension for individuals with pAD, in Article III, comprising two studies, I move from word-level to sentence-level tasks, designed to reproduce the action compatibility effect (ACE) originally found by Glenberg & Kaschak (2002). I also manipulate overt movement and language in order to establish the nature of their relationship.

2. Article I: Representations of verbs in probable Alzheimer's Disease: Better at representing, better at understanding?

2.1 Abstract

It has been shown that the process of understanding a verb activates a spatial representation; healthy young individuals displayed a high level of agreement when asked to externalize their spatial representations. This work has three aims. First, to establish whether representations of older adults and individuals with probable Alzheimer's Disease (pAD) match those of healthy young adults; second, to establish whether enacting spatial representations elicit different responses, and third, to investigate in what way spatial representations may relate to verb comprehension. In study 1, individuals with pAD, younger and older adult participants all judged a set of verbs normed according to their orientation in space; in a different testing session, they judged the same verbs by enacting the orientation of their choice. In study 2, verb comprehension was measured with a verb picture verification task. It was hypothesized that (1) the representations of older adults and volunteers with pAD would match those of the young adult group; (2) that enacting the spatial representations would result in enhanced representations, specifically, in the older adult and pAD groups; (3) that there would be a positive relationship between how verbs are represented spatially and comprehension. A commonality of spatial representations between the three groups was found; when participants enacted their representations, their responses showed higher commonality compared to the non-enacted responses; highly common representations were related to better verb comprehension in the healthy older group, but not in the pAD group. Despite the fact that the representations of the group with pAD were not significantly different from those of the healthy older group, the lack of relationship between representing and understanding may indicate a less efficient integrating function during the process of comprehension in individuals with pAD.

2.2 General Introduction

Embodiment theorists view language comprehension as a process during which perceptual and action-related mechanisms interact with linguistic and mnemonic systems (Glenberg & Kaschak, 2002; Jeannerod, 2006). Findings from behavioural, eye tracking and imaging studies converge to support this *embodied* account of language comprehension (Glenberg, Sato & Cattaneo, 2008; Spivey & Geng 2001). The view that this multi-layered process of comprehension recruits also non memory-dependent systems, such as perceptual and action-related processes, opens up new possibilities for research on language comprehension in individuals with probable Alzheimer's Disease (pAD). Because perceptual and action-related processes are predicted to be preserved in the mild and moderate stages of the disease (Smith, Murdoch & Chenery, 1989; Perry, Watson, & Hodges, 2000; Caine, & Hodges, 2001; Venneri, McGeown, Hietanen *et al.,* 2008), the role played by those components could be investigated to assess whether or not their contribution to the understanding of language is also intact. The present study represents a first attempt to advance understanding of comprehension in pAD from an embodied perspective. Given that comprehension failures in individuals with pAD impact enormously on their quality of life, and that of their carers', greater understanding in this area could result in a direct application in either clinical settings or real life communication.

Traditional studies have approached language comprehension in pAD by attempting to tease apart memory and language contributions. A large body of research was aimed at investigating whether or not the failures experienced by individuals with pAD were due to generalised memory impairment, or should be attributed to deficits specific to language. Proponents of both positions were able to gather evidence to support their respective hypotheses mainly because different methodologies were used and different results were obtained. According to Caplan (1999), for instance, on-line and off-line tasks assess different stages of comprehension, and so can produce incoherent results, which need to be compared with caution (Kempler, Almor, Tyler *et al.*, 1998). Language and memory processes have so far been found to be inexorably intertwined (Macdonald, Almor, Henderson *et al*., 2001), so any effort to shed light on mechanisms operating during comprehension should perhaps be directed to finding approaches able to avoid this problem.

Selective comprehension deficits – nouns relative to verbs, concrete relative to abstract words, motion verbs relative to static verbs, etc. – became the focus of research in more recent times, but data interpretations have not yet offered up an overall framework to identify *loci* of impairments and so don't fully explain selective comprehension in individuals with pAD (Masterson, Druks, Kopelman *et al.*, 2007). Whether there is selective comprehension is in itself the subject of debate (Archer, Edison, Brooks *et al.*, 2006; Medina, Detoledo-Morrell, Urresta *et al.*, 2006).

This is undoubtedly a research area characterized by theoretical dilemmas and methodological difficulties, but tackling the comprehension failures in AD via the non memory-dependent processes at play during comprehension seems a fruitful way forward.

A further reason for approaching comprehension from an embodied perspective is provided by evidence emerging from research on action-based memory in relation to AD. For example, Hutton, Sheppard & Rusted (1996) and, more recently, Senkfor, Van

Petten & Kutas (2008) found that mild to moderately impaired individuals with pAD can remember enacted events better than verbally described ones and concluded that 'this may mean that the memory structures that sustain this enactment effect, whether these can be regarded as motoric or multimodal processing, are sufficiently preserved to create this advantage' (Hutton *et al.*, 1996, p. 126-7).

If an advantage in remembering is created thanks to preserved non memory-dependent processing, it may be that language comprehension could also benefit from such processing. In the present article three groups of volunteers – healthy younger adults, healthy older adults and older adults with pAD – were asked to choose which orientation they would associate with a particular verb. This exercise was repeated by asking them to pick a direction by enacting the response rather than writing the response, to see whether this produced any difference. Their verb comprehension was then tested by means of an implicit task, in order to have a measure of their understanding. Finally, the representation and comprehension data were analysed *a posteriori* to find out whether there was a connection between how well participants represented and how well they understood the verbs.

Richardson *et al.* (2001) provided a set of norms for future research on spatial representations; although the database contains only thirty verbs, it was the first attempt to reveal that the intuitions people have about verbs are spatial, regardless of their level of concreteness, and are common to a vast majority of people. It was found that more than two thirds of naive healthy young participants (n=173) chose the same image schema for a particular verb. For example, most people ascribed a vertical orientation to *respect* and a horizontal alignment to *chase*. In many cases, when it can be argued that the action described by the verbs could theoretically take place in either orientation (i.e. *push*), the data suggest that one of the two orientations is dominant, as, for example, the vast majority of people would choose the horizontal plane for *push*. Of course, when the verb is embedded in a context expressing directionality, such as *Mary pushed the window up and waved to her father*, the specific representations are built through semantic integration across words, rather than from words alone, and so the inherent orientation of the single verb is not important (Moody & Gennari, 2010).

To mentally depict a verb as an orientation is neither an ability, nor a skill, nor a piece of knowledge; it can rather be regarded as a form of implicit information about the verb, in other words, an aspect of knowledge we normally would not know we possess, until it is put at test. For example, a substantial portion of verbs, both concrete and abstract, can be mentally represented like a vector aligned along a vertical axis or on a horizontal plane (Richardson, Spivey, Edelman *et al.*, 2001, Richardson, Spivey, Barsalou *et al.*, 2003; Stanfield & Zwaan, 2001). Researchers have conceptualised these vectors as spatially laid out image schemata.

Theorists such as Murphy (1996) argued against the idea that spatial representations are automatically activated as we process language, and constitute part of the core meaning of language. Instead he viewed them as merely associated with verbs like a well-established metaphor would be to its referent (see also Glucksberg, Brown, & McGlone, 1993). For example, *respect* could be represented with a vector pointing upward on the basis of cultural reasons (taller/older people, heavenly things demand respect, in hierarchical societies people at the top of the ladder are respected, etc.), rather than the culture of 'looking up to someone' having stemmed from the core meaning of *respect*.

But evidence has recently supported embodied theories that language processing includes spatial components and that language itself has a spatial grounding. Stanfield & Zwaan (2001) found that people mentally represent the vertical/horizontal orientation of an object mentioned in a sentence. Participants who read a sentence describing an object with an implicit orientation, and then viewed pictures of that object, responded faster when the orientation of the pictures matched the orientation of the object. These results endorse the theory that it is by a perceptual-motor simulation of the actions implied by sentences that language conveys its meaning, providing language with grounding to the things in the world (Barsalou, 1999).

On the basis of the fact we communicate successfully, sharing the experience of a common world, a high degree of commonality of representations across speakers was also predicted and found in Meteyard & Vigliocco's (2009) survey of naive young participants' intuitions. A large number of verbs (299) were normed according to the spatial image schemata attribute to them. The aim was to capture the motion content of individual verbs, rank it and provide a database for forthcoming experimental work. For each verb, healthy young participants (n=100) were able to express more than one preference in terms of orientation and direction and were able to rank their preferred picture depicting the directionality of the verb. When no specific direction was preferred across participants, the verb was ranked as neutral, or lacking inherent directionality.

Unlike Richardson's database, which only ranked verbs according to their level of concreteness, Meteyard & Vigliocco (2009) controlled for frequency, length, and other linguistic parameters; they categorized verbs in vertical, horizontal, neutral, as with Richardson's, but they also maintained the categories upward, downward, leftward, and rightward. Toward and away motion scores, crucial for embodied studies, were also provided, giving ample flexibility in item selection for future research on the semantic representation of motion.

Richardson's and Meteyard's norming studies did not merely provide norms; they managed to access the inherent spatial element of verbs, which emerged in the form of an <u>offline</u> deliberative response, showing an embodiment effect at the word level. Experimental evidence for spatial representations being activated during <u>online</u> comprehension is also persuasive. In a dual-task, participants listened to sentences and engaged in a visual discrimination task; latencies showed an interaction between the orientation (horizontal/vertical) embedded in the sentence and the position of the visual stimulus (horizontal/vertical) (Richardson, 2003).

Richardson *et al.* (2003) argued that the "spatial effect of verb comprehension provides evidence for the perceptual-motor character of linguistic representations", (p. 767). Subsequent evidence (Boulenger *et al*., 2008), however, has led to a redefinition of Richardson's interpretation: perceptual and action-related mechanisms are not merely a *characteristic* of linguistic representations; rather, they are the very same mechanisms which are at play during actual action and perception. What Richardson *et al.* found seems to be that the 'embodied' spatial content of a sentence interacts with perceptual cues and elicits a spatial effect.

The ‘subsequent evidence’ mentioned above is provided by behavioural, imaging and eye movement studies. The outcome of these experiments seems to point at the direct involvement of the pre-motor and motor areas during language comprehension, by highlighting interactive spatial and motoric elements of language and perceptual and motoric processes active during the processing of language. What role, exactly, then do the spatial representations have during comprehension? Is how we represent a verb important in terms of how quickly and well we understand it? If this spatial interaction can be manipulated so as to enhance comprehension, implications beneficial to individuals with pAD may become apparent.

In Meteyard, Bahrami, & Vigliocco’s (2007) study, participants had to detect up/down motion in visual stimuli while listening to verbs that implied up/down motion and directionally neutral verbs. A compatibility effect was found: when the orientation of the verb’s implied motion was congruent to the orientation of the motion in the motion-detection task, there was facilitation. Listening to the verbs activated spatial representations that interfered with detection of a motion signal, showing that low-level perception processes are affected by language comprehension. This type of interaction supports the idea that processing perceptual cues and processing of language recruit the same mechanisms (see also Meteyard, Zokaei, Bahrami *et al.*, 2008).

Eye movements provide a measure of where attention is directed and can be used to track the integration of linguistic stimuli and perceptual cues. Data from studies using eye movements have supported the embodied theory that perceptual information is implicated in semantic representations (Meteyard & Vigliocco, 2009).

In Spivey & Geng (2001) participants listened to scene descriptions that referred to objects and events extending upward, downward, leftward, or rightward, for example, they had to imagine being on top of a cliff watching people rappel down the cliff face. It was found that more eye movements compatible with the implied direction of the scene were made, when compared with eye movements made in the same direction when listening to a control story with no directional bias. This evidence suggests that eye movements may be integral to visual imagery and sentence comprehension (when language is directional) supporting the embodied idea that visual systems are involved in processing imaginal or semantic content that has visual referents.

Altmann (2012) described an eye movement study whereby participants listened to verbs implying a going up or down motion while watching dots going up or down on a screen. They were faster at identifying upward or downward motion when there was compatibility between the implied motion of the verb and dots' movement, suggesting that language mediated eye movements were simulating the directionality implied in the verbs.

Using brain imaging techniques, it has been shown that sentence content can differentially modulate different motor regions. During processing of language about various effectors, effector-specific sectors of the premotor and motor areas become active (Hauk, Johnsrude, & Pulvermuller, 2004; Tettamanti, Buccino, Saccuman *et al.*, 2005). In another experiment, single-pulse TMS was used to index activity in the motor system while participants read sentences describing transfer of objects or information and no transfer sentences. A greater modulation of activity was found in the hand muscles area when reading sentences describing transfers (Glenberg *et al.*, 2008).

Interestingly, the size of the effect was comparable when the pulse was at the verb and when the pulse was at the end of the sentence, reliably identifying the verb as pivotal in priming the action schema.

Although all experimental work testing embodied theories so far has been carried out on a healthy young population, attempts to find clinical applications for spatial and motoric effects have begun to emerge (Pulvermuller's Intensive Language Action Aphasia Therapy, unpublished trials, 2011; Glenberg's reading intervention, reported in Glenberg, Brown, & Levin, 2007). Study 1 focuses on whether commonality of verbs' spatial representations can be extended to an older population and to individuals with pAD. To be able to establish whether representing words is an intact component of language processing during the early stage of pAD seems a valid starting point to carry out research on memory-independent components of comprehension. Whether spatial representations hold any predictive validity in relation to comprehension will be investigated in Study 2.

2.3 Study 1: Non motoric and motoric forced choice tasks

Study I is a replica and an extension of Richardson et al., (2001). In Study 1 it was tested whether representations of older adults and individuals with probable Alzheimer Disease (pAD) match those of healthy young adults; two ways of accessing spatial representations were tested, in order to ascertain whether different representations are elicited.

It was predicted that there would be no significant differences between the three groups in how they represented verbs spatially. This was predicated on findings from Richardson *et al.* (2001), who demonstrated that naïve participants displayed a high level of agreement when asked to draw schematic representations of verbs. Because these schemata are essentially 'implicit information' inherent to the verb, there was no reason to believe that aging and age-related cognitive impairment would result in differences. The responses were hypothesised to match to the norms provided in Richardson *et al.* (2001).

It was also hypothesized that how participants were required to respond would influence responses. Specifically, when participants were required to respond by enacting the chosen representation for the verb (motoric task), their responses were predicted to be better at matching the normed spatial representations. This Enactment Effect was predicted to be specifically significant for participants with pAD and older adults because previous research showed that young participants are more likely to reach ceiling effects at baseline performance, forfeiting the possibility to display differences in performance due to task manipulation (Hutton *et al.*, 1996).

2.3.1 Method

2.3.1.1 Participants

Fifteen volunteers with mild to moderate probable Alzheimer's Disease (pAD) (late onset), twenty cognitively healthy older adults, and twenty young adult University of Sussex students took part in the study. All reported normal or corrected to normal vision and all were naïve about the purpose of the experiment.

The volunteers with pAD were recruited from two local memory clinics, and they were selected on the basis of a clinical diagnosis of probable Alzheimer's, currently in the Mild to Moderate phase, a Mini Mental State Examination (MMSE) score between 19/30 and 25/30 at the time of testing, and no other cause of cognitive impairment present in their medical history. The MMSE was administered by the experimenter. All volunteers were receiving Alzheimer related medication (Aricept, Exelon) with a stable dosage for at least one year. Informed consent was obtained from the volunteers and from their carers' prior to data collection. Ethical approval was obtained by the National Research Ethics Services.

The healthy older adults were recruited mainly in sheltered accommodation; only participants who scored 28/30 or higher in the MMSE and were generally healthy (self-evaluated) were selected. Volunteer characteristics for the three groups are reported in Table 2.1.

Table 2.1 Sample characteristics & background test scores

	Healthy younger	***Healthy older***	***pAD***
Number of participants	20	20	15
Gender (male/female)	8/12	7/13	6/9
Handedness (right/left)	19/1	18/2	15/0
	Mean & Std Error	**Mean & Std Error**	**Mean & Std Error**
Age (in years)	21.45 ± .89	79.05 ± .93	80.8 ± 1.26
Education (in years)	/	11.3 ± .45	10.26 ± 0.52
MMSE correct (0-30)	/	28.9 ± .19	22.93 ± 1.05
Full scale IQ (NART-R converted)	115.04	115.91	115.22

Age, number of years spent in education and number of errors in the NART were not significantly different in volunteers with pAD and in the healthy older group, as indicated by independent t-tests (p >.05, two-tailed).

2.3.1.2 Materials

The stimuli consisted of thirty verbs, which were identical in both tasks. Although the stimuli were taken from Richardson *et al.* (2001) the following changes were made. First, three stimuli, presented as phrasal verbs (*pointed at, argued with, gave to*) in Richardson *et al.* (2001), were presented omitting their preposition in this study to avoid contamination with the spatial representations that may be brought about by the prepositions. Second, verbs were presented embedded in rebus sentences in Richardson *et al.* (2001), but were presented individually (without the rebus sentences) in this study, as the main focus of the present study consisted of looking at the inherent orientation of verbs at word level.

Verbs were presented conjugated in the past tense so that they could not have been interpreted as nouns. This was in line with Richardson *et al.* (2001), but was different from Meteyard & Vigliocco (2009) who chose the present tense because verbs in the past tense have been shown to be less salient than verbs in the present tense (Zwaan, 1996).

Half of the verbs were low in level of concreteness and half were high in concreteness, according to the MRC psycholinguistic database (Coltheart, 1981). One third of the verbs were normed as ‘horizontal’ in their alignment in space, one third as ‘neutral’ (no specific alignment was normed), one third as ‘vertical’ (Richardson *et al.*, 2001). The verbs are listed in Appendix A.

In Richardson *et al.* (2001) the norming procedure to demonstrate the directionality of motion for concrete and abstract verbs consisted in a Forced Choice and a Free Drawing task. The latter, however, was deemed not suitable to pAD volunteers and so two Forced Choice tasks were utilised.

Forced Choice Task 1: non motoric task

A booklet, the size of a cheque book, was created, in order to allow participants to look at one verb at a time. Each page of the booklet featured a verb followed by a choice of four arrows, pointing backward, downward, forward and upward, as illustrated in Figure 2.1.

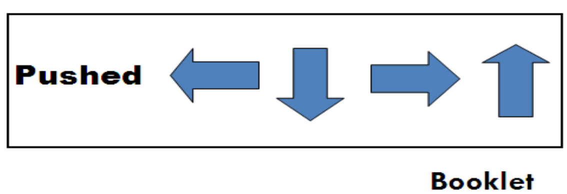

Figure 2.1 Example of one page of the booklet in the non motoric task

<u>Forced Choice Task 2: Motoric Task</u>

In the motoric task, spatial representations were operationalized as two-dimensional sliders running along either the vertical axis or the horizontal plane. Participants responded on a magnetic board where four big arrows were drawn, pointing in the direction of the four cardinal points. Central to the four arrows, there was a verb card, the size of a playing card, magnetically attached to the board, as illustrated in Figure 2.2.

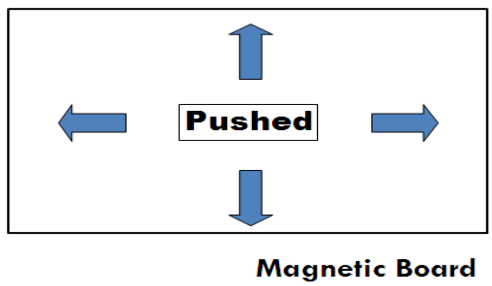

Figure 2.2 Example of a verb card on the board in the motoric task

2.3.1.3 Procedure

Participants were shown three examples, different from the experimental trials, and it was explained that there was no correct or incorrect answer; they just needed to go with the answer that first came to mind, without thinking too hard about it, and no emphasis on speed of response was mentioned. They were asked to decide whether a verb could be best depicted as either horizontal or vertical. By not providing the neutral option, participants were made to respond intuitively, even in those instances when they felt they did not know the answer.

During the first testing session, participants performed the Non Motoric Forced Choice Task. They were given the verb booklet and were asked to mark with a pen the arrow they felt best depicted each verb. They worked continuously and with no time restriction, but they were asked not to go back and change their choices. The task lasted an average of ten minutes.

During the second testing session, the 'motoric' forced choice task was administered. The researcher placed a verb card on the magnetic board and asked the participant to move the card according to the direction best depicted by the verb using their dominant hand. The verb card could be moved up, down, and sideways on the magnetic board. The researcher recorded the responses. This task took an average of fifteen minutes.

These two experiments were administered always in the same order at a time interval of two weeks. If the motoric task had been presented first, it may have produced unwanted influences.

2.3.2 Results

Because the main interest lay in the inherent orientation of a verb in space, rather than in the direction of the motion, upward and downward responses were collapsed to create a unified vertical axis, and side to side responses were collapsed to create a unified horizontal axis. Horizontal and vertical responses were then converted into angle degrees (0° for horizontal, 90 °for vertical), and the mean angle for each verb in both tasks was calculated, as well as the mean angle for each participant' s responses to verbs normed as horizontal, neutral, or vertical. Mean angles by group are reported in Appendix A.

Two 3x2x3x2 factor mixed design analyses of variance were computed first by subject and then by items. In the analysis computed by subjects, the between subjects' variable was the type of group (young/older adults/pAD); the within subjects' variables were the type of task (non motoric/motoric), the category of the verbs (high in concreteness/low in concreteness) and the orientation of the verbs (horizontal/neutral/vertical). In the analysis computed by items, the between items' variables were the type of verb (high in concreteness/low in concreteness) and the expected axis of the verb (horizontal/neutral/vertical); the within items' variables were the type of task (non motoric/motoric) and the group (young/older adults/pAD). The dependent variables were the participants' responses (forward, backward, upward, downward), converted into angles. Analyses conducted across participants are denoted F_1, and analyses conducted across items are denoted F_2. Greenhouse-Geisser correction factors were applied to the degrees of freedom when the condition of sphericity was not met.

A main effect of axis was found, F_1 (1.76, 91.52) = 206.49, $p < .001$, $\eta = .79$, F_2 (2, 27) = 9.09, $p < .001$, $\eta = .4$, indicating that all participants chose significantly more arrows aligned on the vertical axis (up/down) when judging verbs that were normed as vertical, and selected more arrows on the horizontal plane (forward/backward) when presented with verbs that were normed as horizontal. There was little consistency in selection of horizontal over vertical axes for the neutral stimuli, resulting in mean angles which lay reliably in between the horizontal and the vertical mean angles, as Figure 2.3 illustrates.

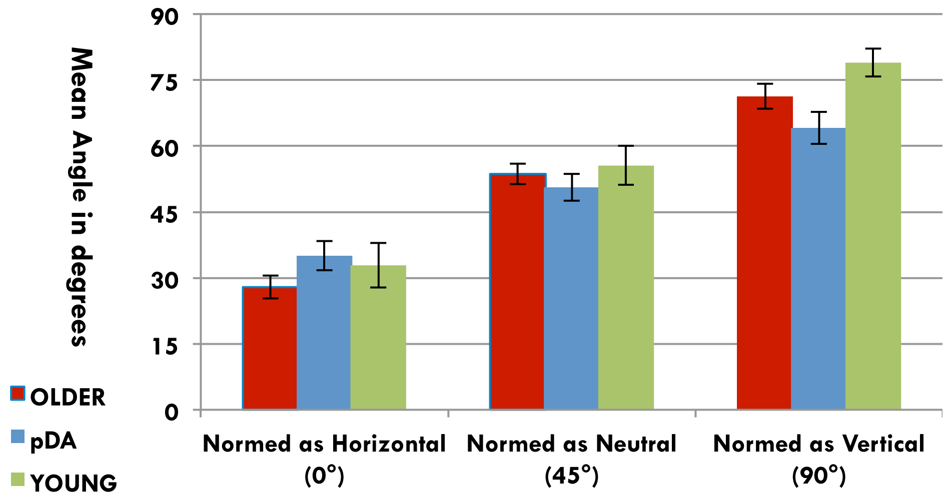

Figure 2.3 Mean angles as a function of axis of the three groups. Scores of the motoric and non motoric tasks were collapsed

Level of concreteness did not produce a significant main effect neither in the analysis by subjects nor in the analysis by items. Level of concreteness, however, interacted with the axis attributed to each verb F_1 (1.95, 101.65) = 39.22, $p < .001$, F_2 (2, 27) = 3.79, $p < .05$. Post hoc analysis revealed that verbs high in concreteness elicited a significantly more marked differentiation between axes than verbs low in concreteness, for horizontal t (31) = 7.27, $p < .05$ and vertical verbs t (31) = 2.84, $p < .05$. Neutral verbs elicited neutral responses with no significant differences between concrete and abstract. Nonetheless, verbs low in concreteness still differentiated significantly between the three axes; t_s (31) = 17.16, 21.46, 15.2, $p < .0001$.

The effect of group was not significant F_1 (2, 52) = 1.95, $p > .05$, F_2 (2, 24) = 1.23, $p > .05$, indicating that the angle means of all three groups were not significantly different, and implying that all three groups represented the verbs similarly.

There was a significant interaction between group and axis F_1 (3.52, 91.52) = 2.75, $p < .05$, $\eta = .96$, F_2 (2.89, 39.11) = 3.69, $p < .05$, $\eta = .21$. Post hoc analysis showed that the main effect of axis was significant in each of the groups ($p_s < .001$). Simple main effects' contrasts showed that, within the data for each axis, the only significant difference between groups regarded the vertical axis, where the group with pAD differed from the other healthy groups, $p < .05$. From Figure 2.3, it is apparent that the mean angles of the pAD volunteers showed less differentiation between the three expected axes; this means that the pAD group was generally less consistent in attributing the orientation to the verbs and was perhaps the main driver of the interaction.

The effect of task approached significance F_1 (1, 52) = 3.21, $p = .07$, η =.05, F_2 (1, 27) = 2.8, $p > .05$, η =.09. A significant interaction between group and task qualified this trend, F_1 (2, 52) = 7.74, $p < .001$, η = .22, F_2 (1.73, 46.79) = 9.47, $p < .01$, η = .26, indicating that the type of task interacted with participants' cognitive health and age. Pairwise comparisons of simple main effects indicated that the only significant mean difference was between the young and older adults in the non motoric task (MD -8.73, SE 3.54, $p = .050$).

However, because the mean angle represents the average of horizontal, neutral and vertical responses, the mean angle itself does not assist us in finding out which of the groups produced responses closer to the norms. For example, in the motoric task, the mean angles and standard errors were: 53° ± 2.6 for the young group; 54° ± 2.6 for the older group, and 44° ± 3 for the pAD group, and so impossible to interpret.

In order to capture the strength of the relationship between participants' responses and norms, a regression model based on the optimal angles (verbs normed as horizontal were given a value of 0°, those normed as neutral were given a value of 45°, and 90° to vertical verbs) was fitted to the responses of each individual in each of the two tasks separately. A Group x Task ANOVA was then performed on the *ß* weights (gradients of the regression lines relating participants' scores to the optimal line).

The Group x Task ANOVA performed on the *ß* weights revealed a main effect of task, F (1, 52) = 5.55, $p < .05$, η = .09, with means indicating that better adherence to norms was observed in responses given in the motoric task (M *ß,* SE - non motoric .39 ± .03; motoric .47 ± .02) and this was true in each group, although the healthy older adults' performance showed less task differentiation, as illustrated in Fig. 4.

A main effect of group, F (2, 52) = 4.32, $p < .05$, η = .143, was found, with means indicating that the young group were the best at adhering to the norms, and the pAD volunteers were the least consistent with respect to the norms (M *ß,* SE – pAD group .33 ± .04; older group .47 ± .04; young group .5 ± .04).

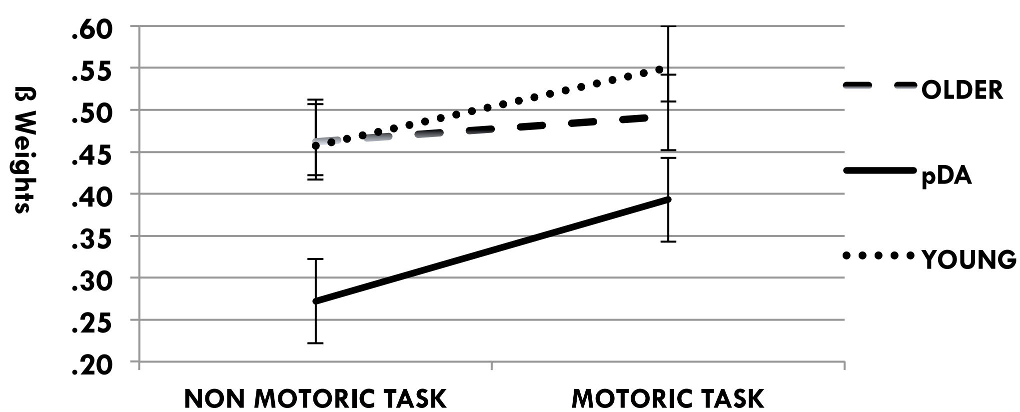

Figure 2.4 Mean beta weights by task for the three groups. The greater the beta weight, the more consensual the representation.

2.3.3 Discussion

Healthy young, older and pAD volunteers showed an overall coherence in assigning a vertical or horizontal orientation to verbs which were previously normed according to their intrinsic orientation (Richardson *et al.*, 2001). The fact that verbs normed as neutral produced a mix of horizontal and vertical responses, reflected their lack of directionality: because participants were forced to choose only between vertical and horizontal arrows (no neutral option was given) the neutrality was expressed through inconsistent responses (a mix of horizontal and vertical responses) for all three groups. Despite the differences in test designs, these findings mirrored the results reported in Richardson *et al*. (2001, 2003).

A significant main effect of axis suggests that the two tasks used in this study tapped into some commonality in the way that verbs are represented; lack of group differences and different level of concreteness of the stimuli show that this commonality of spatial representations is reliably stable. Although, at first glance, these main effects may suggest that this strong spatial effect does not seem to be affected by age, cognitive impairment, type of task, and level of concreteness of stimuli, mean differences and interactions revealed a more complex picture.

First, a more clear-cut differentiation between the vertical axis and the horizontal plane characterized verbs with high level of concreteness, although there was no significant difference with verbs low in concreteness. The significant concreteness by axis interaction indicates that more consistent choices of orientation across groups were given when concrete verbs were judged. Verbs normed as neutral did not elicit significant differences between levels of concreteness.

Second, although group differences were not significant, young volunteers were better at representing verbs with orientations that matched the norms; the pAD volunteers were more inconsistent with respect to the norms, as their differentiation between the vertical axis and the horizontal plane was less marked.

Third, the two tasks seemed to have triggered different responses in the three groups, as indicated first, by how the groups interacted differently with the type of task, and second, by the results of the analysis conducted on the ß weights. The young and pAD groups showed a stronger task effect than the healthy older adults, whose performance did not seem to be much influenced by the modality of response. This result will be discussed more thoroughly in the general discussion.

Importantly, in the motoric task, the performance of the pAD volunteers, expressed in ß weights, was not significantly different from that of the healthy older adults. This means that when *enacting* the orientation of the verb, it was easier for individuals with pAD to become aware of the spatial content of the verb. Furthermore, the performance of the volunteers with pAD and the one of the young volunteers were represented by a similar slope capturing how, in the motoric task, a better adherence to the norms was achieved.

2.4 Study 2: Comprehension task

Masterson, Druks, Kopelman *et al.*, (2007) report an interesting study on object and action naming, and noun and verb comprehension, which concludes that so far, evidence of selective deficits cannot be supported. In the present study, a test contained in Masterson et al. (2007) is replicated partially: rather than comparing nouns with verbs, the present article is concerned with verbs only. The stimuli are also somewhat different, as explained in the Methods.

The word-picture verification task used in the present study is considered highly sensitive to semantic loss, which is experienced by most individuals with pAD in the mild-moderate stage (Venneri *et al.*, 2008; Masterson *et al.*, 2007). Comprehension abilities in the pAD group were predicted to show impairment relative to the healthy older adults in response times, but not so in number of errors, as the test chosen was a word picture verification task in which participants were only required to make a matching judgement.

Older and pAD participants were tested on their verb comprehension, in order to have a measure of their comprehension, so as to better interpret the representation data. Their measure of comprehension was used *a posteriori* to investigate whether it related to how participants represented verbs.

It was hypothesized that there would be a relationship linking the type of representation participants ascribed to verbs and their level of verb comprehension. Better comprehension would be related to spatial representations closer to the norms (those most people agree upon). This hypothesis is based on data (Richardson *et al.*, 2003; Meteyard *et al.*, 2007) showing that spatial representations are an active component of the simulation evoked during language comprehension and therefore may have a role in enhancing understanding (Fischer & Zwaan, 2008).

2.4.1 Method

2.4.1.1 Participants

The same sample of volunteers with pAD and healthy older volunteers was tested in Study 2, but the young undergraduates did not take part, as a measure of implicit comprehension was deemed redundant in a cognitively healthy and young undergraduate population.

2.4.1.2 Materials

A subset of thirty verbs was taken from An Object and Action Naming Battery (Druks & Masterson, 2000), and was used to create a word-picture verification task. This subset presented equal numbers of transitive/intransitive verbs, and each verb was normed according to the following criteria: number of phonemes, number of syllables, frequency, familiarity, age of acquisition, imageability, visual complexity and matched with regards to these characteristics the stimuli used in Study 1. For a complete list of stimuli, see Appendix B).

Each item in the task consisted of a verb-picture (a picture depicting implied motion) presented three times with different printed words; with the verb matching the picture, with a verb semantically related to the picture, and with a verb unrelated to the picture, as illustrated in Fig. 5, 6, and 7.This design built upon one dimension of the experimental design used in Masterson et al. (2007).

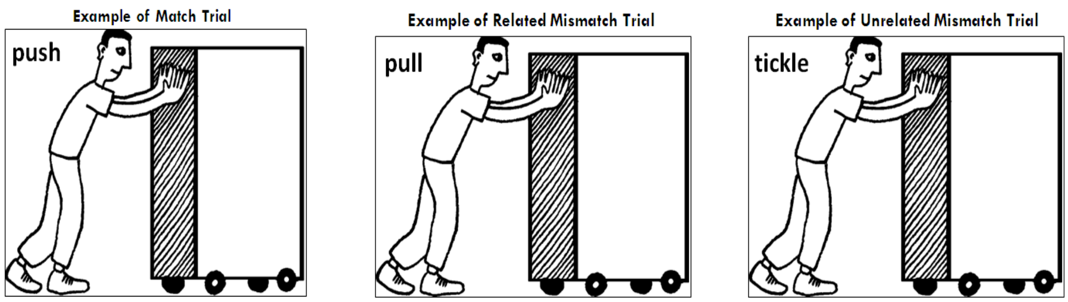

Figure 2.5 Examples of the three types of trial in the comprehension task

The task was presented in E-Prime (Schneider, Eschman, & Zuccolotto, 2002a; Schneider, Eschman, & Zuccolotto, 2002b) on a laptop computer. The 'q' and 'p' keys on the keyboard were designated 'yes' and 'no' keys respectively, and were labelled.

2.4.1.3 Procedure

In order to avoid tests with memory loads for volunteers with pAD, participants performed a Word Picture Verification Task, which is a validated implicit test of comprehension. This was a close replica of one of the tests used in Masterson *et al.* (2007).

Participants received instructions from the examiner and/or read them on the screen. They had to judge whether a word and a picture they could see on the computer screen was a match or a mismatch. They had to press either the 'YES' or the 'NO' key, according to whether they thought the word and the picture matched or not. They were told that if a word was related to the picture, but was not a match, they had to press 'NO', and that there were more mismatching (66%) than matching trials (33%). They carried out a practice session before beginning the task.

The task was split into three sessions of thirty slides each and each session was split into two blocks of fifteen slides each. After one block, participants could take a rest if they so wished; after each session, participants took a two minutes rest. This task took an average of fifteen minutes.

The three types of trial (with matching words, with related but mismatching words, with unrelated mismatching words) were allocated to sessions so that the same picture would appear in a session only once. Matches and mismatches were distributed evenly but randomly among blocks and sessions. Two counterbalanced lists were constructed so that half of the participants received Block 1 first and half received Block 2 first. Accuracy of key-presses and latencies to respond, measured from the onset of the picture and word to response, were recorded.

2.4.2 Results

By subject and by item analyses of variance were computed on accuracy and on latency data. The between subjects independent variable was the type of group (healthy older adults, pAD volunteers) and the within subjects independent variable was the type of trial with three levels (match, related mismatch, unrelated mismatch). The dependent variables were the number of errors and the reaction times in milliseconds. A Type 1 error rate of .05 was adopted. Greenhouse-Geisser correction factors were applied to the degrees of freedom when the condition of sphericity was not met.

The accuracy rate across all groups and condition was 90%. In the analysis of the accuracy data, there was a main effect of group, F (1, 33) = 8.01, $p < .01$, $\eta = .19$, and a main effect of type of trial, F (1.34, 44.21) = 76.02, $p < .001$, $\eta = .69$. with mean number of errors as a function of type of trial, as shown in Figure 2.6. These effects were qualified by a significant interaction between group and trial F (1.34, 44.21) = 16.67, $p < .001$. Within subjects contrasts revealed that related mismatch trials differed significantly from both match trials, F (1, 33) = 74.7, $p < .001$, $\eta = .69$, and unrelated mismatch trials, F (1, 33) = 106.01, $p < .001$, $\eta = .76$. Match and unrelated trials did not differ significantly ($p > .05$).

Independent *t*-tests revealed that pAD and healthy older volunteers differed in the number of errors made only when responding to related mismatch trials, t (33) = 3.96, $p < .001$ (2-tailed), but did not differ in the other two types of trial ($p > .05$). As summarised in Fig. 2.6, pAD volunteers were differentially affected by semantic relatedness relative to the healthy older group.

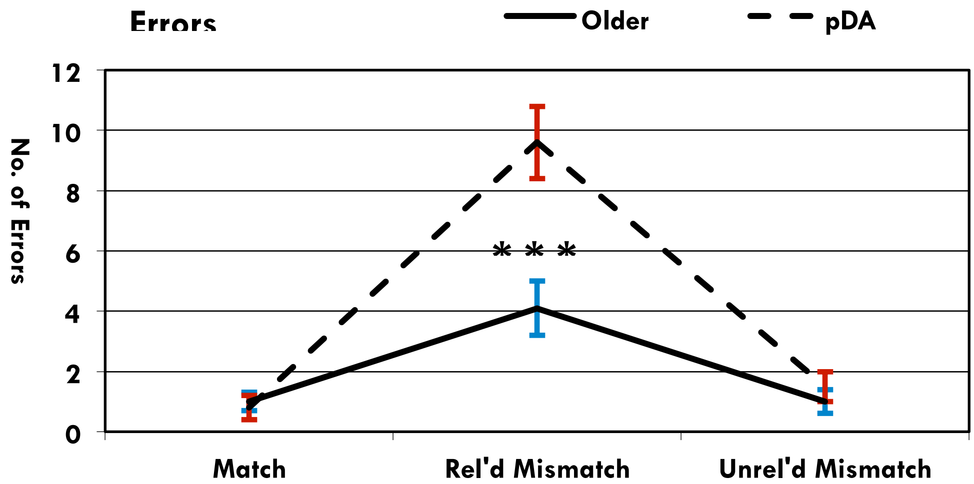

Figure 2.6 Mean number of errors as a function of type of trial (30 trials per type) for the two groups

In the analysis of the latency data only correct responses were included. The effect of group, F (1, 33) = 18.16, $p < .001$, $\eta = .35$, and the effect of trial type, F (2, 66) = 28.98, $p < .001$, $\eta = .46$, were significant; mean reaction times according to trial type are shown in Fig. 2.7. Pairwise comparisons revealed significant differences in latencies between all three trials ($p_s \leq .01$, Bonferroni adjusted). The interaction was not significant.

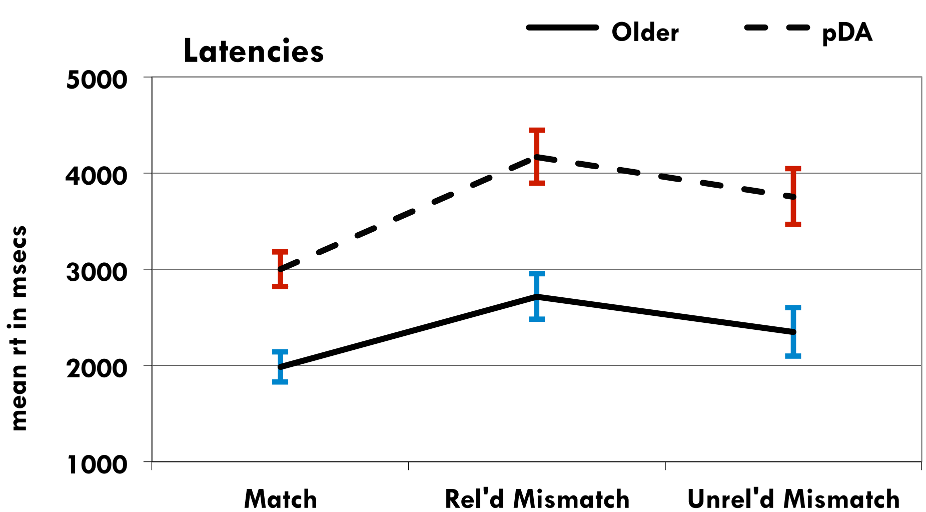

Figure 2.7 Mean reaction times as a function of trial type for the two groups

To conclude, the pAD volunteers made more errors in the semantically related mismatch trials and were generally slower in verifying pictures and words than the healthy older participants. The slowest trials to be processed were the related mismatch trials, where participants had to verify whether a picture and a word related to the picture matched.

Analysis across Study 1 and 2

A Pearson correlation was conducted between the ß weights (capturing the strength of the relationship between responses and norms in Study 1), and the accuracy and latency data collected in the comprehension task (Study 2), in order to explore possible relationships between spatial representations and comprehension.

The mean beta weights derived from a composite of the scores from both the non motoric and the motoric tasks were negatively related to number of errors made in the comprehension task, $r = -.35$, $p < .05$, and with latency in the comprehension task, $r = -.5$, $p < .01$. These two negative correlations suggest that the higher the beta value, that is to say the closer the spatial representations of verbs were to the norms, the fewer mistakes were made and the shorter the reaction times were during the comprehension task. There was also a positive relationship between accuracy and latency in the comprehension task, $r = .43$, $p < .01$, all p_s one-tailed, suggesting that the higher the number of errors, the longer the reaction times were.

In order to understand what drove the relationship, the representational data was then split by group and by task and correlated to comprehension data. The representational data of the healthy older volunteers related significantly with their comprehension data. The ß values relating to non motoric responses were negatively related to latency in the comprehension task, $r = -.41$, $p < .05$. The ß values relating to motoric responses were negatively related to accuracy in the comprehension task, $r = -.44$, $p < .05$ and were marginally correlated to latency ($r = -.35$, $p = .06$) all p_s one-tailed, the power of the first two correlations for a significance level of .05 was 0.6, for the marginally significant correlation, the power was 0.5. Using the Fisher *r* to *z* transformation, the significance of the differences between these correlations were assessed and found not significant. However, the fact that the beta values of the motoric scores correlated both with latencies and, although marginally, with errors, may suggest a more reliable relationship between the motoric responses and comprehension than between the non motoric responses and comprehension. Accuracy and latency data collected in the comprehension task did not correlate.

The representational and comprehension data of the pAD group did not correlate significantly (only the correlations that were significant in the sample of the older adults were reported: non motoric scores and reaction time: $r = -.14$; motoric scores and reaction time: $r = -.14$; motoric scores and errors: $r = .09$, the power of these correlations was between 0.2 and 0.4.). The significance of the differences between the correlations of the older adults and the pAD group were assessed and found not significant, except for the correlation between motoric scores and accuracy, where the difference between the coefficients of the two groups approached significance, $p = .06$ (one-tailed).On the contrary, accuracy and latency data of the comprehension task correlated positively with each other, with higher number of errors being associated to longer reaction times, $r = .45$, $p < .05$, the power was 0.5. This significant correlation suggests that more demanding trials are reflected in both longer reaction times and in the greater number of errors.

2.4.3 Discussion

In line with the main hypothesis, in individuals with pAD, comprehension was impaired despite their intact spatial representations: they made more errors and had greater latencies than healthy older volunteers. However, with regards to accuracy, participants with pAD performed at ceiling level when responding to match trials, showing that the task did not overload them.

It was exclusively in the semantically related mismatch trials that significant differences emerged. In this type of trial, participants had to verify whether a printed word, e.g. WALK, was or was not a match for a picture showing a person running. The semantically related mismatch trials proved to be a sensitive measure of the semantic damage experienced by the pAD participants. They met these 'demanding' trials with a lower level of accuracy, paired with longer latencies. The healthy volunteers also found this type of trial more difficult than the other two, as error rate and response times showed. These findings mirror the findings in Masterson *et al*. (2007) and a more in depth interpretation of these results will be considered in the general discussion.

Correlational analysis revealed that among the healthy older participants, comprehension scores were related to how verbs were represented. Participants' representations in the motoric task were associated with both number of errors and reaction times in the comprehension task. In the non motoric task, there was a relationship only with the number of errors. Fewer errors and shorter reactions were associated with higher beta values, that is to say with spatial representations that were more consistently chosen. This slight difference between the two tasks in relating to the comprehension data was not predicted, given that the performance of healthy older adults did not show a big task effect.

The pAD group, however, did not show significant relationships between representational and comprehension data. This difference with respect to healthy older adults may reflect a breakdown in the ability to effectively integrate representations into the process of comprehension, but may also reflect low power.

2.5 General Discussion

Healthy young, older and pAD volunteers were able to judge the orientation in space implicitly contained in a set of verbs. Their responses were found to agree across the three groups, and match with the normed responses collected in similar studies (Richardson *et al.,* 2001, Meteyard & Vigliocco, 2009). When participants were asked to enact the orientation of the verb by sliding a magnetic arrow on a board, an enhanced spatial effect was found in the young and in the pAD groups, but not in the healthy older group. When tested on their comprehension abilities, volunteers with pAD made more errors than healthy older volunteers. It was found that in the healthy older group, higher levels of verb comprehension were significantly related to high degree of commonality of verb representations, whilst in the pAD group there was no significant relationship between understanding and representing.

The result that spatial representations were found to have a high degree of commonality across the three groups tested in the present study is in line with the hypothesis that age and age-related cognitive impairment, such as Alzheimer's dementia, does not influence how representations are formed. The high degree of similarity found implies that spatial representations are based on the configurations and actions of our bodies - as intuitions of orientation in space or movement across individuals. Given this premise, it follows that the representation that best 'fits' a verb must needs be characterized by a high degree of commonality.

This result is also evidence for an embodied effect at word-level, operationalized as a vector / verb association. It is not surprising that the trajectory, or orientation, of verbs are represented at the level of a single word, as this constitutes an essential spatial information for 'drawing' more complex simulations of actions expressed in sentences. These simulations, far from being 'impressionistic', are instead highly normative, as Moody & Gennari wrote: "representations retain a degree of specificity that was previously unsuspected" (p. 782, 2010).

The evidence of the embodied effect at word level presented here supports the idea that language itself has a spatial grounding, and that it is not merely the processing of different linguistic parts that elicit this effect. The debate is quickly moving away from asking whether representations reflect structures of the world (Chatterjee, 2001; Malt, Gennari, Imai *et al.*, 2008) or that they are merely cultural metaphors (Murphy, 1996, 1997), to a discussion of the extent to which language is embodied (Meteyard & Vigliocco, 2010).

The performance of individuals with pAD was similar, although slightly less reliable, than that of the cognitively healthy groups. This fits well with the idea that dementia differs quantitatively rather than qualitatively from the cognitive status of healthy older adults (Walters, 2010). Viewing dementia as a dimensional construct lying on a continuum and not as a categorically distinct entity, makes it closer to an 'accelerated form of normal age-related changes in cognitive function' (Imhof *et al.*, 2007), rather than a disease.

Volunteers with pAD and young volunteers showed a stronger task effect than the healthy older adults, whose performance did not seem to show much sensitivity to task difference. As it was hypothesised that it would be volunteers with pAD and older adult volunteers to specifically benefit from the enactment effect brought about by the motoric task, the results are only partially in line with the hypotheses.

Previous research showed that young adults are more likely to reach a ceiling effect in their baseline performance, forfeiting the possibility of the emergence of the Enactment Superiority effect in the motoric version of the task. Older adults, however, are more likely to perform below ceiling and therefore have scope for showing the effect. (Hutton *et al.,* 1996; Zimmer & Cohen, 2001). However, in Study 1, intuitions rather than performance were tested, and so ceiling effects were not an issue.

Volunteers with pAD reliably displayed the advantage of the enacted responses, as their performance in the motoric task was so enhanced to become similar to that of the healthy older adults. An enriched performance effect, through the multi-mode facilitation brought about by e*nacting* the orientation of the verb in the motoric task made it easier to unlock the spatial content of the verb.

Although verbs high in concreteness did produce more consistent responses, level of concreteness did not manage to influence how well verbs were represented overall, as differences were not significant. As Richardson *et al.* (2001) found a similar slightly contradicting result, much research is currently addressing on what basis vivid embodied representations can be claimed for abstract verbs. Given that, first, abstract verbs do not refer to physical actions and lack sensory-motor associations, and, second, evidence gathered in category specific studies has often associated high level of concreteness with an advantage in comprehension, priming and automatic activation (Bushell & Martin, 1997; Gainotti, 1990; Gonnerman, Andersen, Devlin, et al., 1997), recent embodied theorists have brought about newer arguments. They suggest that it is necessary to take into account not only the fact that language is grounded in the sensory-motor system, but also that language represents a linguistic-social experience (Scorolli, Binkofski, Buccino *et al.,* 2011). Scorolli *et al.* (2011) explain that social experiences are represented in trajectories oriented on different axes, and Kousta, Vigliocco, Vinson *et al.* (2009) argue that emotional experiences are also represented spatially.

Whilst this recent work on the representation of abstract words can partially account for the spatial content of abstract verbs found in the present study, the variance in representing certain verbs deemed ‘neutral’ has not yet been sufficiently addressed. Questions such as what delimits these verbs and why they are impervious to the embodiment effect remain unanswered.

In the comprehension task, the performance of the pAD volunteers was hypothesised and indeed found to be compromised with respect to the performance of healthy older adults. Individuals with pAD were generally much slower than the healthy group, but they were significantly less accurate only in one of the three conditions, the semantically related mismatching condition. These results mirror the findings in Masterson *et al.* (2007), in which volunteers with mild to moderate pAD were tested on the same task.

The impairment experienced by volunteers with pAD in responding to semantically related trials could be viewed as a semantic loss, i.e. no longer being aware of the difference between two words sharing some features within a particular semantic field (e.g. 'walk' and 'run'). Verbs' semantic fields are so close to each other that they make it hard to differentiate between them and the semantically related trials tested specifically the ability to distinguish between two semantically close verbs (Kohonen, 1997; Zannino, Perri, Carlesimo, *et al.*, 2002; Zannino, Perri, Pasqualetti, *et al.*, 2006).

It is important to note, however, that the healthy group also made semantic errors and was slower at answering semantically related trials, although the degradation was no doubt greater in individuals with pAD. These findings may be reflecting both a natural semantic degradation, also experienced in healthy aging, and a more important degradation, specific to probable Alzheimer's Disease. This pattern of selectively impaired performance in verb/picture matching tasks replicates in other studies (Masterson *et al.,* 2007).

Although a relationship between how well verbs are understood and how well they are represented (expressed in terms of closeness to norms or to their optimal angle) was hypothesised, correlational analyses of representational and comprehension data only indicated this relationship for the healthy older individuals, and not for the volunteers with pAD.

These results could be seen as an indicator that disruption in comprehension experienced by individuals with pAD may occur at the stage of integration, and not during mental representation, although questions remain regarding the reasons why pAD volunteers could access the orientation that best depicted a verb, but could not integrate this representation during comprehension. Since research shows how spatial representations are activated during language comprehension, it may be that spatial representations are indeed 'comprehension enhancers', contributing to the process of understanding, making it quicker and sharper (Fischer *et al.*, 2008), and that the degenerative processes brought about by Alzheimer's dementia disrupts this higher resolution comprehension system.

To conclude, the data seem to suggest that in healthy aging individuals, higher levels of verb comprehension are associated with representations capturing inherent spatial information about the verb, and may also point to the possibility that representing verbs appropriately in relation to the spatial dimension may constitute an advantage during comprehension, an advantage that the cognitively unhealthy group has perhaps lost. Because the correlations including data from the pAD group lacked power, it is not possible to draw definitive conclusions at this stage.

In the present study, spatial representations of verbs were compared for the first time across healthy young, older adults, and volunteers with pAD. A high degree of commonality matching the normed responses was found, suggesting that representing is a preserved component of the process of comprehension in pAD. In line with findings from research conducted on action-based memory, individuals with pAD were better at tapping into spatial representations of verbs when they could benefit from enacted responses. This study also represented a first attempt to assess the role of representations in the process of comprehension. The results suggest pAD may precipitate failure in comprehension by disrupting the integration stage of verb comprehension, although the residual scheme of representation remains intact.

3. Article II: Do people with probable Alzheimer's Disease engage perceptual resources during language comprehension?

3.1 Abstract

It has been shown that spatial representations embedded in language interact with perceptual cues; both priming and interference can be the result of this interaction. The present study assesses whether susceptibility to such priming is intact in AD and whether the interplay between linguistic and perceptual processes results in the same effect that is found in healthy volunteers. Volunteers with pAD, older and younger adults first saw an arrow moving along the vertical or horizontal axis on the screen, then saw a picture of a vertical or horizontal action with a printed word, and had to verify whether the verb picture and the word (a verb) matched. Across the three groups, trials where the orientation of the arrow and the orientation of the verb picture were incompatible were responded to faster than when the two were compatible, resulting in an incompatibility advantage relative to trials where the stimuli were compatible. The present study provides evidence that the strong interactions between perceptual processing and spatial representations noted in comprehension performance of healthy young adults are preserved in spite of age- and disease- related cognitive decline. The incompatibility advantage found in the present study represents a starting point for further research to look at how perceptual processing might boost comprehension. A greater understanding in this area could contribute to interventions aimed at improving real-life communication and so be very welcome, as comprehension failures in individuals with pAD have a substantial impact on their quality of life and that of their carers.

3.2 Introduction

People spontaneously form visual mental images when understanding language and it has been shown that these representations, generated during the course of language comprehension, can share processing resources with perception, thereby recruiting or competing for some of the same brain regions. For example, the act of intentionally imagining motion, the exposure to linguistic description of motion or the exposure to pictures depicting motion have all been shown to produce reliable motion after-effects, demonstrating how processing language can spontaneously create sufficiently vivid mental images to produce direction-selective adaptation in the visual system (Toskos & Boroditsky, 2010).

Theoretical support for the ‘cognitive psychological reality’ of these representations can be found in the Perceptual Symbol Systems theory, holding that representations and image schemata activated during cognitive processes are governed by the same systems that control perception and action (Gibbs 1995; Barsalou 1999). Evidence from the neuropsychological literature is also supportive of this idea, as language processing has been found to produce activation in perceptual-motor areas (Tanel 1997). The assumption that verb comprehension interacts with perceptual-spatial processes, at least with verbs that imply literal or metaphorical spatial relationships (Richardson, 2003, p.767) is also backed up by behavioural evidence, in that those processes can influence on-line performance and delay memory tasks (Percher 2005).

However, there is to date a very limited amount of evidence regarding the resilience of these effects in the face of age- and disease-related changes. Such work could inform embodied theories of semantic representation: almost all experimental work testing embodied theories so far has been carried out on a healthy young population. Although the findings carry significant implications for supporting failing systems. attempts to find clinical applications for spatial and motoric effects have only begun to emerge (e.g. Glenberg's reading intervention, reported in Glenberg, Brown, & Levin, 2007).

Given the difficulties encountered by researchers on comprehension in individuals with pAD (due to volunteers' memory failing to assist them during tasks), the embodied approach to language comprehension described above could be useful as it would allow the experimental bypassing of the cognitive impairment brought about by AD, because it focuses on perceptual and action-related processes activated during language comprehension - components that are memory-independent. A greater understanding in this area could contribute to interventions aimed at improving real-life communication and so be very welcome, as comprehension failures in individuals with pAD have a substantial impact on their quality of life and that of their carers.

Perceptual and motoric processes are preserved in the mild and moderate stages of Alzheimer's disease (Smith, Murdoch & Chenery, 1989; Perry, Watson, & Hodges, 2000; Caine, & Hodges, 2001; Venneri, McGeown, Hietanen *et al.,* 2008), and so the hypothesis that mental representations of perceptual features interact with perceptual referents is plausible. The present study assesses whether susceptibility to priming is intact in AD and whether the interplay between linguistic and perceptual processes results in the same effect that is found in healthy volunteers.

From the behavioural studies so far conducted on healthy young volunteers, there is evidence showing that there can be both an incompatibility and a compatibility advantage in the interaction between perceptual cues and language comprehension.

For example, in an off-line task, Stanfield & Zwaan (2001) found a compatibility advantage when participants read a sentence describing an object with an implicit orientation, and then viewed pictures of that object; their responses were faster when the orientation of the pictures matched the orientation of the object. When this physical referent was presented again, it is recognized more rapidly. This study also provides clear evidence that people mentally represent the vertical/horizontal orientation of all objects mentioned in a verbal description, without being aware of doing it.

In a study by Richardson et al (2003), participants listened to sentences that described events taking place either on the vertical axis or on the horizontal plane, while concurrently engaging in a visual discrimination task in which they had to judge whether a shape appearing on the screen (at the top, bottom, left or right) was a circle or a square. Responses were faster when the spatial content of the sentence and the position of the shape were incompatible, suggesting that spatial representations activated in reading conflicted with visual processing of objects sharing the same spatial orientation to the contrary of what was expected.

As indicated in the literature reviewed below, when the perceptual cue and orientation (either expressed or embedded in language) are made to interact, the outcome may vary, and it is not clear from the studies to date precisely what variables influence the performance of the volunteers. It may be that the present study, exploring perceptual processing during language comprehension in individuals with pAD, could shed further light on studies that have so far been confined to a healthy and young population.

In a study by Kaschak, Madden, Therriault et al. (2005), participants were presented with visual displays moving either toward or away from them and simultaneously heard sentences with an implied motion content, either toward or away from the participants. They had to decide if the sentences were sensible or not. Again, their responses were faster when the direction of the two stimuli was incompatible, suggesting that processing mechanisms recruited to construct direction-specific simulations during language comprehension were also used during direction-selective visual perception; competition for resources caused interference in the compatible condition. In their study there was no base-line condition, and so the results were interpreted as reflecting interference in the compatible trials, and not as a priming effect taking place in the incompatible trials. In their study, the stimuli were also presented in two different modalities (visual and auditory), and the authors thought that this lack of integratibility between modalities could be responsible for the lack of priming in the compatible trials.

In a further study, Kaschak, Zwaan, Aveyard & Yaxley (2006) set out to test the above explanation of their results, i.e whether stimuli presented in the same or different modality can influence the effect of compatibility or incompatibility. Participants had to judge the sensibility of sentences implying motion while hearing auditory percepts of moving noise. When both the sentences and the noise were presented auditorily, responses were faster when the direction of motion in the sentence was compatible with the direction of motion in the perceptual stimulus, producing a compatibility advantage. However, when the sentences were not heard, but read by the participants, responses were slower, suggesting that compatible and incompatible modalities with which the two interacting set of stimuli are presented could influence the resulting embodied effect.

Meteyard, Bahrami & Vigliocco (2007) tested participants who listened to verbs that referred to upward or downward motion and to verbs that did not refer to motion, while performing a motion-detection task in which they had to detect motion in visual stimuli containing threshold levels of coherent vertical motion. Listening to verbs that were incompatible with the direction of the motion they were viewing impaired their perceptual sensitivity, whereas in compatible trials their perceptual sensitivity was intact. The results, however, were not conclusive, with no evidence of absolute advantage in comparison with the control trials.

Meteyard, Zokaei, Bahrami et al.'s (2009) study significantly contributed to the research on the effects of the interplay between perception and language. Participants were asked to judge whether a string of letters was a recognizable word while they were exposed to visual background motion. The words had a spatial content aligned on the vertical axis, expressing up, down movements; words with no spatial content were also included as a control. Visual motion was up or down and was presented at sub- and supra- threshold levels, which had previously been determined for each participant. They found that at sub-threshold levels reaction times were slower in the incompatible condition, and they suggested that under those conditions no strategies to initiate suppressive feedback would be in place. At supra-threshold levels, there was a lack of interference, which they explained as being due to suppression by "higher level cognitive mechanisms involving inhibitory feedback" (p. R733). Interestingly, accuracy data showed an advantage for the control words, implying disruption of semantic processing for all motion words, both compatible and incompatible. This disadvantage for words with spatial content compared to words with a neutral content was explained as the cost of inhibiting spatial processing, or, to put it another way, the cost of suppression. These findings constitute a first breakthrough in the understanding of the effects of the intertwining of perceptual and cognitive processes.

With respect to the behavioral evidence indicating an incompatibility advantage, or lack of interference, occurring during the cross-talk between perception and language (Richardson et al., 2003; Kaschak et al., 2005; Kaschak et al., 2006), the most common position taken is that, whilst there is a delay in processing in compatible trials because direction-selective neural mechanisms compete for resources, there is no need to share resources in incompatible trials, thereby resulting in a base-line like performance. This is illustrated in Kaschak et al.'s (2005) study by means of the Motion Aftereffect (MAE) phenomenon: perceiving motion in one specific direction engages neurons that respond preferentially to motion in that direction. Because these neurons are engaged by the visual stimulus, they are less available for simulating (e.g. while comprehending a verb) a motion in the same direction at the same time, hence the delay (Mather, 1998).

Behavioural evidence indicating a compatibility advantage is weaker. Kaschak et al.'s work at sentence-level argued that a prerequisite to produce a compatibility effect in the interplay between perceptual and linguistic processes is that all stimuli need to be presented in the same modality (integratibility) but this requirement is yet to be shown to be necessary. Meteyard et al.'s work at word-level, on the other hand, suggests that it is when participants are exposed to percepts at sub-threshold levels that the possibility of a compatibility advantage could be found, because at those levels participants do not initiate any strategy to inhibit or suppress feedback (Kaschak et al., 2006; Meteyard et al., 2007; Meteyard & Vigliocco, 2009). The off-line experiment conducted by Stanfield & Zwaan (2001) does not involve direct interaction of perceptual and linguistic stimuli, so it is not strictly relevant to this specific discourse on compatibility.

Questions remain about the mechanisms that underlie these results, which are partially overlapping but also partially inconsistent. The fact that from the existing studies it is not yet possible to deduce the general conditions that govern the facilitation in interactions between perceptual and cognitive processes does not mean that the compatibility advantage does not exist, however.

Some remaining questions may be considered in relation with the literature on the interplay between language and overt movement. For example, it was found that when the linguistic stimulus is presented before the movement (e. g. Glenberg & Kaschak, 2002), it is more likely that a compatibility advantage is found, and when the linguistic stimulus and the movement are concurrent, an incompatibility advantage can be expected (Borreggine & Kaschak, 2005), suggesting that the order of presentation can influence the embodied effect that results from the interaction of language and movement.

As well as the order with which the linguistic and motoric stimuli are presented, timing can be instrumental in creating an assisting or hindering effect. Boulenger, Roy, Paulignan et al., (2006) showed that perceiving action verbs can either interfere or prime a subsequent arm movement: interference occurred as early as 170 msec after word onset, whereas priming became evident at about 550 msec after word onset, revealing the temporal relationship between the two. It also matters whether it is the linguistic processing or the perceptual processing that is supposed to prime performance (e.g. Glenberg & Kaschak, 2002; Glenberg, Sato, Cattaneo et al., 2008), but this aspect will be dealt with in Article III. In general, the compatibility effect so far was more reliably found in language and action studies than in language and perception studies.

In the present study I embraced the general hypothesis that comprehending verbs that have embedded horizontal or vertical image schemata interacts with other forms of spatial processing along those same axes (Richardson et al., 2003). I looked at the interaction of linguistic and perceptual orientations on the horizontal/vertical axes, disregarding left/right and up/down directions in line with related work by Stanfield & Zwaan, 2001, Richardson et al 2003, where the interest was on the implicit orientation in space, and not on the direction of motion. As it is anticipated that the orientation of an arrow would interact with the implied orientation of a verb picture, which is a static image of implied motion, a main effect of compatibility/incompatibility is predicted. A norming study of the perceived orientations of the verb-pictures preceded this experiment.

As reported earlier in this introduction, implied motion in still pictures, purely imagined motion, or linguistic descriptions of motion have all been validated as equivalent in producing spatial image schemata which interact with perceptual cues (Toskos & Boroditsky, 2010; Winawer, Huk & Borodistsky, 2008; Winawer, Huk & Boroditsky, 2010). In the present study, verb pictures and arrows are both presented at visual level, thus this study explored the potential competition within the same modality across the two stimuli. The study compared younger adults, older adults, and individuals with pAD in order to investigate how comprehension can be affected by exposure to perceptual cues, either sharing the same orientation with verb pictures or featuring the opposite orientation.

All participants were exposed to an arrow moving in either the vertical or horizontal plane. Soon after, they had to decide whether a picture of implied motion and a word matched and response times were measured. Pictures were selected to imply motion on either the vertical or horizontal plane, so that arrow/picture compatible and incompatible trials were created.

In order to perform the verification required in the task, participants need to make inferences in order to verify pictures against words. This process of inferring so as to verify has been validated as an implicit form of language comprehension (Masterson, Druks, Kopelman et al., 2007). Based on the evidence that individuals with pAD exhibit unimpaired performance in implicit tasks, such as the word-picture verification task utilised in the present study, it was predicted that volunteers with pAD would perform at ceiling level in terms of accuracy, as there is no memory load (Maki, 1995) and no generation of a target required. There is ample evidence supporting uncompromised performance of individuals with pAD in verification tasks such as the one used in the present study (Bondi, 1991; Keane, 1991).

Anticipating slower responding in the group with pAD, and that this delay might have an effect on the time-sensitive interactions being tested, we predicted group differences with regards to perceptual and linguistic interactions. More specifically, the longer response times in the pAD group (and older group) might dilute the embodiment effect.

Differences were also predicted according to type of trial. There will be two types of trials: match trials are those with a verb-picture and a printed word matching, and mismatching trials where the word does not match with the verb-picture. In order to verify mismatch trials participants have to represent both the verb picture and the printed word, which is not the case in matching trials, because the two coincide. Because of these two different processes characterizing the two types of trial, it is possible that type of trial may interact with the other variables so that the embodiment effect may be present only in match trials.

I anticipated that perceptual cues and the process of understanding verb-pictures will interact producing either compatibility or an incompatibility effect. Processing a perceptual cue, such as an arrow, prior to performing the verification task makes available a mental representation that is a fully-fledged component of the subsequent processing (verb picture verification), as the cue anticipates the orientation of the verb shown subsequently. According to Leboe, Whittlesea & Milliken, 2005, if the perceptual cue provided in advance is truly relevant to the processing required by the task, facilitation should be found. So, according to them, in the present study the expected result would be of priming in the compatible condition, however, this theory is compromised by the evidence published so far, which suggests that the embodiment effect resulting from the interplay of percepts and linguistic stimuli is still not easily predictable.

3.3 Method

3.3.1 Participants

Participants for the young group were recruited from the University of Sussex Psychology students' pool; older adults were recruited mainly from sheltered accommodation and volunteers with mild to moderate probable Alzheimer's Dementia (late onset) were recruited from two local memory clinics. All participants were native English speakers and all reported normal or corrected to normal vision.

Volunteers with AD were selected on the basis of a clinical diagnosis of probable Alzheimer's, currently in the Mild to Moderate phase, a Mini Mental State Examination (MMSE) score between 19/30 and 25/30 at the time of testing, and no other cause of cognitive impairment present in their medical history. The MMSE was administered by the experimenter. All volunteers were receiving Alzheimer related medication (Aricept, Exelon) with a stable dosage for at least one year. Ethical approval was obtained from National Research Ethics Services. Informed consent was obtained from all volunteers prior to data collection; in the case of volunteers with AD, their carers' consent was also obtained.

Only participants who scored 25/30 or higher in the MMSE and were generally healthy (self-evaluated) were selected for the older adults' group. Volunteer characteristics for the three groups are reported in Table 3.2.

Table 3.2 Sample characteristics & background test scores

	Healthy Younger	*Healthy Older*	*pAD*
Number of Participants	21	20	15
Handedness (right/left)	19/2	19/1	14/1
Gender (male/female)	1/20	4/16	5/10
	Mean & Std Error	**Mean & Std Error**	**Mean & Std Error**
Age (in years)	21 ± 1.9	79.7 ± 2.71	80.27 ± 2.49
Education (in years)	/	11.6 ± 1.39	10.33 ± 1.22
MMSE correct (0-30)	/	28.15 ± 0.36	22.92 ± 0.74
Full scale IQ (NART-R converted)	116.66 ± 2.3	117.24 ± 2.47	115.89 ± 1.37

Age, number of years spent in education and number of errors in the NART were not significantly different in volunteers with pAD and in the healthy older group, as indicated by independent t-tests ($p > .05$, two-tailed).

3.3.2 Materials

A word-picture verification task, similar to the one used in Article I, was used. In this version of the task, the 'related mismatch condition' was removed because volunteers with pAD in this condition performed with more difficulty. The other difference was that each verb picture was preceded by an arrow, as shown in Figure 3.1.

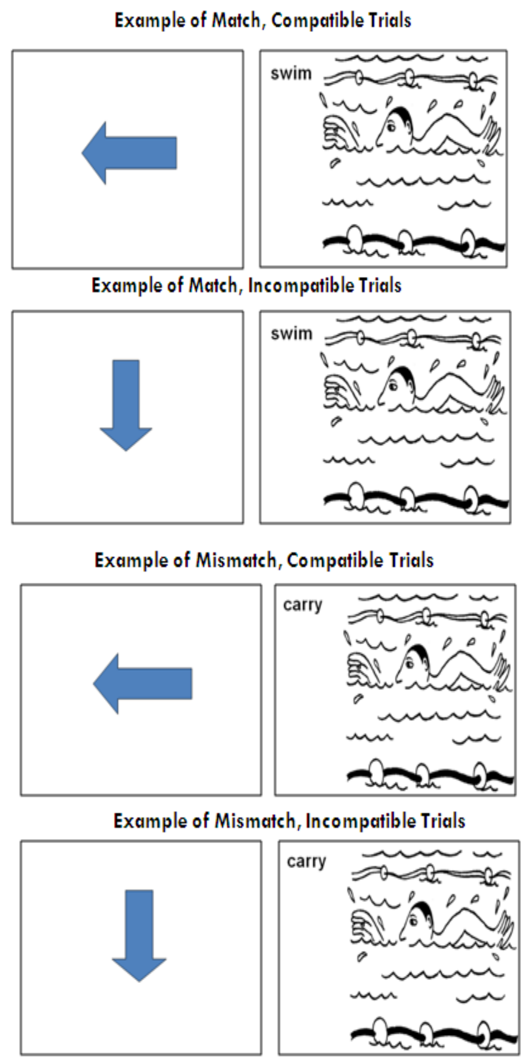

Figure 3.8 Examples of picture/word match and mismatch trials, and arrow/verb picture compatible and incompatible trials

A subset of forty drawings depicting actions, taken from An Object and Action Naming Battery (Druks & Masterson, 2000), was used to create the task. In the above mentioned battery, each verb is normed according to the following criteria: number of phonemes, number of syllables, frequency, familiarity, age of acquisition, imageability, and visual complexity. The subset of verbs used in this experiment was selected to include verbs with comparable measures in the horizontal and vertical verbs.

Norming Study

The chosen subset of drawings and the unrelated words appearing in mismatching trials were normed for orientation of the action or implied motion. Participants in this norming study were asked to say whether they thought the action depicted in the picture was laid out on a horizontal, vertical axis or whether they thought there was not a specific axis or orientation. They were asked the same about the unrelated words. A pool of 50 participants aged from 20-80, different from the volunteers used in the experiment, was used to norm the data. Younger participants were Psychology student volunteers, older participants were healthy volunteers living in sheltered accommodation or independently.

Participants were given a booklet with a word written on each page. They had to mark whether the word had a horizontal, vertical orientation, or had no orientation at all. They were then given a hard copy of each verb picture, and had to choose whether the action was taking place on a horizontal, vertical plane or on no specific orientation. Responses were given orally and the experimenter recorded the responses on a sheet. Results confirmed the *a priori* indication of orientation with average ninety-seven percent of the participants agreeing with the orientation attributed to each verb picture, and eighty-seven percent agreeing that the unrelated words had no orientation. The verbs and the total number of errors made by the participants are listed in Appendix C in this thesis.

Experimental Task

The present design was a partial replica of the experimental design reported in Masterson & Druks (2007) and a modified version of study 2 reported in Article I. Each item in the task consisted of a single picture presented four times: once preceded by an arrow compatible to the action taking place in the picture (for example, ‘a man pushing a cart’ preceded by a horizontal arrow, crossing the screen from left to right) and with a printed word on the top left corner matching the drawing (for example, ‘pushing’), once with the same compatible arrow but with a mismatched word printed on the top left corner (for example, ‘tickling’), once preceded by an arrow incompatible to the action taking place in the picture (with regards to the same example used so far, the arrow would travel from the top to the bottom of the screen) and with a matching label printed on the top left corner saying ‘pushing’ and, finally, once preceded by the same incompatible arrow and with a mismatched label in the top left corner saying ‘tickling’. The words used as mismatches were normed as ‘not having a specific orientation’.

A total of 160 stimuli (4 x 40 different pictures) were used in one session, and were presented in eight blocks of twenty trials each according to the following rules: the four types (picture with matching word and compatible arrow, picture with matching word and incompatible arrow, picture with mismatching word and compatible arrow, picture with mismatching word and incompatible arrow) were allocated so that the same picture would appear only once in every other block. Matching and mismatching trials were distributed evenly but randomly among blocks.

The task was presented in E-prime (Schneider, Eschman, & Zuccolotto, 2002a; Schneider, Eschman, & Zuccolotto, 2002b) on a laptop computer. The instructions required participants to make a 'yes' or 'no' response regarding the match between the word and the picture. The 'q' and 'p' keys on the keyboard were designated 'yes' and 'no' keys respectively, and were labelled. The arrows preceded the stimuli with no perceivable time interval, but with an interval caused by the change of screen. The presentation time of the arrow was of one second. Accuracy of key-presses and latency to respond were recorded, the latter was measured from the onset of the picture and word to response. The duration of the task was approximately twenty minutes.

3.3.3 Procedure

After preliminary testing, participants were asked to read the instructions on the screen and carried out a practice session consisting of 8 trials different from the experimental trials. The instructions said that an arrow would appear on the screen and soon after, a word and a picture would appear. Participants had to verify if the word and the picture matched. If there was a match, they had to press the 'YES' key, if not, they had to press the 'NO' key. They were requested to press the key as soon as their mind was made up and there was no emphasis on speed of response. They were informed that there would be 20 trials before they could have a rest. The group with pAD only was also given verbal instructions.

Participants were randomly assigned to two counterbalanced lists, with the constraint that an equal number of participants received each of the two lists. An analysis of variance with Counterbalance List as a between subjects factor did not produce significant effects involving this factor, and so it was not considered in the Results section.

3.4 Results

3.4.1 Accuracy data

The overall accuracy rate on the one hundred sixty trials was 99% in all three groups. Although all at ceiling, in the young group only, there was a main effect of trial type (match, mismatch); F (1, 20) = 33.38, $p < .001$, indicating that the number of mistakes participants made was significantly higher when they responded to trials where pictures and words matched (match trials: M: 1.52 (out of 160), SE: 0.15; mismatch trials: M: 0.54 (out of 160 trials), SE: 0.16). No other effects were significant. As the number of errors was significantly higher in match trials, latency was added to the analysis as a co-variate, F (1, 19) = 1.17, $p < .01$, and its significance hints at a speed/accuracy trade-off. Total errors by item for the group with pAD and older adults are reported in Appendix C.

3.4.2 Latency data

Analyses of variance by subjects and by items were conducted with a Type I error rate set to .05; analyses were performed only on the correct responses, and any response time greater than 2.5 standard deviation from the cell mean was replaced by the cell mean by subjects and by items. To remove outliers, I first omitted any response times shorter than 200msec and longer than 4,000 msec, then replaced responses more than 2.5 SD from each participant's (or item's) mean in each condition. The outlier screening led to the exclusion of 1% of the response times. Counterbalance list and direction of motion (toward, away, up or down) were included as factors in the statistical analyses but because they produced neither main effects nor interactions, results are not considered further.

Younger group

The younger group was analysed separately from the older participants and participants with pAD, as variability in the two older groups was so much greater than in the younger group. In the analysis by subjects, the within subjects' variables were the type of trial with two levels (match/mismatch), the orientation or axis of the verb picture with two levels (horizontal/vertical), and the type of arrow with two levels (compatible to verb picture/incompatible to verb picture). In the by items analysis the between items' variable was the orientation or axis of the verb picture (horizontal/vertical); the within items' variables were the orientation of the arrow (compatible to verb picture/incompatible to verb picture) and the type of trial (match/mismatch). The items *wave* and *drill* were excluded from the by items analysis because of technical problems. Analyses conducted across participants are denoted F_1, and analyses conducted across items are denoted F_2.

Two 2 (trial type: match/mismatch) x 2 (axis of the verb picture: horizontal/vertical) x 2 (arrow compatibility to axis: compatible/incompatible) ANOVAs were performed on the younger adults' reaction times of correct trials only. There was a main effect of trial (match vs. mismatch): F_1 (1, 20) = 23.41, $p < .001$, η = .54, F_2 (1, 36) = 32.21, $p < .001$, η = .47, because trials where verb pictures and words matched were responded to faster. There was a main effect of arrow/axis compatibility,

F_1 (1, 20) = 4.35, $p < .05$, η = .18, F_2 (1, 36) = 3.41, $p = .07$, η = .09, because of an advantage in incompatible trials, as shown in Figure 3.9 (though it should be noted that this effect was only approaching significance in the by -items analysis).

The type of trial (match/mismatch) interacted significantly with the orientation of the verb picture (vertical/horizontal) in the by subjects analysis only, F_1 (1, 20) = 9.66, p < .01, η = .33, F_2 (p > .05). Post hoc analysis indicated that in match trials, that is in those trials where the picture and the printed word match, horizontal verb pictures were responded to significantly faster than vertical ones, t (20) = 2.58, p < .01. Contrary to my hypothesis, trial type did not interact with arrow/axis compatibility (p > .05).

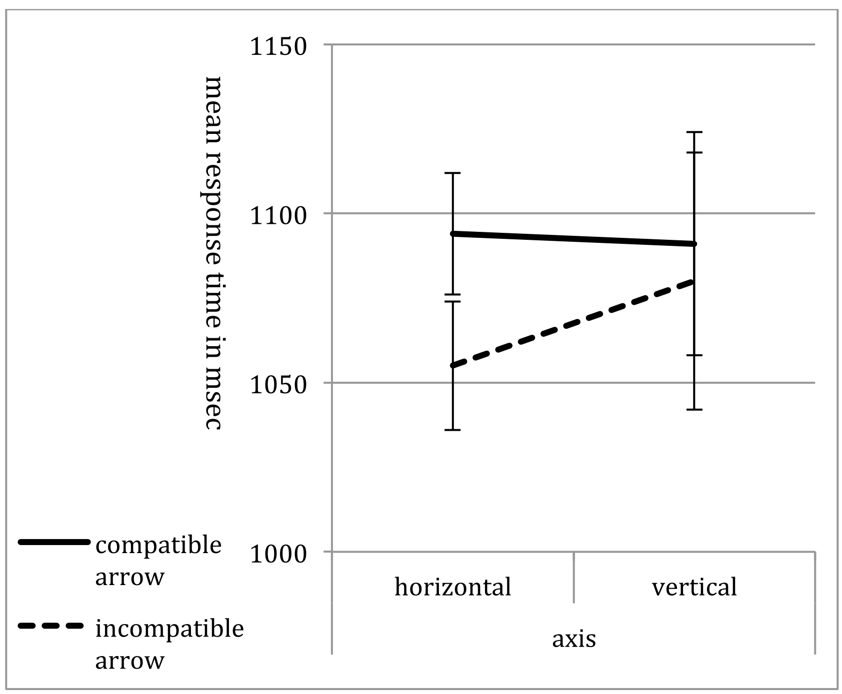

Figure 3.9 Mean response times for younger adults showing the incompatibility advantage

Older Group and Group with pAD

Two 2 (group: older adults/adults with AD) x 2 (trial type: match/mismatch) x 2 (verb picture orientation or axis: horizontal/vertical) x 2 (arrow compatibility to verb picture: compatible/incompatible) mixed analyses of variance were computed on the latency data.

As predicted, a main effect of group was found, F_1 (1, 33) = 15.69, $p < .001$, η = .32, F_2 (1, 38) = 789.84, $p < .001$, η = .95, because the older adults were faster than volunteers with pAD. A main effect of trial type was also found, F_1 (1, 33) = 49.75, $p < .001$, η = .61, F_2 (1, 38) = 26.55, $p < .001$, η = .41, because match trials (when word and verb picture matched) were faster than mismatch trials.

There was also a significant main effect of arrow/axis compatibility, F_1 (1, 33) = 16.42, $p < .001$, η = .33, F_2 (1, 38) = 3.77, $p = .06$, η = .09, because when the orientations of the arrow and of the verb picture were incompatible, response times were, again, significantly faster than when they were compatible, though it should be noted that this effect was only approaching significance in the by -items analysis.

The following significant interactions were found: type of trial (match/mismatch) interacted with group, F_1 (1, 33) = 8.14, $p < .01$, η = .2, F_2 (1, 38) = 12.16, $p < .001$., η = .24, showing that match trials were faster than mismatch trials for both groups and that in both match and mismatch trials the two groups were significantly different. Type of trial also interacted with the orientation of the verb picture, F_1 (1, 33) = 10.48, $p < .01$, η = .24, F_2 was not significant ($p > .05$),with paired t tests showing that vertical verb pictures were responded to faster than horizontal verb pictures in mismatch trials, *t* (34) = 2.4, $p < .05$, but not in match trials, $p > .05$. Type of trial and group did not interact significantly with arrow compatibility (*F*s < 1). There was no three way interaction between type of trial, axis of the picture and arrow/axis compatibility.

Finally, type of trial, orientation of verb picture and group interacted significantly F_1 (1, 33) = 6.07, $p < .05$, η = .16, F_2 (1, 38) = 3.12, p =.08, η = .09. The following by group analysis will explore this interaction further.

Older Adults

Two 2 (trial type: match/mismatch) x 2 (verb picture orientation or axis: horizontal/vertical) x 2 (arrow compatibility to verb: compatible/incompatible) ANOVAs were performed on the older group's latency data. There was a main effect of trial, F_1 (1, 19) = 32.12, $p < .001$, η = .63, F_2 (1. 38) = 22.64, $p < .001$, η = .37, because trials where verb pictures and words matched were faster. There was a main effect of arrow compatibility to the orientation of the verb pictures, F_1 (1, 19) =13.53, p < .01, η = .42, F_2 (1. 38) = 3.77, p = .06, η = .09, because of an advantage in incompatible trials, as shown in Fig. 3.10, (though it should be noted that this effect was approaching significance in the by -items analysis).

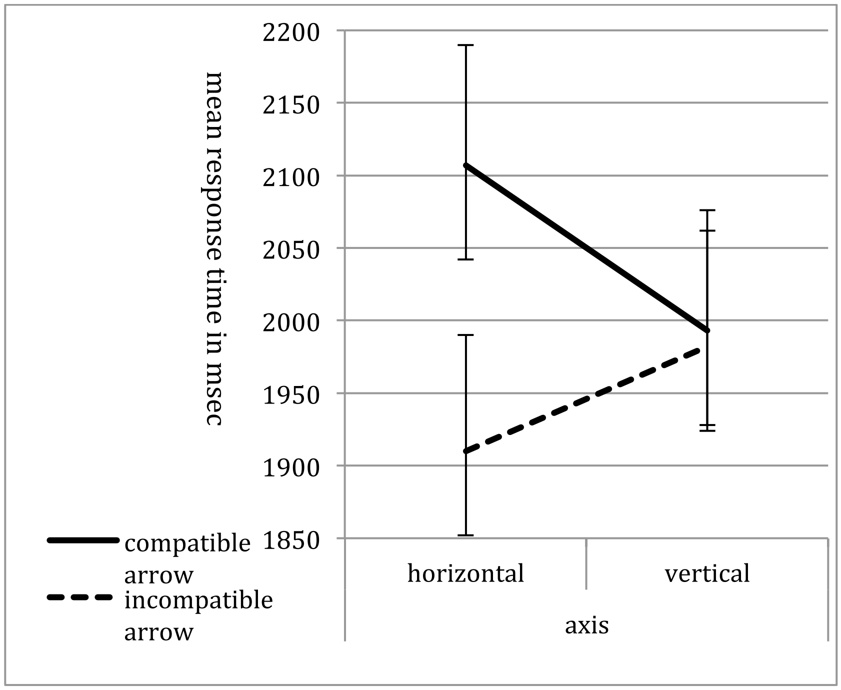

Figure 3.10 Mean response times for older adults showing the incompatibility advantage

There was a significant interaction between the verb picture orientation (horizontal/vertical axes) and the arrow's compatibility with the axis of the verb picture, F_1 (1, 19) = 18.69, p < .001, η = .5, F_2 (1, 38) = 4.17, *p* < .05, η = .1. As Figure 3.10 clearly illustrates, verb pictures depicting action laid out horizontally are significantly more sensitive to facilitation and interference than vertically laid out verb pictures. It is difficult to provide an explanation for this interaction, as it occurs only in the older group.

Volunteers with pAD

A 2 (trial type: match/mismatch) x 2 (verb picture orientation: horizontal/vertical) x 2 (arrow compatibility to verb: compatible/incompatible) ANOVA was performed on the reaction times of volunteers with pAD. There was a main effect of trial, F_1 (1, 14) = 22.34, p <. 001, η = .62, F_2 (1, 38) = 23.79, p <. 001, η = .39, because trials where verb pictures and words matched were faster.

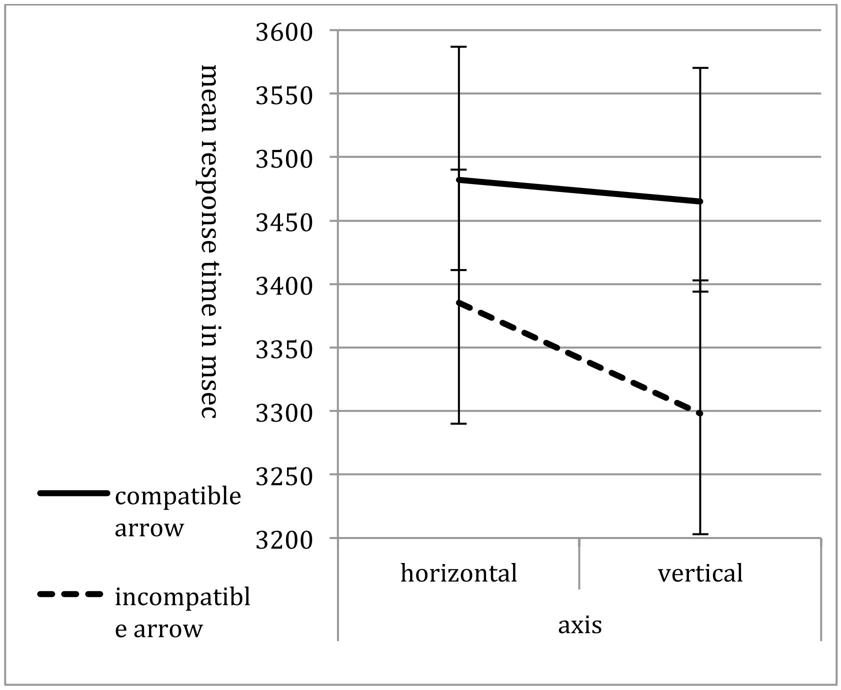

Figure 3.11 Mean response times for the group with pAD showing the incompatibility advantage

There was a main effect of arrow compatibility with the orientation of the verb pictures, F_1 (1, 14) = 5.64, p < .05, η = .3, F_2 (1. 38) = 3.29, p = .08, η = .08, because of an advantage in incompatible trials, as shown in Figure 3.11 (though it should be noted that this effect was approaching significance in the by items analysis). No variable interacted significantly with the others.

3.5 Discussion

The present study was designed to address two main questions. First, in what way can the verification of a pictorial description of an action verb against the printed version of the verb be primed by perceptual cues either compatible or incompatible to the orientation of the action depicted in the picture? Given that previous studies, conducted on young volunteers, had demonstrated both a significant compatibility effect, and a significant incompatibility effect, this question was presented as an open-ended hypothesis that one of the effects would result from this interaction.

The second question was whether individuals with pAD show different responses to healthy older and younger groups in performing this task. We predicted longer reaction times for individuals with pAD, because similar studies reported this outcome (e.g. Masterson et al., 2007). Although there would be no reason to believe that susceptibility to perceptual cues should be different, group differences related to the interaction between cues and comprehension were expected because the longer reaction times which typically characterize the group with pAD could result in a loss of, or in the production of different embodied effects.

I also predicted that match and mismatch trials may interact with compatible and incompatible trials, since in mismatch trials participants had to represent not only the verb picture, but also a mismatching word, and this was predicted to dilute the spatial representation primed by the arrow. Results were contrary to this last prediction, as it was found that the type of trial did not interact with arrow/axis compatibility, and so no priming effects were reflected in the accuracy and latency data in any group. All three groups were consistently faster to respond to trials where the picture and the accompanying word matched. Interestingly, more mistakes were made by the younger group in responding to match trials, but not by the two older groups, indicating a possible speed-accuracy trade-off. As participants performed at ceiling, equivalence between groups cannot be assumed.

With respect to the first main question, it was found that volunteers with pAD, older adults and young adults were consistently faster at responding to trials when the orientation of the perceptual cue and the orientation of the verb picture were incompatible. This result demonstrates that there was a strong interaction between the spatial representations activated by the cues and those activated when verifying pictures against words. Although this *incompatibility advantage* has indeed been found in previous studies (e.g. Richardson et al., 2003; Kaschak et al., 2005; Kaschak et al., 2006), the literature to date, as reported in the Introduction to this article, has provided evidence for priming and hindering effects when the priming of perceptual and cognitive processes were tested. If perceptual priming is going to have any practical benefit, it is important to understand the conditions under which an incompatibility effect is produced.

With regards to the second main question, despite the group differences which emerged in the latency data, with the older group being faster than the group with pAD, there was no important group difference in the interaction with perceptual cues. Despite the reliability and the longevity of the effect, taking into consideration latency data of participants with pAD, this effect represents a relative advantage against the compatible trials. Previous studies have recognized that the incompatibility effect appears when compatibility trials are subject to interference, but have not at all established the incompatibility effect as an absolute advantage, i.e. an advantage over control trials as well. Because the present study was concerned with testing the simple comparison between compatible and incompatible trials, together with testing perceptual priming in volunteers with pAD, no neutral condition was included in this design. A condition with no arrows was not included in the present study because the arrows used in this experiment could have influenced performance on the trials not preceded by an arrow. It is recognized that without a control condition results cannot be conclusive of any absolute advantage, however, the purpose of this study was to test first and foremost whether perceptual priming brings about effects that are similar to those found in healthy groups. Further studies will continue the investigation by making comparisons between reaction times of both incompatible trials and compatible trials compared to trials that were preceded by no arrow. Thus, these results should be regarded as the basis for further investigation of the nature of this incompatibility effect. Does it occur? Is it indeed only a relative advantage? Under what circumstances could this effect be produced?

There are various attempts at explaining this advantage of incompatible trials. First, there is the argument of competition for shared resources (Richardson et al., 2003), which states that the same neural mechanisms are engaged in processing the perceptual and the linguistic stimulus, and so compete. According to this argument, resources used in compatible trials to process the cue were temporarily unavailable to complete the task, hence the slower response than in the incompatible trials.

Second, there is the argument of Motion After Effect (MAE), as Kaschak et al. (2005) had originally posited. The MAE occurs when, after adapting to upward motion, people are more likely to see a stationary stimulus of moving dots as moving downward, or *vice versa.* This phenomenon is basically a motion illusion. According to this argument, participants could have adapted to the after-image effect projected from, say, a vertical moving arrow onto spatial representations activated during cognitive processing, favouring an horizontally laid out verb picture. The problem with this explanation is that the MAE is a cumulative chasing effect and is also short lived; because the arrows in this present study were randomized, and because the verification task interrupted the perceptual exposure, it is unlikely that the response time reflected any MAEs. The longer latencies that characterized the performance of individuals with pAD would have definitely reduced the MAE.

Third, there is the argument of transfer-inappropriate processing, which provides an explanation for the occurrence of negative priming, which is when interference (rather than facilitation) is found in compatible trials (Leboe et al., 2005). Leoboe et al., 2005 argue that when the perceptual cue is irrelevant to the processes involved in the subsequent task, then interference is obtained rather than facilitation. In other words, when the feature activated during priming is not the focal dimension of the subsequent task, that feature will introduce a cost to the subsequent performance in a compatible trial. If we were to follow Leboe et al. (2005), the incompatibility obtained in these trials would be an example of transfer-inappropriate processing: i.e. that the arrows did not transfer appropriately to the subsequent task. If this were indeed to be the case, it would cast doubt on our conclusions with respect to the importance of the representation of spatial features during comprehension (cf. Article I).

The argument of integratibility, posited by Kaschak et al. (2005, 2006), cannot explain the findings of the present study. No compatibility effect was found in spite of both stimuli being presented in the same visual modality.

A parallel analysis between motor and perceptual processing could be useful to consider in terms of experimental designs. Latest studies focussing on the interaction between movement and language have supported the idea that compatible and incompatible effects can be dependent on the timing and order of presentation of the two stimuli and that the magnitude of the compatible effect varies as a function of time (Boulenger et al., 2006). A compatibility effect, for example, was found when, while processing the linguistic stimulus, the action was planned (Kaschak et al., 2006).

The experiments conducted in order to explore this area are motoric manipulations toward or away from the body of the participant, which makes the processing highly self-referential, and definitely more self-referential than the use of perceptual cues. With the use of overt movement, or even of imagining the movement, comes the advantage of self-referentiality, which seems to play a tangible part in creating facilitation (Glenberg & Kaschak, 2002, Glenberg et al., 2008, Borreggine & Kaschak, 2006; see also article III of this thesis). From a neural point of view, a more accurate match of overt movement and movement implied in language is achieved than with perceptual cues, producing higher levels of specificity that can also help to create a facilitation, as a fast growing body of evidence seems to be pointing to.

Future studies could improve the present work in a number of ways: first, control trials could be added in order to be able to further interpret the effect obtained; second, a manipulation of the timing of the arrow (delays) could be helpful in exploring at what stage does the arrow produce an activation of middle temporal cells which then fit into the activation brought about by the processing of the verb picture; third, manipulating the salience of arrow imagery could be a way of interrogating further the relationship between perceptual and cognitive processes. The fact that the incompatibility effect was produced after a few seconds from the exposure to the arrow in individuals with pAD, could lead us to test a young healthy population on this timing, inserting a forced delay between cue exposure and verification task, in order to ascertain whether the incompatibility effect is due to processing or its longevity is in the nature itself of the effect.

It would be interesting to explore further what the conditions are that promote a scenario where perceptual cues transfer an assisting effect to comprehension, as this could be useful for concrete applications to populations experiencing difficulties in comprehension.

The relationship between language and perceptual processes has been shown to be highly complex and further research is necessary to disentangle the interaction between these. Our main aim was to find out whether arrow-imagery can prime or interfere with participants' performance on a word-picture verification task (in which the pictures of actions occurring on the same or on the opposite plane of the arrow needed to be verified); and to find out whether AD and age produce different outcomes. Arrows and actions on the same plane were not found to be facilitatory, whereas arrows and actions on an opposite plane were found to be faster in each group. This confirms that perceptual cues interact with language comprehension regardless of age and cognitive impairment such as AD.

4. Article III: The absolute advantage of transfer schema and the relative advantage of compatibility in probable Alzheimer's Disease

4.1 Abstract

It has been shown that when participants are asked to make sensibility judgments on sentences that describe a transfer of an object toward or away from their body, they are faster to respond when the response requires a movement in the same direction as the transfer described in the sentence. This phenomenon is known as the Action Compatibility Effect (ACE). This study investigates whether the ACE exists for volunteers with probable Alzheimer's disease (pAD), whether the ACE can facilitate language comprehension, and also whether the ACE can still be produced if the order of the two events is inverted, that is whether overt movement can prime comprehension of transfer sentences. In Study 1, participants with pAD, younger and older adults were tested on an adaptation of the ACE Paradigm. In Study 2, the same paradigm was modified to include an arm movement that participants had to perform prior to sentence exposure on screen. In Study 1 young, older adults and individuals with pAD were faster to respond when the direction of the response movement matched the directionality implied by the sentence (ACE). In Study 2, no traditional ACE was found; participants were faster when the direction of the movement immediately preceding the sentence matched the directionality of the sentence. It was found that compatibility effects generated a relative advantage, that transfer schemata are easier to process and that an ACE-like effect can be the result of mutual priming between language and movement. Results suggested preservation in AD of the neural systems for action engaged during language comprehension, and conditions under which comprehension in AD can be facilitated in real life may be identified.

4.2 General Introduction

A central idea of the embodied approach to cognition is that language comprehension prompts activation of the same perceptuo-motor processes that are activated in perception and planned action, as well as actual action. Glenberg & Kaschak (2002) tested the hypothesis that it is by cognitively simulating the actions implied by sentences that language conveys meaning. If this were not the case, language would be a closed circuit of arbitrary symbols in need of connections to real objects in the world. It is the idea of embodied meaning that provides grounding to the things in the world.

Glenberg & Kaschak (2002) identified an effect that provides the evidence that merely understanding a sentence can facilitate or interfere with a physical response, the Action Compatibility Effect (ACE). They demonstrated that comprehending a sentence that implies action in one direction (e.g. “close the drawer”) interfered with real action in the opposite direction (e.g. movement toward the body). An action-compatible response, on the contrary, was facilitated, hence the ACE. This constitutes evidence, they claim, that language comprehension must be grounded in bodily action and cannot be explained by a symbol system with no grounding in the real world (Glenberg & Kaschak, 2002).

But how can this effect be explained? Understanding an ‘away sentence’ such as “close the drawer” results, they suggest, in simulating the action of closing, which entails a movement away from the body. We understand sentences about action (e.g., Open the door) not in terms of the meaning of the individual words in the sentence, but in terms of the motor patterns needed to perform the action (e.g., pulling your arm towards your body), (Glenberg, Sato, Cattaneo et al., 2008). Because it is hypothesized that this simulation requires the very same neural pathways as planning action and taking action, understanding an "away sentence" interferes with making a movement towards the body. In more generic terms, understanding action and motion sentences involves a 'translation' of the sentence's implied action or direction into an action pattern. It is assumed that it is this 'translation' that interacts with the motoric response given by the participants.

It is significant that the ACE was found not only for imperatives, but also for descriptive sentences with a double-object construction (i.e. *Mike handed you the book*) and with a dative-construction (i.e. *Mike handed the book to you*). Moreover, the effect was also found for abstract "transfer sentences", such as *Mike told you the story/Mike told the story to you* (Glenberg & Kaschak, 2002, Glenberg et al., 2008). These sentences seem to have in common two things: one is that they imply a transfer of something to someone; the other is that they are self-referential: these two aspects are in fact interconnected.

The transfer of an object from someone to oneself and from oneself to somebody else is expressed in syntactic constructions to which babies and children are amply exposed during early language acquisition (e.g. to *give or bring something to somebody, to tell something somebody,* etc.). These syntactical structures become then deeply associated with 'movement toward and away from the body', even when the content is abstract (Tomasello, 2000; Glenberg & Gallese, 2011), and can therefore explain why the internal simulation of such sentences interacts with overt movement.

Furthermore, the ACE occurs specifically when the transfer is related to the self. Buccino, Riggio, Melli et al. (2005) used sentences in third person and obtained interference effects; Glenberg et al. (2008) used sentences in the first person and obtained a facilitatory effect.

When we try to comprehend a situation, it is as if we put our body in the situation. We simulate not just our own but other people's behaviour as well, as part of our attempt to understand. This experiential grounding applies to both conscious and unconscious representations. Furthermore, it applies to abstract language as well, to the extent that we often make sense of language about social or psychological causation in terms of the 'pushes' and 'pulls' of our bodily experience (Lakoff, 1987;Talmy 1988; Glenberg & Kaschak, 2002, Scorolli, Binkofski, Buccino et al. 2011, Kousta, Vigliocco, Vinson et al., 2011). Examples of embodiment provided by Ochs, Gonzales & Jacoby (1996) showed that a sort of explicit bodily identification is overtly used when we try to understand something complex, and this includes scientists having a difficult time coming to grips with a new hypothesis. It is about putting one's own body in the situation we are trying to make sense of (Jeannerod, 2006).

The self-referential advantage was also found in studies on action-based memory: information about the self was remembered better than information related to someone else or processed in other ways (Rogers, Kuiper, & Kirker, 1977). This purportedly mnemonic advantage of the self was explained by the fact that information relating to the self is preferentially encoded and organised above other types of information, a phenomenon known as the self-reference effect (Symons & Johnson, 1997).

This self-reference effect, together with the enactment effect - enacted events are remembered better than verbally described ones. - have both been known as effects assisting memory (Hutton, Sheppard & Rusted, 1996; Senkfor, Van Petten & Kutas 2008). Research on action-based memory and research on action-based language are loosely related, despite the fact that they have been studied independently of each other so far, and so it is not surprising that these effects could enhance not only memory, but also language comprehension.

The action-compatibility effect (ACE) which is associated with language comprehension, is based on the principle of enactment and is self-referential. However, to be able to say that it assists comprehension, in the same way the self-referential and enactment effects assist memory, it would be helpful to find out whether it produces a relative advantage (relative to the opposite condition, in which there is a mismatch between the direction embedded in the sentence and the direction of the overt movement), or an absolute advantage (relative to sentences where no transfer is implied). The studies conducted so far do not make this absolutely clear. For example, in Glenberg & Kaschak (2002) a non-transfer condition was not present; in Glenberg et al.'s (2008) Experiment 1, non-transfer sentences are presented in a graph but are excluded from any analysis; in Experiment 2, the motor evoked potentials of transfer and non-transfer sentences were compared, and it was reported that the peak size of the motor evoked potential was at the verb of a transfer sentence. This evidence was used to ground the argument that activation of the transfer action schema in motor cortex contributes to language comprehension, and that activation of the motor cortex is not a mere epiphenomenal activity.

It is particularly crucial to establish the relative or absolute advantage brought about by the ACE when it comes to translating this hypothetical advantage into better comprehension strategies for a cognitively impaired population such as those suffering from probable Alzheimer's disease (pAD): if the ACE could function as a comprehension 'enhancer' (Fischer & Zwaan, 2008), it could inform adaptations to techniques designed to communicate with individuals with pAD and the implications would be extensive. Neurally there would be no reason to believe that the ACE should not be observed among people with pAD, given that motor trace activation has been shown to be preserved in AD (Hutton et al, 1996). However, reaction times in individuals with pAD are significantly longer than those of healthy younger participants, and so the question arises whether the effect could last sufficiently long, given that, so far, only a healthy younger population has been tested.

The time course of the ACE was studied by manipulating the kinematics of the response movement (Boulenger, Roy, Paulignan et al., 2006) and the timing at which one prepares the response movement (Borreggine & Kaschak, 2006) and it was found that they both directly affect the magnitude of the ACE. Pulvermüller (2008) found that motor activation occurs very soon after a linguistic stimulus is presented (22msec), but priming becomes evident at about 550-580 msec after word onset (Boulenger et al., 2006). It is not yet known how long this window remains open. Borreggine & Kaschak (2006) also provided evidence that timing is a key aspect of the ACE: they found a facilitating effect when participants had the opportunity to plan their motor response while processing the sentence, and a reversed effect when there was no time for action planning, as the direction of the required movement was not revealed until after the sentence was presented (lagged response).

Study 1 aims to explore whether individuals with AD can produce the ACE, given that its time–course will need to be different from that found in the young healthy participants and, if the ACE is found, whether it elicits relative or absolute facilitation in a population with AD.

4.3 Study 1: Sentence and action compatibility

Study 1 is a close replica of Glenberg's original study (Glenberg & Kaschak, 2002; Glenberg et al., 2008), with its design adapted to a cognitively impaired population; the details of these methodological differences are illustrated in the Method section. It looks at whether the ACE can be found in a healthy older population and among individuals with Alzheimer's disease (AD) in their mild to moderate stage in order to explore the possibility of using the ACE to facilitate comprehension. The main research question in this Study is whether the effect can be sustained throughout the longer response times that are predicted for the group with pAD.

The accuracy rate (i.e. the ability to distinguish sensible from nonsensical sentences) was predicted to be above 90% in all three groups. Group effects were predicted for latency: the young participants were hypothesised to be the fastest at responding and the healthy older adults were hypothesised to be faster than volunteers with AD. These two hypotheses are predicated on results from previous studies and on the preliminary comprehension test administered to older adults and volunteers with pAD (see p.8).

It was hypothesized that the three groups would give faster responses when the direction implied in the sentence and the direction of the subsequent response movement are compatible. This hypothesis is predicated on published evidence (Glenberg & Kaschak, 2002; Borreggine & Kaschak, 2006; Glenberg et al. 2008). Compatible trials were predicted to be faster than non-transfer trials, predicated on the assumption that the compatibility effect brings about an advantage.

4.3.1 Method

4.3.1.1 Participants

Thirty-five psychology students, twenty healthy older adults, and nineteen volunteers with probable mild to moderate Alzheimer's Type disease (pAD) with late onset were recruited. All participants were native English speakers and had normal or corrected-to-normal vision. Handedness was noted and participants were requested to utilize their dominant hand when performing the tasks. Ethical approval was obtained by the National Research Ethics Services. Informed consent was obtained from all volunteers prior to data collection; in the case of volunteers with pAD, their carers' consent was also obtained.

The healthy older adults were recruited mainly in sheltered accommodations; only participants who scored 28/30 or higher in the MMSE and were judged healthy on the basis of their medical history were selected.

The pAD volunteers were recruited from two local memory clinics, and they were selected on the basis of a clinical diagnosis of Alzheimer's dementia, in the Mild to Moderate phase, with a Mini Mental State Examination (MMSE) score between 19/30 and 25/30 at the time of testing, and no other cause of cognitive impairment present in their medical history. All volunteers were administered the MMSE by the experimenter and were all receiving Alzheimer related medication (Aricept, Exelon) with a stable dosage for at least one year. Volunteer characteristics for the three groups are reported in Table 4.3.

Table 4.3 Study I sample characteristics and background test scores

	Healthy Younger	*Healthy Older*	*pAD*
Number of participants	35	20	19
Gender (male/female)	12/23	9/11	9/10
Handedness (right/left)	32/3	18/2	18/1
	M & Std Error	**M & Std Error**	**M & Std Error**
Age (in years)	20.85 ± 1.77	76.85 ± 2.45	78.14 ± 2.44
Education (in years)	/	12.9 ± 1.62	11.79 ± 1.41
MMSE correct (0-30)	/	28.8 ± 1.05	22.63 ± .58
Full-scale IQ (NART-R converted)	115 ± 1.3	125 ± .74	122 ± 1.5
Comprehension Test error (0-26)	/	1.3 ± .37	2.72 ± .73

Older adults and volunteers with pAD were tested on their comprehension by means of the Comprehensive Aphasia Test (Howard, Swinburn & Porter, 2004): the researcher pointed to the target sentence and asked the volunteer to read the sentence and find the picture that matches. The response was noted on a score sheet (*0* for an incorrect response; *1* for an accurate response after delay (over 5 seconds) or for a self-correction; *2* for a correct, prompt answer. There were 13 trials. Older adults had an accuracy rate of 95%, the group with pAD scored 90% correct.

Older adults and individuals with pAD did not significantly differ in age, number of years spent in education, NART IQ scores or accuracy rate in the Comprehension Test ($p > .05$).

4.3.1.2 Materials

Stimuli for the experimental task consisted of 160 sentences appearing one by one on the computer screen; 108 were sensible, 52 were nonsensical, in the sense that they described actions that could not take place. The stimuli sentences used in Glenberg et al. (2008) were utilised, with the exclusion of the abstract sentences. To replace the abstract sentences, additional sensible and nonsensical concrete sentences were built, half in the dative and half in the double object form.

Each sentence was part of a triad, with a toward version (*Mark dealt the cards to you*), an away version (*You dealt the cards to Mark*) and a non-transfer version (*You and Mark dealt the cards*).

Sentences were presented in eight blocks of twenty sentences each; blocks were built so that sentences belonging to the same triad would not appear in the same block. A typical block could consist of fourteen sensible (5 away, 5 toward, 4 non- transfer) and six nonsensical (2 away, 2 toward, 2 non- transfer) sentences.

A laptop computer connected to a desktop keyboard was utilized. The keyboard was oriented so that the long axis projected away from the participant, and the middle key was designated as the start key. A sentence would appear on the screen at the press of the start key. The keys symmetric to the start key at the two far extremes of the board were utilized as *yes* and *no* keys, and were labelled "yes" and "no", as shown in Figure 4.12.

Figure 4.12 The keyboard, for the purposes of this study rotated at 90° from its usual orientation, and the three critical keys.

In the *yes-is-away condition*, illustrated in Figure 4.12, the key closest to the participant's body is a no and the key further away from the participant is a yes. In the *yes-is-toward condition*, the yes and no keys were switched.

The task was presented in E-prime (Schneider, Eschman, & Zuccolotto, 2002a; Schneider, Eschman, & Zuccolotto, 2002b).

Counterbalance Lists

Participants were randomly assigned to two counterbalanced lists, with the constraint that an equal number of participants received each of the two lists. In List A, the task began with the *yes-is-away* condition; in List B, the task began with the *yes-is-toward* condition.

4.3.1.3 Procedure

Participants sat with a PC keyboard on their lap, placed at a 90º angle from its normal orientation. A monitor was placed on a desk, in front of the participants. The sentence sensibility judgment task, in which participants had to decide, as quickly as possible, whether a sentence was sensible or nonsensical, was administered. Participants were naive about the implied direction of the sentence and of the response.

On-screen instructions stated that participants were going to see a series of sentences appearing on the monitor one by one, and had to decide if the sentence made sense or not as quickly as they could. They had to press the "YES" key if they thought the sentence made sense, and the "NO" key if they thought the sentence did not make sense. They were instructed to return to the start key and press it in order to initiate appearance of the next sentence. Volunteers with pAD had the instructions explained to them verbally as well.

Participants were told to use their dominant hand only and to utilize the index finger only to press keys. As the sentences remained on screen until a response was given, participants were instructed to keep their finger on the start key, and were monitored by the experimenter during the task in order to maintain consistently this position throughout the task.

Participants received one set of practice before beginning the first block of trials. This set consisted of 16 trials; after this practice, participants received the first four blocks of trials. At this point, the *yes* and *no* labels were switched by the experimenter and participants received another set of practice in order to become accustomed to the new positions of the response keys. The remaining four blocks of trials followed. The whole task took approximately twenty minutes to complete. The reaction time (the time between lifting the finger from the start key and lifting the finger from the response key) and the identity of the key depressed were registered.

Although the present study is a close replica of the original study (Glenberg & Kaschak, 2002; Borreggine & Kaschak, 2006; Glenberg et al., 2008), the design was adapted for participants with pAD; the main differences are illustrated in Table 4.4.

Table 4.4 Study I design differences

	Original Design	*Present Study*
Practice Session	Participants had two different practice sessions: they practised with buttons only; then they practised the task.	Participants only practised the task
Instructions	"Consider each sentence as about yourself"	No special instructions given
Error monitoring	Feedback tone	No tone
Latency Measure	Start key kept depressed until response Responses to be given within 3 sec.	Start key depressed & released No time limit

4.3.2 Results

Item totals for errors and mean latencies referring to the performance of t he younger adults ' group in Study I and II are reported in Appendix D. It has to be noted that the totals include transfer and non transfer, sensible and nonsensical sentences.

Transfer Sentences

4.3.2.1 Accuracy

The overall accuracy rate on the 108 sensible sentences analysed was 99% for the young and older groups, and did not differ significantly between them (p >.05); the accuracy rate was 95% for the volunteers with pAD, differing significantly from the other two groups (*p*s <.05). One participant with pAD was excluded from the analysis because his accuracy rate was lower than 90%.

4.3.2.2 Latency

An analysis of variance with Counterbalance List as a between subjects factor did not produce significant effects involving this factor, and so it was not considered further. Treatment of data matched as much as possible that described in Glenberg et al., (2008): the longest and shortest 1 % of responses was eliminated, any response time greater than 2.5 standard deviations from the *subject/item x condition mean* was replaced by the *subject/item x condition mean*. It has to be noted that in the older groups the outlier screening led to the replacement of circa 9 % of the response times because of the large variability in reaction times that characterizes these groups.

The analysis of the latency data focused on the correct trials of sensible sentences only, given that the movement made in order to depress the *yes* button was measured. In order to neatly test the compatibility effect, the data from the non-transfer sentences were dealt with separately. Therefore, in the analysis of variance, the independent variables were the direction of the sentence with two levels (toward, away) and the direction of the response movement with two levels (yes-is-toward the body, yes is away from the body). The dependent variable was the time elapsed between presentation of the sentence and response. This response time was measured from release of middle button (sentence onset) and response given (yes/no key depressed). All analyses were conducted with a Type I error rate set to .05.

A mixed 3 (group) x 2 (sentence) x 2 (response movement) ANOVA was performed on the latency data and a main effect of group was found, $F(2, 70) = 44.73$, $p < .001$, $\eta = .56$, with contrasts showing that there was no difference between the young and the healthy older group, but the group with pAD differed significantly from the other two groups, mirroring the accuracy results.

There were no other significant main effects, but there was a significant interaction between the direction of the transfer in the sentence and the direction of the response movement, $F(1,70) = 14.51$, $p < .001$, $\eta = .17$, with means indicating that compatible trials were responded to faster than incompatible trials, producing a *sentence-action* compatibility effect (ACE). Because the response times of volunteers with pAD were approximately double of those of the healthy groups, each group was analysed individually with by subjects, denoted as F_1, and by items, denoted as F_2, analyses, so that group specific behavioural differences could be noticed.

In the younger group, there was only a significant interaction of sentence direction and response direction, F_1 (1, 34) = 4.62, $p < .05$, η .12, F_2 (1, 70) = 6.81, $p < .05$, η .08, with direction compatible being consistently faster than direction incompatible trials, as illustrated in the lower part of Figure 4.13. Paired sample *t* tests indicated that for toward sentences there was a significant difference whether the response was toward or away, t_1 (34) =1.88, $p < .05$, t_2 (36) = -1.93, p = .05, with the compatible direction being faster (difference in msec was 138). This difference between responses was not significant for away sentences ($p > .05$, difference in msec 87) in the by subjects analysis, and was only approaching significance in the by items analysis, t_2 (36) = 1.75, p=.08.

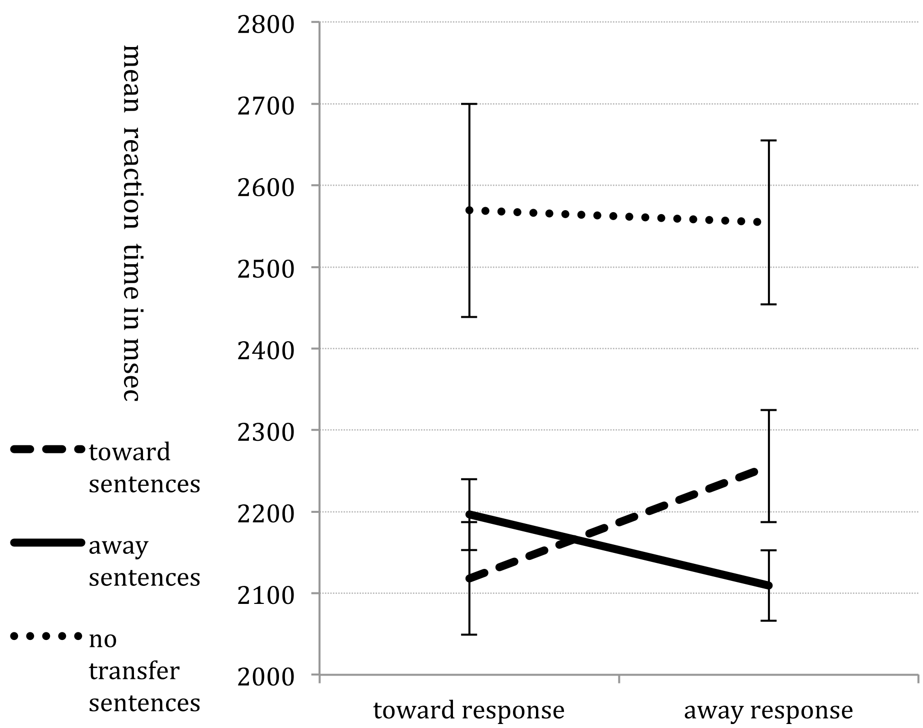

Figure 4.13 Younger group's mean response times as a function of sentence and response direction for Study 1.

The size of the interaction in which the ACE was manifest can be quantified as the average difference between incompatible and compatible sentence direction by response direction pairings, and from now on it will be referred to as the size of the ACE (Glenberg *et al.*, 2008, p.911). In the present study, this was 112 msec, as obtained by the difference of the means reported in Table 4.5, and was 139 msec when means from the by items analysis were used.

Table 4.5 Younger group's mean response times & standard errors

Condition	*MEAN in msec*	*Std Error*
compatible	2114	54.94
incompatible	2226	83.48
Non-transfer	2562	102.00

In the older adults group, there was again a significant interaction of sentence direction and response direction, F_1 (1, 19) = 4.75, $p < .05$, η .2, F_2 (1, 70) = 4.32, $p < .05$, η .06, in which the ACE was manifest, with compatible trials being faster than incompatible trials, as the lower part of Figure 4.14 indicates. The size of this ACE interaction was 80 msec by subjects, as means in Table 4.6 indicate, and was 145 msec when means from the by items analysis were used.

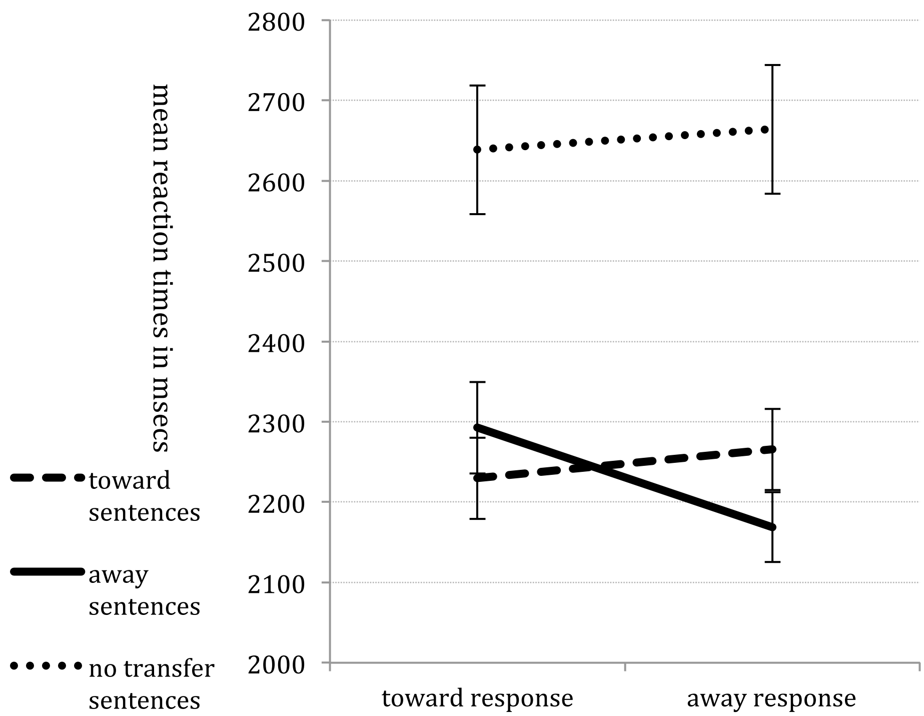

Figure 4.14 Older adults' mean response times as a function of sentence and response direction for Study 1

A paired sample *t* test indicated that for away sentences there was a significant difference whether the response was toward or away, t_1 (19) =1.8, $p < .05$, t_2 (36) = 1.83, p =.07, with compatible direction being faster (difference in msec was 124). This difference between responses was not significant for toward sentences in either analysis ($p_s > .05$), resulting in another asymmetric interaction, this time as a mirror image of the one found in the younger group.

Table 4.6. Older group's mean response times & standard errors

Condition	*MEAN in msec*	*Std Error*
compatible	2199	46.94
incompatible	2279	53.69
Non-transfer	2651	80.23

In the group with pAD, there was again a significant interaction of sentence direction and response direction, in which the ACE was manifest, with compatible trials being faster than incompatible trials, F_1 (1, 17) = 6.29, $p < .05$, η .27, F_2 (1, 70) = 4.54, $p < .05$, η .06, as the lower part of Figure 4.15 indicates. The size of the ACE was 220 msec, as means in Table 4.7. indicate, and was 194 msec when means from the by items analysis were used.

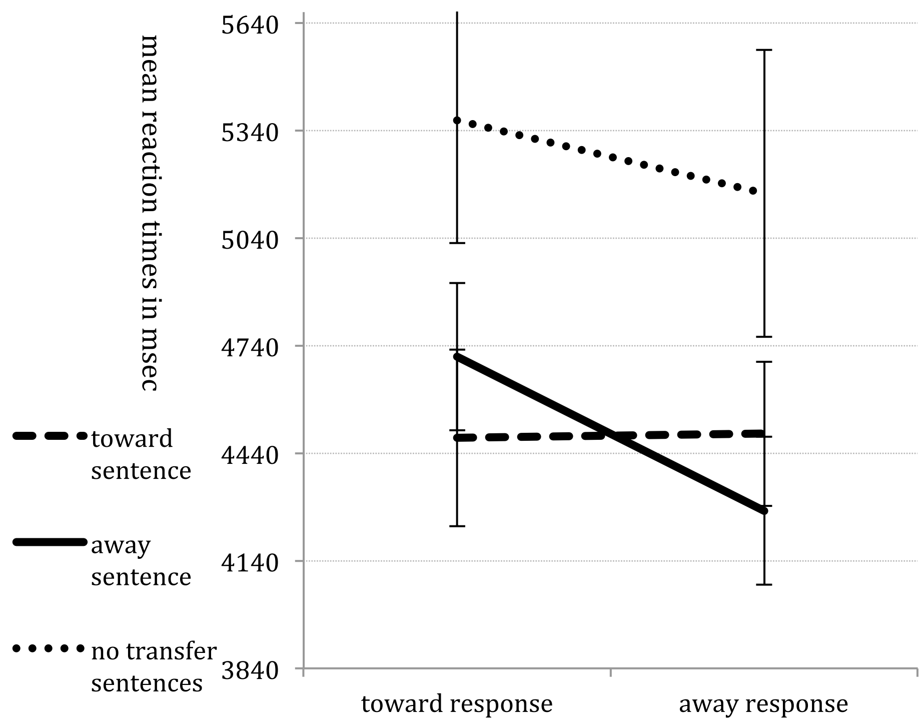

Figure 4.15 Group with pAD's mean response times as a function of sentence and response direction for Study 1

Paired sample *t* tests indicated that toward sentences did not show a significant difference as a function of response (*p*s > .05). For away sentences, there was still no significant difference in the by subjects analysis, but the by items analysis was significant, t_2 (35) = 2.17, $p < .05$. The lower part of Figure 4.15 shows that for toward sentences there is almost no difference between the two responses, resulting in an asymmetric interaction, similar to the one found in the older group.

Table 4.7. pAD group's mean response times & standard errors

Condition	*MEAN in msec*	*Std Error*
compatible	4381	226.37
incompatible	4602	203.07
Non-transfer	5412	371.5

Non-transfer Sentences

Participants in all groups made significantly more mistakes when responding to the non-transfer sentences than to transfer sentences, as paired t-tests performed on data of each group showed (young: t (30) = 6.04, p < .001; older adults: t (19) = 3.07, p < .001; pAD group: t (18) = 4.6, p < .001, all 2-tailed).

Non-transfer sentences took significantly longer to understand than transfer sentences, as indicated by paired samples t tests, (ps < .05, 2-tailed), and, as expected, did not differ significantly as a function of the response movement, as indicated again by paired samples t tests, (ps > .05, 2-tailed), and as illustrated in the upper parts of Figures 4.13, 4.14, 4.15.

4.3.3 Discussion

Healthy young participants, older adults and volunteers with probable Alzheimer's disease were faster to respond when the direction implied in the sentence matched the direction of the response movement. These results are in line with our hypothesis that in AD the brain mechanisms linking language and action, or at least a portion of them, are preserved. Both in terms of accuracy and latency, however, the performance of the volunteers with pAD was significantly more compromised than the other two groups' performance, which did not differ. This pattern of results mirrors findings in the preliminary comprehension task reported earlier.

Non-transfer sentences took significantly longer to respond to and more mistakes were made when responding to them in all groups, highlighting the strong advantage of a transfer schema in language. This advantage, however, still cannot answer the question of whether the ACE is a relative or an absolute advantage and so whether it can be used for real-life applications. The reasons for this lack of definiteness will be discussed.

In the present study, the mean size of the ACE for the young group was bigger than the one found in the original study (Glenberg & Kaschak, 2002). This inflated effect may be attributed to the methodological differences described in the Method. For example, the distance between the buttons the participants used to respond was greater in the present study, perhaps producing a more substantial effect, or perhaps this could be due to the fact that only concrete sentences were used here. Glenberg et al. (2008) showed, however, that abstract sentences produced a greater ACE than concrete sentences, and Glenberg & Kaschak (2002) showed that it is the action rather than the spatial locations of the buttons that matters. The size of the ACE in the group with pAD was approximately double the size of the ACE produced by the two healthy groups, in line with the fact that pAD response times were also double.

In Glenberg & Kaschak (2002) and Glenberg et al. (2008), young participants responded faster to concrete *toward* sentences than *away* sentences. Interestingly, in the present study, this trend was also found in the young group, together with a stronger compatibility effect emerging in *toward* sentences. A different pattern of performance emerged in the two older groups, with the ACE emerging more substantially in the *away* sentences.

The asymmetry with which sentences and response movements interacted seems to be defining an aging effect, where *away* sentences produced stronger compatibility effects. This may be because of an agent effect, making them easier to process, describing an action performed by, rather than to the participant. The *away* sentence, *You give the book to Laura,* refers to the self as the agent performing the action, whereas the *toward* sentence *Laura gives the book to you* does not directly involve an action by the participant. A way to further test this explanation could be to test toward action in the Imperative mode (for instance, *Open the drawer*), to see whether self-referential *toward* sentences are still weaker than *away* sentences in terms of producing a compatibility effect.

Non-transfer sentences were similar in syntax and content to transfer sentences, as the examples reported earlier show, but, unlike the transfer sentences, they did not interact with the response movement. This result provides strong evidence that the significant interaction between response movement and type of transfer sentence was indeed driven by the implied motion involved in the transfer, and not by the meaning of the verb or by the syntax of the sentence.

Non-transfer sentences also proved to be more difficult to understand than transfer sentences, as shown by the longer reaction times and the greater number of errors all three groups made. These results indicate that transfer language is easier to process, precisely because the implied motion involved in the transfer from A to B activates a motor schema, which facilitates comprehension.

In transfer sentences the component of self-referentiality, both as agent and as recipient, is stronger than in non-transfer sentences, and this component could also be assisting comprehension. Whether concrete or abstract, transfer sentences are those which babies and young children are mostly exposed to (Pulvermüller, 2005), and so these data seem to support the notion of a transfer action schema in the motor cortex, which facilitates language comprehension (Glenberg et al., 2008).

The present study identified what it takes to reproduce the ACE - when, where and in which population it reproduces more vividly. It showed how longer response times, which characterized the group with pAD, did not result in a loss of compatibility effect. What it did not demonstrate was its absolute over its relative advantage. Despite the clear advantage of compatible versus incompatible trials and the clear advantage of compatible versus non-transfer trials, the latter seems to be over-ridden by the wider divide between the compatible and incompatible trials, on the one hand and the non-transfer trials, on the other hand. The notion of transfer, and not that of compatibility, emerges as a defining difference.

This study demonstrated that, despite the substantial differences in reaction times between the groups, the ACE exists for individuals with pAD and healthy older adults. Although it is promising that the distributed neuronal assemblies in which language and action might interact are preserved in AD, whether the Action

Compatibility Effect could be exploited to assist comprehension in individuals with pAD remains unanswered for now. Compatible trials were faster than incompatible and non-transfer trials, but what these results reliably say is only that language expressing a transfer from A to B, when either A or B are self-referential, is easier to process, regardless of cognitive impairment and age.

4.4 Study 2: Action – sentence compatibility

If we were to think about ways in which the hypothetical advantage brought about by the ACE could be exploited in relation to language comprehension in AD, then it would be practically more useful if the ACE involved 'movement priming language comprehension', rather than the opposite. In the original paradigm, participants are first exposed to linguistic stimuli and then are required to move their arm in order to respond to the task, and so the compatibility advantage arises because the motor simulation constructed while comprehending the sentence creates a pattern of activation in motor planning, that is facilitatory. Our question here is whether a compatibility advantage arises also when activation in the motor area, due to an overt movement, primes the motoric simulation taking place during sentence comprehension, resulting in quicker processing.

Within the theoretical framework of embodiment, there is no reason why this should not be the case, given the 'strong within-assembly connections that link language and action representations' (Pulvermüller, 2005, p.578). Pulvermüller did not just find evidence for action words activating the motor system in a specific somatotopic fashion; he also found that when transmagnetic stimulation was applied to the cortical leg area leg-related words were responded to faster than, for example, arm-related words (Pulvermüller, Hauk, Nikulin et al., 2005).

In Glenberg, Sato & Cattaneo (2008) participants were required to transfer beans from one container to another, with a movement that could be either toward or away from their body. After moving the beans, they had to judge sensibility of transfer sentences. An interaction between the direction of the movement and the direction of the sentence was found, but, unexpectedly, when the directions were incompatible the reaction times were significantly faster (Reversed Compatibility Effect). These results were explained with the notion that movement in one direction induces peripheral fatigue in the effector and, as a response to fatigue, there is an increased output with a loss of specificity to one action. Another explanation for these results was that the voluntary arm movement of transferring beans becomes semi-automatic after a while, thus down-regulating the activity in the action-specific controllers (Glenberg, Sato & Cattaneo, 2008). No explanation was presented to account for the reversed interaction, in which the incompatible trials were significantly faster.

The study described above is perhaps the only study to specifically test overt movement affecting language processing; other studies, manipulating the timing and the order with which movement and language were presented, produced mixed results (Boulenger et al. 2006; Borreggine & Kaschak, 2006).

Boulenger et al. (2006) examined how timing modulated the interplay between language processes and overt motor behaviour by closely analysing the kinematics of an arm reaching movement performed in relation to a language task. They found that processing action verbs concurrently with executing the reaching movement slowed the execution of the movement itself and justified this behavioural delay as the possible result of competition for shared resources, arguing that the very same mechanisms are at play both when processing language and when executing a movement. The Boulenger et al. (2006) study also showed that this reversal of the compatibility effect was stronger when the action verbs required the same effector (arm area). This tells us that the link between action verbs and motor resonance is not a generic and automatic activation of the motor system, but rather, it is more like a fine-tuned relationship which can be specific to word-content.

This evidence for word-content specificity needs to be considered with the evidence suggesting that the action compatibility effect is evoked by early learned syntactic structures, such as the double object and the dative form (Glenberg et al., 2008). Motor resonance can occur at word level (Richardson, Spivey & Barsalou, 2003, Meteyard, Zokaei, Bahrami et al., 2009, De Scalzi et al. 2012), at sentence level (Glenberg & Kaschak 2002; Borreggine & Kaschak 2006), or both (Glenberg et al. 2008), and so there may be various levels at which the motor cortex, the premotor cortex and Broca's area show their connectivity, by generating compatibility effects during language processing (Pulvermüller, 2005).

Borreggine & Kaschak (2006) found that "when the direction of the required response movement was not revealed until after the sentence was presented (lagged response), a hindering effect was found, demonstrating that the presence of the ACE relies on being able to prepare the motor response required <u>while</u> the sentence is being processed, allowing the two neural simulations to interact" (p.1098, Borreggine &

Kaschak, 2006). The design manipulated the timing with which the response cue was given but did not include reversing the order in which the sentence and the movement were presented.

Although the exact mechanisms that underlie these results remain debatable, there is ample evidence supporting the idea that the time and order of the linguistic stimuli relative to the motoric task (and *vice versa*) are crucial for the production of the ACE. If we aim to understand and ultimately use this effect for clinical or real-life applications with regards to AD, it is important to understand the rules that govern the switch from a hindering to facilitatory effect. The criteria that have so far proved to be crucial to the occurrence of the ACE are listed in Table 4.8.

Table 4.8 Basic criteria for occurrence of ACE

Linguistic Stimulus	*Response Movement*
Must be self-referential Must precede the movement	Must be planned before sentence Must be performed 550 msec or longer after the linguistic stimulus

In Study 2 the sentence sensibility ACE paradigm was further manipulated to include an arm movement that participants had to perform before a sentence appeared on screen, so rather than a *Sentence-Action* compatibility effect, we tested an *Action-Sentence* compatibility effect, because the action came before the sentence. The present study aimed to determine whether the ACE could be obtained when the movement (toward or away from the participants' body) is used to prime comprehension of transfer sentences (away or toward the participant's body).

The evidence gathered so far in studies looking at the cross-talk between action or perception and language, would predict that the *Action-Sentence* compatibility effect is a hindering effect; the embodiment theoretical framework, however, would predict an assisting effect. The main purpose of Study 2 is therefore to test between these alternative hypotheses.

4.4.1 Method

4.4.1.1 Participants

The same volunteers who took part in Study1 took part in Study 2; however, because there was attrition within the groups, the adjusted characteristics are reported in Table 4.9. Twenty-seven young, twenty older adults and fifteen volunteers with pAD took part in Study 2.

Older adults and individuals with pAD did not significantly differ in age, number of years spent in education, NART IQ scores. There was a significant difference in their accuracy rate in the Comprehension Test ($p < .05$).

Table 4.9 Study 2 sample characteristics and background scores

	Healthy Younger	*Healthy Older*	*pAD*
Number of participants	27	20	15
Gender (male/female)	11/16	9/11	5/10
Handedness (right/left)	25/2	18/2	14/1
	Mean & Std Error	**Mean & Std Error**	**Mean & Std Error**
Age (in years)	20.78 ± .69	76.85 ± 2.45	78.4 ± 1.54
Education (in years)	/	12.9 ± 1.62	11.8 ± .51
MMSE correct (0-30)	/	28.8 ± 1.05	21.79 ± .63
Full-scale IQ (NART-R converted)	118 ± 1.01	125 ± .74	121± 1.46
Comprehension test error (0-26)	/	1.3 ± .37	3.2 ± .78

4.4.1.2 Materials

The materials were the same as those used in Study 1, with the difference that to initiate sentence onset on screen participants had to press two keys: start key1 and start key 2. This second start key would be positioned *away* from the participant, relative to the middle key (start key 1), in the *away* condition, as illustrated in Figure 4.16, or *toward* the participant relative to the middle key in the *toward* condition. The arm movement stretching from the pressing of start key1 to start key 2 is the preliminary movement.

Figure 4.16 The location on the keyboard of the operational keys when the preliminary move is "away" and yes is "away"

Counterbalance Lists

Participants were randomly assigned to four Counterbalancing Lists: A, AA, B, BB with the constraint that an equal number of participants received each of the four lists. In List A, for example, participants began the task in the *yes-is-away* condition with a start key 2 away from their body. They then switched according to the procedure described in the next section. Table 4.10 illustrates the differences of the four lists:

Table 4.10 shows the four counterbalance lists

	A	*AA*	*B*	*BB*
Position of start key 2	start key 2-is-away	start key 2-is-toward	start key 2-is-toward	start key 2-is-away
Position of response key	yes-is-away		yes-is-toward	

4.4.1.3 Procedure

This testing session took place two weeks after the session described in Study 1. Participants were instructed to press the start keys 1 and 2 in order to initiate the appearance of each sentence, and press the response key *yes* or *no* when the sensibility judgement was made. They received one practice session.

At the end of the second block, the researcher moved the start key “2” to the opposite position on the keyboard (if they started with key 2 in a position toward them, it was moved to a position away from them), and then participants were requested to continue with the task.

At the end of the fourth block, the response keys were reversed (the *yes* and *no* labels were switched, like in Study 1), and the participants received another practice session on the new response assignment. This practice was followed by block 5 and 6. At this point, the experimenter moved the label of start key 2 back to its original location. Participants were requested to continue with the task for a further two blocks of trials (7 and 8).

The time between lifting the finger from the start key 2 and lifting the finger from the response key and the identity of the key depressed were registered. This task took from fifteen to twenty minutes to complete.

4.4.2 Results

Counterbalance List, as a between subjects factor, did not produce any significant list effects or interactions in the analysis and this variable was not considered further.

Transfer Sentences

4.4.2.1 Accuracy

The accuracy rate was 98% in the young and older adults' groups, with no difference between them (p >.05), and was 90% for volunteers with pAD. Contrasts indicated that the pAD group made significantly more errors than the other two groups (ps <.05). No other effects were significant.

4.4.2.1 Latency

The critical conditions referring to transfer sentences are reported in Table 4.11; note, in the last column, the variables created as a function of type of compatibility. The dependent variable was the time elapsed between presentation of the sentence and response. This response time was only analyzed for correct trials.

Table 4.11 Critical conditions of transfer sentences

Preliminary Move	*Sentence Direction*	*Response Movement*	*Compatibility*
TOWARD	TOWARD	TOWARD	*total*
AWAY	AWAY	AWAY	
TOWARD	TOWARD	AWAY	*1st pairing*
AWAY	AWAY	TOWARD	
AWAY	TOWARD	TOWARD	*2nd pairing*
TOWARD	AWAY	AWAY	
AWAY	TOWARD	AWAY	*none*
TOWARD	AWAY	TOWARD	

A mixed 3 (group) x 2 (preliminary movement) x 2 (sentence) x 2 (response movement) ANOVA was performed on the latency data. There was a main effect of group, F (2, 59)= 32.09, p < .001,η = .52, with contrasts showing that there was no difference between the young and the healthy older group, but the group with pAD was significantly slower than the young and the older adults. There was no other significant main effect.

The interaction between the sentence direction and the response movement was not significant (F<1), indicating that the ACE was not manifest. The preliminary movement, made by participants to initiate the sentence (toward or away), interacted with the sentence direction (toward or away), F (1, 59) = 13.11, p < .01, η = .18, with means indicating that compatible trials were responded to more quickly than incompatible trials. This compatibility effect refers to the first four rows of Table 4.11, which indicate compatibility between the preliminary movement and the sentence, regardless of the response movement. We refer to this effect as the *Action-Sentence* compatibility effect, because the action comes before the sentence.

Because the response times of volunteers with pAD were approximately double of those of the healthy groups, in order to obtain a better insight into the behavioural differences that are specific to each group, latency data were analysed by group: a within subjects 2 (preliminary movement) x 2 (sentence) x 2 (response movement) ANOVA and a between items mixed ANOVA were performed. In the by items analysis, the between items variable was the type of sentence (toward or away) and the within subject variables were the preliminary and the response movement.

In the young group, the interaction between the preliminary movement and the sentence direction was significant, F_1 (1, 26) = 4.15, p = .05, η .14, F_2 (1, 70) = 11.62, p < .01, η .14. When responding to away sentences the mean response time differed significantly as a function of the preliminary move, t_1 (26) = -2.48, p < .05, t_2 (35) = 2.88, p < .01; but when responding to toward sentences, response times did not differ significantly in the by subjects analysis (p > .05), explaining the asymmetry of the interaction illustrated in Fig. 4.17, and only approached significance in the by items analysis, t_2 (35) = 1.85, p = .07. The size of the *action-sentence* compatibility effect was 79 msec by subjects, or 82 msec if means from the by items analysis were used.

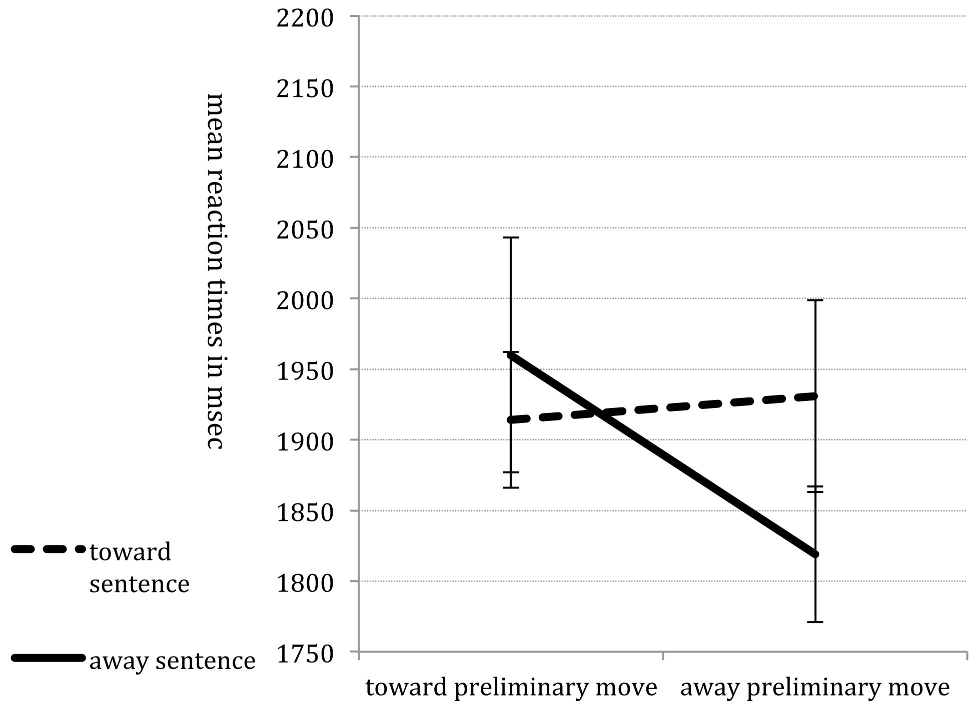

Figure 4.17 Mean Response times & standard errors for the interaction between preliminary move and sentence in the younger group

In the older adults' group the interaction between the preliminary movement and sentence direction, as illustrated in Figure 4.18, was significant, F_1 (1, 19) = 4.04, p = .05, η = .17, F_2 (1, 68) = 8.37, $p < .01$, η = .11. This interaction was asymmetric as it was only when responding to away sentences that the mean response time differed significantly as a function of the preliminary move, t_1 (19) = 2.76, $p < .05$, t_2 (35)= 4.07, $p < .001$. The size of the *action-sentence* compatibility effect was 51 msec by subjects, or 75 msec if means from the by items analysis were used.

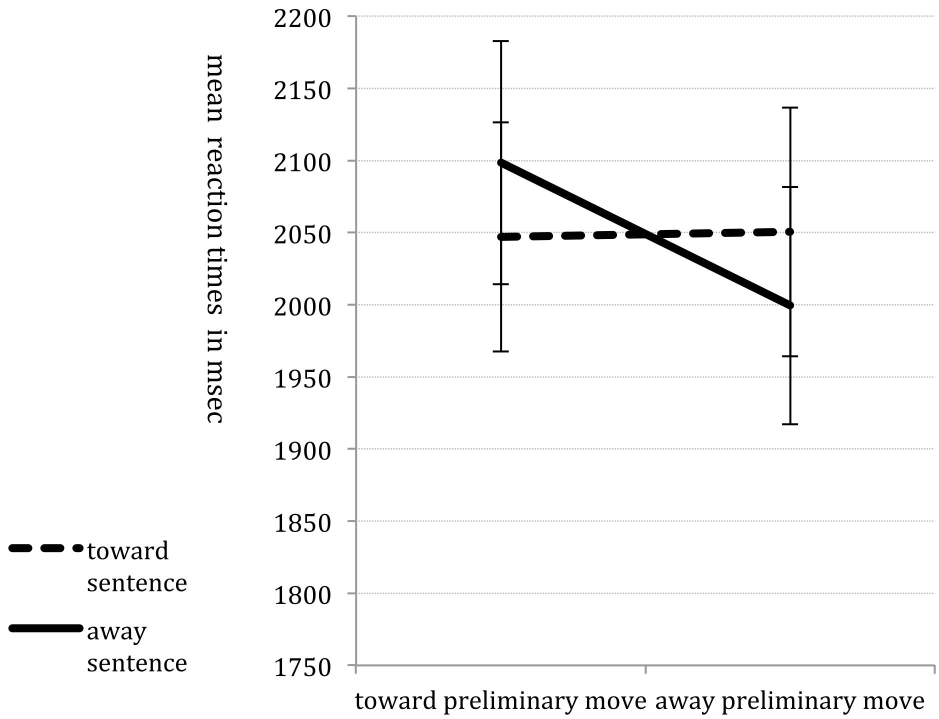

Figure 4.18 Mean Response times & standard errors for the interaction between preliminary movement and sentence in the older adults group

In the pAD group, the interaction between preliminary movement and sentence direction, as illustrated in Figure 4.19, was also significant, F_1 (1, 14) = 4.55, $p = .05$, η .24, F_2 (1, 70) = 5.24, $p < .05$, η .07. This interaction was asymmetric as it was only when responding to away sentences that response times differed significantly as a function of the preliminary move, t_1 (14) = 2.25, $p < .05$, t_2 (35)= 2.39, $p < .05$. The size of the *action-sentence* compatibility effect was 167 msec by subjects, or 158 msec if means from the by items analysis were used.

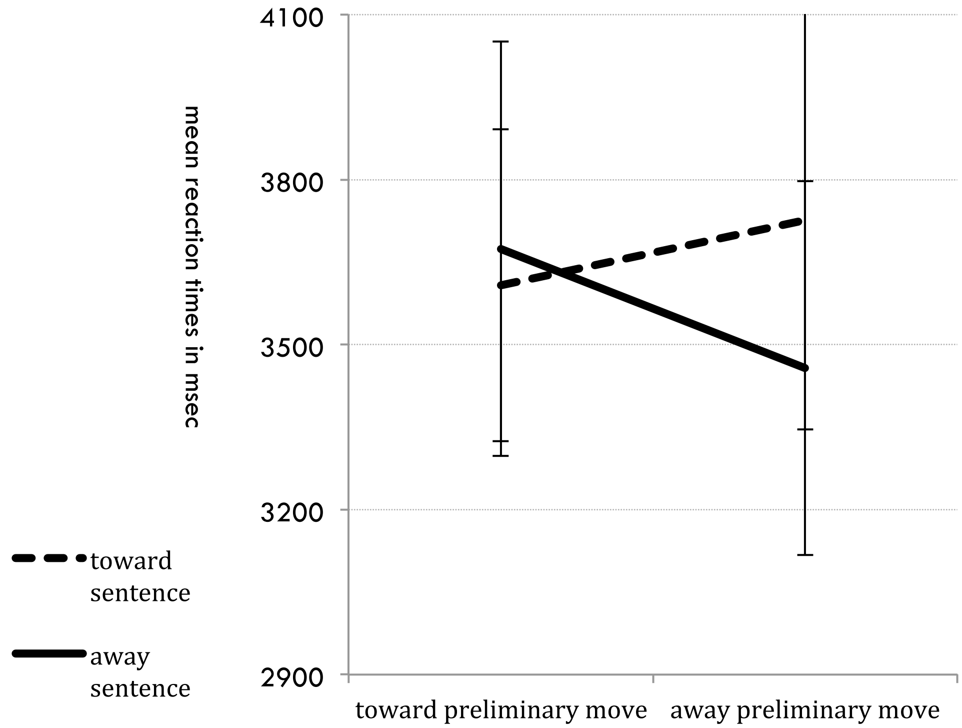

Figure 4.19 Mean Response times & standard errors for the interaction between preliminary movement and sentence in the pAD group

The *action-sentence* compatibility effect is produced by trials where the preliminary movement, the sentence and the response movement are all direction compatible and trials where only the preliminary movement and the sentence are compatible, but the response movement is not, as illustrated in Table 4.11. In order to compare the different types of compatibility overlapping in the conditions presented in Table 4.11, a repeated measures ANOVA was performed on the three possible types of compatible pairings (first/ second/ total compatible).

There was a main effect of type of compatibility in the young, F (1.42, 37.15) = 4.06, $p < .05$, $\eta = .14$ (Greenhouse-Geisser corrected because the condition of sphericity was not met), and in the older group approaching significance, F (1, 19) = 4.01, $p = .06$, $\eta = .17$. Contrasts indicated that the *totally compatible* trials differed significantly with the *second pairing compatible* trials, (*ps* < .05,) but did not differ with *first pairing compatible* trials*,* (*ps* > .05). in the group with pAD the types of compatibility did not differ significantly. Mean reaction times are reported in Table 4.12.

Table 4.12 Mean reaction times in msec and std errors as a function of types of compatibility

Compatibility Types	*Younger*	*Older Adults*	*Group with pAD*
Total Compatibility	1802 ± 57.51	2001 ± 82.16	3548 ± 303.01
Action-sentence compatibility	1864 ± 53.26	2045 ± 82.3	3518 ± 325.02
Sentence-action compatibility	1984 ± 63.16	2084 ± 85.62	3690 ± 303.79
Incompatibility	1950 ± 59.04	2065 ± 84.49	3711 ± 361.55

Non-transfer Sentences

Participants in all groups made significantly more mistakes when responding to the non-transfer sentences than to transfer sentences, as paired t-tests performed on data from each group showed (*p*s < .001, 2-tailed), and took significantly longer to understand them (*t* tests significant at $p < .001$).

The critical conditions referring to non-transfer sentences are reported in Table 4.13. In the younger group, a repeated measure 2 (preliminary movement) x 2 (response movement) ANOVA indicated that there was a compatibility effect between the preliminary and the response movement, F (1, 29) = 5.27, $p < .05$, $\eta = .15$. This shows that, in the absence of a transfer being described in the sentence, the preliminary movement primed the response movement, as indicated by means, compatible trials were faster (M: 1997msec, SE 62.98) than incompatible trials (M: 2125 msec, SE 85.88). In the older adults and pAD groups neither significant effects nor interactions were found ($p > .05$).

Table 4.13 Critical conditions of non-transfer sentences

PreliminaryMovement	*Sentence Direction*	*ResponseMovement*	*Compatibility*
TOWARD	NEUTRAL	TOWARD	*1st & 3rd component*
AWAY	NEUTRAL	AWAY	
TOWARD	NEUTRAL	AWAY	*None*
AWAY	NEUTRAL	TOWARD	

4.4.3 Discussion

The main result of Study 2 was that participants were faster to respond in trials in which the direction of the movement preceding the sentence was compatible with the direction of the transfer sentence that followed. The response movement following the sentence did not influence the reaction time; this result was consistent across the three groups. No traditional ACE was found, as it was overridden by the preliminary movement interacting with the sentence. In other words, what we found suggests that the first pairings of motor schemata interacted, washing out the effect of the response movement, and that compatible preliminary movement and sentence also produced a facilitatory effect, as indicated by the significantly faster response time.

In the present study it was hypothesized that the preliminary movement could make comprehension either significantly slower or significantly faster. Previous research in testing interactions between action and perception on the one hand and language on the other found a hindering effect. However, because embodiment theories state that the grounding of language in action is a bi-directional effect and a neurobiological account can now explain this (Pulvermüller, 2005), it would also be reasonable to expect an assisting effect.

In general terms, accuracy and latency rates of the three groups mirrored the results reported both in Study 1 and in the preliminary comprehension test: there were no significant differences between the two healthy groups; the group with pAD made more errors and took approximately twice as long to respond compared to the older adults and young adults groups. In terms of cross-talk between language and action, volunteers with pAD shared a similar pattern of performance with the two healthy groups, despite their longer reaction time, suggesting preservation of the neural systems for action engaged during language comprehension in AD. The interactions were similar in size in the two healthy groups, whereas in the group with pAD the size was double that of the other groups, in line with the double response times exhibited throughout. The interaction was driven mostly by *away* sentences in all three groups.

Across the three groups, non-transfer sentences were more difficult, as shown in poorer performance, both in accuracy and latency. As expected, in non-transfer trials there was no interaction between the sentences and the movements, but in the healthy young group only, an interaction between preliminary movement and response movement indicated that the preliminary movement may prime the following movement (in the absence of the motion simulation brought about by the sentence).

The fact that the interaction between action and language is bi-directional with respect to producing a compatibility effect (*sentence-action* and *action-sentence* compatibility effect) opens up possibilities for potential intervention strategies. ‘Action priming language’ is more useful practically because it offers a concrete opportunity for comprehension to be supported by simple overt movements; naturally, 'language priming action' could not offer the same potential.

4.5 General Discussion

In line with previous results obtained from a young sample of the population, the action compatibility effect (ACE) was replicated and, for the first time, was demonstrated to exist in volunteers with pAD, despite their longer response times. It was also shown that comprehension of transfer language and overt movement can interact producing a compatibility effect, regardless of the order in which the two appear. The latter finding is propitious for either clinical or real-life interventions aimed at individuals with pAD, as it is 'action priming language' that offers important implications in terms of assisting communication with individuals with pAD.

Boulenger et al. (2006) tested how early such priming effects can emerge, the present study tested the opposite: how long-lived the priming effect produced by compatible language and action can be. The ACE proved to be active for four or five seconds after presentation of the linguistic stimulus, and as such was shown to be a sustained effect: its longevity disproved previous theories stating that motor effects tend to be relatively short lived (Borreggine & Kaschak, 2006; Hommel et al., 2001).

Boulenger et al. (2006) interpreted the priming effect of language over action as a *reminiscence* of mental motor imagery left over from linguistic processing, and defined it as a 'lingering phenomenon'; Fischer & Zwaan (2008) named this phenomenon 'motor resonance' to indicate the internal simulation of the action described in the sentence. This motor resonance is the essence of the *sentence-action* compatibility effect, which occurs when it is the process of understanding language to influence movement. However, this explanation could not be applied to the event when it is the action that needs to prime language, as in this case it is an activation of the motor cortex to be responsible for facilitated comprehension. The two-way interaction shown in Study 1 and 2 confirms the neurobiological account that 'the automatic and extremely rapid linkage of motor information in our brains benefits comprehension' (Pulvermüller, 2005, p.581).

The occurrence of the ACE in the performance of volunteers with pAD also demonstrated that the neural systems for action engaged during language comprehension are preserved at least in mild-moderate cases of AD. We also set out to find out whether the ACE could facilitate comprehension, in view of the possibility of building this advantage into interventions geared at individuals with pAD.

Although response times indicate that there was an advantage of compatible trials over incompatible and non-transfer trials, this advantage was over-ridden by a much more powerful advantage brought about by the transfer versus non-transfer trials. For this reason, the real advantage of the ACE cannot be claimed yet. Motor schemata are engaged more effectively in transfer language than in non- transfer language, so it appears that it is the transfer motor schema which is responsible for the advantageous comprehension. Within transfer language, we could say that the transfer schemata are more engaged in *away* sentences compared to *toward* sentences, because in away sentences the reader is the agent, whereas in toward sentences the reader is the recipient. This could explain the trend (present in both studies) that movement and language interactions were more vivid in *away* sentences. In Study 2, where it was an away arm movement to prime comprehension of an away sentence, the interaction was driven exclusively by away sentences across all groups. In Study 1, on the contrary, it was *toward* sentences that produced a stronger ACE in the young group, and in previous work on young groups it was consistently *toward* sentences that were processed faster (Glenberg & Kaschak, 2002, Glenberg et al., 2008, Borreggine & Kaschak 2006).

When it comes to language processing, an aging population may have to rely more heavily on schemata, and perhaps this could explain why the *away* sentences interacted more effectively with movement, so that the ACE emerged more distinctively in the aging groups. This argument would lead to the idea that if the motor schema is indeed a comprehension assistant, then the advantage is real and applications for a population with comprehension difficulties, such as the AD, could be found. It seems also that this effect is not 'all-or-nothing', but that it may occur on a sliding scale: from non-transfer sentences to transfer sentence to *away* sentences, where it peaks.

Although in terms of performance (accuracy and latency) all three groups produced a similar trend, despite age and cognitive abilities, the significant differences in the results lay between the AD and the other two groups, and not between the older adults and the young group. A closer look at their respective performances shows up more subtle differences: the main difference in pattern of performance lay between the young and the two aging groups (healthy older adults and older adults with pAD). In other words, whilst in terms of performance the cognitive impairment that characterized AD clearly emerged from the results, in their performance the groups followed a very similar trend, within which an aging effect became apparent in the analysis of their respective performances.

The main differences between the two studies were that in Study 2, the interaction sizes were smaller in all three groups, and the young group did not differ from the aging groups in the direction of the interaction: in Study 2 in all three groups away sentences drove the interactions and toward sentences did not exhibit great interactivity with the preliminary movement.

The results of Study 2 demonstrate that there is reciprocal connectivity between language and action systems. A movement determined the priming of comprehension generating an *action-sentence* compatibility effect; this movement determined what happened next, overriding any other possibility of interaction. This outcome was different from previous results which had found the *action-sentence* compatibility effect, i.e. when the action precedes the sentence, to be a hindering, rather than an assisting effect (Glenberg, Sato & Cattaneo, 2008, Borreggine & Kaschak 2006).

These studies produced useful results both in view of aiding comprehension in AD and, more broadly, in view of extending our knowledge of the interactions between movement and language. First, the ACE was preserved in individuals with pAD, and this tells us that the ACE is a sustained and long-lived effect; second, the ACE was produced by the mutual, bi-directional relationship of action and sentence, a result that has greater practical applications. Finally, transfer motor schemata were identified as key players in terms of assisting comprehension, generating an absolute advantage against language without transfer motor schemata; *sentence-action* (Study 1) and *action-sentence* (Study 2) compatibility effects resulted in a more relative advantage to comprehension, specifically against incompatible and differently compatible trials.

5 Conclusions

This final chapter draws together the common strands the three articles presented in this thesis, and considers how the work might be developed further.

As illustrated in the Introduction to Article I, the studies of comprehension deficits in Alzheimer's Disease (AD) have been rendered problematic because of seemingly intractable dilemmas and methodological difficulties. Tackling comprehension failures in AD via the non memory-dependent processes at play during comprehension offered a very real hope that these dilemmas might be made less insurmountable, so that a) very real advances in our understanding of language comprehension can be made, and b) this understanding might lead to clinical applications to help those with probable AD to communicate better.

The purpose of this thesis was thus to explore the process of language comprehension in individuals with pAD to identify components of the comprehension process that are spared in spite of the degeneration taking place at mild to moderate stage of AD. Could the study of language comprehension by means of experimental work based on these non-memory processes lead to the development of mechanisms that could facilitate comprehension in individuals with pAD? Furthermore, could this investigation ultimately – and intriguingly - lead to both corroboration and a greater understanding of embodiment theory? The experimental work reported in this thesis represents an incipient attempt to answer these questions.

Embodiment is a relatively new but persuasive theory, which argues that the way we generate and understand language is inextricably linked to our perception of our own bodies in the real world. Because Embodiment posits that language comprehension includes non-memory dependent processes such as perceptual and motoric ones, this theory seems to offer an opportunity to study comprehension in pAD. This thesis constitutes the first time embodiment-inspired experimental paradigms are used on older volunteers and individuals with pAD.

Off-line comprehension tasks which load the compromised mnemonic resources of individuals with pAD would not be able to be completed accurately by the vast majority of the group with pAD, and are not, therefore, useful for learning about comprehension in AD. For this reason, each task the participants performed in the present thesis was planned with the constraints of pAD at mild to moderate stage in mind. All measures of comprehension consisted of implicit tasks, such as verification and sensibility judgment tasks, where volunteers were required to verify whether two stimuli match, or whether a stimulus (i.e. a sentence) makes sense. The high accuracy level reached in all experiments confirmed that individuals with pAD were able to complete the tasks appropriately, confirming also that the methodology employed to test embodied effect at word- and sentence-level worked well. Volunteers with pAD worked through the tasks at a slower pace compared to their healthy controls.

In Article I we found that individuals with pAD build internal representations of verbs that are not different from those built by healthy older and younger adults. The representations we prompted our participants to focus on were laid out in space, on either a vertical or a horizontal axis; these representations proved to be stable across two different ways of retrieving them, although when retrieved by enacting the orientation with their hand, participants matched the normed (or most common orientations) more accurately than when they retrieved the representations non-motorically.

Although the group with pAD appeared to choose orientations closer to the norms when enacting their responses (to the point that their responses got very close to those of the younger group), this was not the case for the older adults group and so this is not completely in line with what was hypothesized. For the older group there was no difference between the results of the motoric and non-motoric tasks.

What interested us here was to find out what role these spatial representations play during verb comprehension, whether we could find the representations that were most commonly chosen meant better understanding. It was found that in healthy older participants comprehension scores were related positively to how verbs were represented but this was not the case for volunteers with pAD. For the latter group, there was no relationship between the two sets of scores, although this may be due to lack of power. For this reason, the pAD results are difficult to interpret, but offer interesting possibilities for further studies, which could focus on the processes at play at the very nexus between representation and comprehension, to investigate whether representations are actually integrated in the process of comprehension or whether there is a disruption at this stage, resulting in poorer comprehension. With regards to the results of the older group, these spatial representations may well constitute an advantage during comprehension, a sort of comprehension enhancer, as it was mentioned in the Discussion of Article I (Fischer et al., 2008). Again, this divergence seen between healthy older adults and older adults with pAD needs to be corroborated with further evidence.

It is in Article II that we can see how spatial information such as orientation is actually ‘switched on’ and interactive during comprehension, with comprehension affected by arrow imagery compatible and incompatible to the orientation of the verb. This study sought to investigate any differences between individuals with pAD and healthy participants in susceptibility to these cues. The aim of this exploration was again to find embodiment effects, which, ultimately, could assist language comprehension itself in real life.

Studies to date on healthy young participants have shown that the interaction between linguistic and perceptual processing produces embodied effects, but this interaction is muddied by the appearance of both priming and interference effects. The hope here was that the study on individuals with pAD could help lead to an identification of the conditions under which we can obtain compatibility and incompatibility effects, which could be reliable and replicable; testing those with pAD gives us an opportunity to factor out some variables so as to come to a better understanding of how spatial representations play a part in verb comprehension – and subsequently learn how to develop practical ways in which those with pAD can be aided to communicate better.

It was found that individuals with pAD and healthy individuals were affected in the same way by the cues presented to them. All volunteers were faster to respond to trials where the perceptual cues and the language trials were incompatible, that is to say where the orientation of the arrow and the orientation of the verb-picture which participants had to verify did not match. Both the perceptual cues and the language stimuli were presented in the same modality – i.e. visual – and stimuli were not presented simultaneously, with the cues preceding the language stimuli. The result indicated that the arrow imagery used as percepts were sufficiently salient to create interference in the compatible condition; this was evidenced in extended reaction times. The incompatibility effect found under these conditions was resilient to the different type of trials and sufficiently long-lived to emerge despite the long reaction times produced by the individuals with pAD.

If the modality in which the stimuli are presented, the timing of their interaction, the salience of the stimuli, and how the effect is measured were all contributors to the emergence of either compatible or incompatible embodied effects, then manipulating these variables systematically could offer possibilities to actually harness their benefits. Ensuing studies should continue to explore all variables that can make a difference on the embodied effect of the inter-play between perceptual and linguistic processes, until the optimal circumstances under which comprehension can be facilitated by perceptual cues can be identified.

In Article III, the overarching aim remained the clarification of how embodiment may aid comprehension in Alzheimer's Disease, but we shifted the object of our investigation from perception to action, and from verb and simple verb sentence comprehension to comprehension of sentences in Dative and Double Accusative forms. The two studies reported in Article III looked at whether movement can aid sentence understanding and what we can learn from sentence comprehension in AD through a replication and extension of Glenberg & Kaschak's (2002) famous experiment.

Article III is thus an exploration of the mutual relationship between language comprehension and body movement, testing for the first time older volunteers and individuals with pAD, as well as young participants. Article III exposed not only how language comprehension processes can affect overt movement, replicating Glenberg & Kaschak (2002), but also whether, and if so how, overt movement can affect language processes, by inverting the order of presentation of language and movement.

This switch, designed to establish whether there is a reciprocal relationship between language and movement, is particularly important for the purposed of this thesis, in finding any clinical applications from the results; if preliminary movement can be shown to prime comprehension, this certainly would be useful for aiding comprehension in individuals with pAD. The results demonstrated that the Action Compatibility Effect (ACE) Glenberg & Kaschak (2002), previously reported in younger adults, exists for volunteers with pAD and healthy older volunteers. Study 1 revealed that while there was a robust compatibility effect for all groups, in the older and older with pAD groups there was a bigger ACE in 'away' sentences, in the young group this was the case for 'toward' sentences. This could be interpreted as aging effect, with the self-referential effect at play in 'away' sentences ('You give the cup to Mary') more pronounced in older adults - with age, people make more use of schemata (Hutton, Shepperd, Rusted et al., 1996).

Results of Study 2 mirrored those of Study 1. It was found that the movement performed prior to the comprehension task interacted with the spatial information contained in the sentence. The arm movement required after the appearance of the sentence showed no interaction.

The interaction between the preliminary movement and the sentence also produced faster compatible trials, providing evidence of a bidrectional ACE effect. In addition, the substantial facilitation effects observed with sentences implying movement demonstrated the strength of the transfer schema that are elicited by the simulation we do mentally of transferring something to somebody. This is important to acknowledge for the potential application to aid individuals with pAD to communicate better.

Although in both Article II and III, the longer response times of the participants with pAD did not result in a loss of embodied effect, we did not manage to demonstrate whether the effects we found were absolute or relative. In Article II, a control condition was lacking, in Article III there was a control condition, which was slower than both the compatible and incompatible condition but this difference was overridden by the more evidently important difference that separates transfer and non-transfer sentences. Transfer sentences, irrespective of whether they are compatible or incompatible with the movement, were faster than non-transfer sentences, exposing the implicit and deeply rooted existence of a transfer or motor schema, which speeds up our language processing. Again, in transfer sentences the component of self-reference was stronger.

These studies sought to corroborate embodiment theory by testing individuals with AD, thus providing patients' evidence, for the first time. The experimental work undertaken in this thesis demonstrates clearly that the brain mechanisms through which language-related processes and perception- or action-related processes interact during comprehension, are preserved in AD at mild to moderate stage. Neither age nor age-related cognitive impairment alter this component of comprehension. This thesis confirms that, in fact, embodiment theory holds true for people with mild-moderate pAD.

The explicit demonstration of embodiment effects in people with pAD is important for many reasons. First, these results corroborate Embodiment theory, but also serve to identify where the theory might need to be adapted in light of these results. For example, the longevity of the embodied effects that became apparent through the observation of the longer reaction times characterizing the performance of individuals with pAD should be noted. Also, an interesting finding was that, although individuals with pAD represent a verb spatially in the same way healthy participants do, this does not seem to translate to better comprehension in the same way that it does for healthy participants, exposing how the perceptual processes may be preserved but that the cognitive resources necessary to integrate and understand may be disrupted.

Second, the studies tested whether the embodied effects for people with pAD were similar in their nature to those reported in healthy young adults (i.e. in their longevity, and their processing). For example, the existence of embodiment effects in the absence of higher-level cognitive strategies (because individuals with pAD are less likely than younger volunteers to use such strategies) indicates that embodiment can be used to aid comprehension within the residual framework available to people with pAD.

To summarize, Articles I and II studied the orientation of verbs, looking at questions such as whether we all represent the orientation of verbs in the same way, and why we have this information in spite of not being aware of having it. Also the studies considered whether there is a link between this spatial representation and comprehension and whether we can speed up understanding of verbs if we prime their orientation in space first.

While Article I focuses on the embodiment effect at word level, and Article III focuses on the embodiment effect at sentence level, Article II sits between these two, in so far as the stimuli used are pictorial depictions of actions. The pattern of embodied effects mirrored each other in each study and across each group

In all experiments reported in this thesis, and across these three different levels, the performance of individuals with pAD has formed a consistent pattern: mainly as accurate as, but much slower than, the performance of healthy older adults. A generalised slowness and a qualitative degradation seems to be taking place, which might be seen as almost an exaggeration of the natural aging process. The slowness of response shown by individuals with pAD clearly has an influence on the power of the embodiment effect – i.e both performance and embodied effects on individuals with pAD are similar but not quite as reliable or strong as the one of healthy groups.

All studies have been designed to be necessary first steps for the experimental exploration of how embodiment could be used for practical purposes to enhance comprehension in AD. A next generation of studies is now needed to harvest these findings and build more carefully planned and systematic experiments.

To date, research into AD has tended to concentrate on analysing and measuring the extent of the loss of comprehension experienced by individuals with pAD. The use of embodiment theory allows us, on the contrary, to test what is retained. A deeper understanding would open up possibilities to aid comprehension for these individuals by means of selecting vocabulary and grammar that would support their comprehension and by creating tools that could be used in clinical and real-life settings to enhance communication.

The comprehension model informed by Embodiment theories of language could therefore offer up a viable approach to unlock the components at play during the process of comprehension; in AD, comprehension is compromised by memory loss and so a better understanding of what the residual framework may be and whether this framework could be enhanced so as to improve comprehension in AD is an important way forward to improve on the tools that we promote to carers and clinicians.

The work in this thesis is a first attempt to do something that was perhaps never envisaged for Embodiment theory, i.e. to apply the theory for the purposes of enabling communication in individuals who are impaired due to memory loss. What we are doing here is taking embodiment theory at its own word (if the pun may be excused!). In taking the theory to its logical extension, we are also doing the theory a favour: it will help to ramify and cement the theory as a conclusive explanation of how language works. I hope this thesis provides an inspiration and a starting point to future researchers to continue what I have started.

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Appendix A: List of verbs used in the forced choice tasks in Article I with mean angles by group in degrees

			younger	older	pAD
	horizontal	CHASED	13.5	6.75	26.25
		POINTED	29.25	27	30
HIGH		PULLED	40.5	6.75	30
		PUSHED	29.25	9	33.75
		WALKED	18	9	22.5
	neutral	HUNTED	42.75	20.25	30
		IMPACTED	47.25	63	33.75
IN		PERCHED	76.5	76.5	56.25
		SHOWED	45	42.75	63.75
		SMASHED	74.25	78.75	75
	vertical	DROPPED	85.5	87.75	78.75
		FLEW	81	69.75	67.5
CONCRETENESS		FLOATED	67.5	49.5	33.75
		LIFTED	90	90	86.25
		SANK	90	87.75	90
	horizontal	ARGUED	47.25	63	45
		GAVE	33.75	40.5	30
LOW		OFFENDED	60.75	65.25	60
		RUSHED	11.25	11.25	22.5
		WARNED	45	38.25	48.75
	neutral	OWNED	67.5	47.25	48.75
		REGRETTED	56.25	74.25	56.25
IN		RESTED	60.75	36.82	48.75
		TEMPTED	33.75	45	60
		WANTED	51.75	42.75	52.5
	vertical	HOPED	81	69.75	60
		INCREASED	87.75	69.75	52.5
CONCRETENESS		OBEYED	63	51.75	45
		RESPECTED	67.5	69.75	63.75
		SUCCEEDED	76.5	69.75	67.5

Appendix B: List of verbs used in the comprehension task in Article I

Target	Related Mismatch	Unrelated Mismatch
BLOW	WHISTLE	THINK
BOUNCE	JUGGLE	BUILD
CATCH	THROW	RIDE
CRAWL	KNEEL	BLOW
CUT	TEAR	CROSS
DANCE	SING	CHASE
DRINK	EAT	OPEN
DRIVE	CYCLE	BEG
DROP	CATCH	BEND
EAT	DRINK	TIE
FLOAT	SINK	COMB
FLY	SAIL	CLIMB
FOLD	TEAR	COOK
JUMP	SKIP	LISTEN
KNOCK	RING	DRIVE
IRON	SEW	SMELL
LAUGH	CRY	CROSS
POINT	WATCH	WALK
PULL	PUSH	TIE
PUSH	PULL	TICKLE
READ	WRITE	SMOKE
RUN	WALK	PRAY
SKI	SKATE	SPRINKLE
SING	DANCE	TYPE
SINK	FLOAT	THROW
SMILE	LAUGH	SCRUB
SHOOT	FISH	LIFT

SWIM	DIVE	CARRY
WATER	PLANT	ROW
WALK	RUN	CUT

Appendix C: List of verb pictures used in the comprehension task in Article II with item error totals

These item error totals (out of 35 participants) are across the older adults'group and the group with pAD.

verb picture	trial type	condition	block no.	no. of participants making errors
blow	match	congruent arrow	session 1	2
run	match	congruent arrow	session 1	0
sleep	match	congruent arrow	session 1	1
pray	match	congruent arrow	session 1	0
bounce	match	congruent arrow	session 1	0
swim	match	incongruent arrow	session 1	1
crawl	match	incongruent arrow	session 1	2
drop	match	incongruent arrow	session 1	0
water	match	incongruent arrow	session 1	1
type	match	incongruent arrow	session 1	1
juggle	mismatch	congruent arrow	session 1	0
plant	mismatch	congruent arrow	session 1	0
march	mismatch	congruent arrow	session 1	0
drink	mismatch	congruent arrow	session 1	4
dance	mismatch	congruent arrow	session 1	1
dive	mismatch	incongruent arrow	session 1	0
build	mismatch	incongruent arrow	session 1	2
jump	mismatch	incongruent arrow	session 1	1

pull	mismatch	incongruent arrow	session 1	0
point	mismatch	incongruent arrow	session 1	0
ride	match	congruent arrow	session 2	3
knock	match	congruent arrow	session 2	0
climb	match	congruent arrow	session 2	1
drink	match	congruent arrow	session 2	0
build	match	congruent arrow	session 2	0
march	match	incongruent arrow	session 2	1
lean	match	incongruent arrow	session 2	0
cut	match	incongruent arrow	session 2	1
sink	match	incongruent arrow	session 2	0
pour	match	incongruent arrow	session 2	0
drop	mismatch	congruent arrow	session 2	0
water	mismatch	congruent arrow	session 2	3
run	mismatch	congruent arrow	session 2	0
crawl	mismatch	congruent arrow	session 2	0
drill	mismatch	congruent arrow	session 2	0
juggle	mismatch	incongruent arrow	session 2	0
type	mismatch	incongruent arrow	session 2	0
blow	mismatch	incongruent arrow	session 2	4
watch	mismatch	incongruent arrow	session 2	1
dance	mismatch	incongruent arrow	session 2	0
crawl	match	congruent arrow	session 3	0
iron	match	congruent arrow	session 3	0
pull	match	congruent arrow	session 3	1
dive	match	congruent arrow	session	1

			3	
juggle	match	congruent arrow	session 3	0
run	match	incongruent arrow	session 3	1
dance	match	incongruent arrow	session 3	0
drink	match	incongruent arrow	session 3	0
plant	match	incongruent arrow	session 3	0
dig	match	incongruent arrow	session 3	0
bounce	mismatch	congruent arrow	session 3	0
sink	mismatch	congruent arrow	session 3	0
skate	mismatch	congruent arrow	session 3	0
lean	mismatch	congruent arrow	session 3	0
ride	mismatch	congruent arrow	session 3	0
drop	mismatch	incongruent arrow	session 3	0
pour	mismatch	incongruent arrow	session 3	2
climb	mismatch	incongruent arrow	session 3	1
march	mismatch	incongruent arrow	session 3	0
knock	mismatch	incongruent arrow	session 3	6
kiss	match	congruent arrow	session 4	1
cut	match	congruent arrow	session 4	0
drop	match	congruent arrow	session 4	0
cry	match	congruent arrow	session 4	0
skate	match	incongruent arrow	session 4	1
drill	match	incongruent arrow	session 4	12
blow	match	incongruent arrow	session 4	0
juggle	match	incongruent arrow	session 4	0
bleed	match	incongruent arrow	session 4	0

bounce	match	incongruent arrow	session 4	0
dig	mismatch	congruent arrow	session 4	0
pray	mismatch	congruent arrow	session 4	3
swim	mismatch	congruent arrow	session 4	1
point	mismatch	congruent arrow	session 4	0
point	mismatch	congruent arrow	session 4	2
wave	mismatch	congruent arrow	session 4	0
water	mismatch	incongruent arrow	session 4	0
sneeze	mismatch	incongruent arrow	session 4	1
ride	mismatch	incongruent arrow	session 4	0
push	mismatch	incongruent arrow	session 4	0
jump	match	congruent arrow	session 5	0
dance	match	congruent arrow	session 5	2
sneeze	match	congruent arrow	session 5	0
drill	match	congruent arrow	session 5	30
water	match	congruent arrow	session 5	0
wave	match	incongruent arrow	session 5	32
sleep	match	incongruent arrow	session 5	2
climb	match	incongruent arrow	session 5	0
ski	match	incongruent arrow	session 5	0
build	match	incongruent arrow	session 5	0
cry	mismatch	congruent arrow	session 5	4
drink	mismatch	congruent arrow	session 5	0
pray	mismatch	congruent arrow	session 5	0
cut	mismatch	congruent arrow	session 5	0
watch	mismatch	congruent arrow	session	2

			5	
bounce	mismatch	incongruent arrow	session 5	1
bleed	mismatch	incongruent arrow	session 5	2
sink	mismatch	incongruent arrow	session 5	0
walk	mismatch	incongruent arrow	session 5	1
iron	mismatch	incongruent arrow	session 5	2
march	match	congruent arrow	session 6	0
push	match	congruent arrow	session 6	0
walk	match	congruent arrow	session 6	0
ski	match	congruent arrow	session 6	1
type	match	congruent arrow	session 6	0
point	match	incongruent arrow	session 6	1
watch	match	incongruent arrow	session 6	0
iron	match	incongruent arrow	session 6	0
dive	match	incongruent arrow	session 6	0
jump	match	incongruent arrow	session 6	0
sneeze	mismatch	congruent arrow	session 6	0
build	mismatch	congruent arrow	session 6	0
wave	mismatch	congruent arrow	session 6	1
blow	mismatch	congruent arrow	session 6	1
kiss	mismatch	congruent arrow	session 6	4
sleep	mismatch	incongruent arrow	session 6	0
cry	mismatch	incongruent arrow	session 6	0
dig	mismatch	incongruent arrow	session 6	2
swim	mismatch	incongruent arrow	session 6	0
cut	mismatch	incongruent arrow	session 6	0

swim	match	congruent arrow	session 7	1
skate	match	congruent arrow	session 7	0
dig	match	congruent arrow	session 7	0
bleed	match	congruent arrow	session 7	0
pour	match	congruent arrow	session 7	0
knock	match	incongruent arrow	session 7	1
pull	match	incongruent arrow	session 7	0
walk	match	incongruent arrow	session 7	0
wave	match	incongruent arrow	session 7	1
sneeze	match	incongruent arrow	session 7	0
dive	mismatch	congruent arrow	session 7	0
type	mismatch	congruent arrow	session 7	0
climb	mismatch	congruent arrow	session 7	1
iron	mismatch	congruent arrow	session 7	1
push	mismatch	congruent arrow	session 7	2
ski	mismatch	incongruent arrow	session 7	1
plant	mismatch	incongruent arrow	session 7	0
kiss	mismatch	incongruent arrow	session 7	1
watch	mismatch	incongruent arrow	session 7	1
drill	mismatch	incongruent arrow	session 7	0
point	match	congruent arrow	session 8	6
lean	match	congruent arrow	session 8	0
run	match	congruent arrow	session 8	0
plant	match	congruent arrow	session 8	4
wave	match	congruent arrow	session 8	3
sink	match	congruent arrow	session	0

			8	
push	match	incongruent arrow	session 8	0
kiss	match	incongruent arrow	session 8	0
pray	match	incongruent arrow	session 8	0
cry	match	incongruent arrow	session 8	0
bleed	mismatch	congruent arrow	session 8	1
jump	mismatch	congruent arrow	session 8	1
pull	mismatch	congruent arrow	session 8	0
knock	mismatch	congruent arrow	session 8	0
skate	mismatch	incongruent arrow	session 8	0
ride	mismatch	incongruent arrow	session 8	0
crawl	mismatch	incongruent arrow	session 8	0
sleep	mismatch	incongruent arrow	session 8	1
ski	mismatch	incongruent arrow	session 8	0
water	mismatch	incongruent arrow	session 8	7

List of stimuli:

Horizontal	**Vertical**
SLEEP	TYPE
WAVE	DIG
KNOCK	DIVE
IRON	BUILD
CRAWL	JUMP
CUT	PLANT
SWIM	JUGGLE
RUN	SNEEZE
PULL	BLEED
BLOW	DRINK
MARCH	SKI

POINT
RIDE
PUSH
SKATE
WATCH
DANCE
WALK
LEAN
KISS

PRAY
CLIMB
BOUNCE
DRILL
POUR
CRY
DROP
SINK
WATER

Appendix D: List of sentences used in Article III

The following item totals refer to the performance of the younger adults' group in Study I and II.
It has to be noted that the item totals include transfer and non transfer, sensible and nonsensical sentences.

	Mean number of	Mean
	Errors	Latency
Mike passes you a note.	0	2416
John and you have a pen.	10	3938
You chair Joe the roast.	0	2885
Steve drives the car to you.	3	3296
John sings the cards with you.	4	3898
You give Tony the cup.	0	2315
You shout the cake to Mina.	0	3043
You and Paul hand over the magazine.	2	3760
Jane rolls you the marble.	2	3019
Sam dances the cookies with you.	0	3066
You and Alex drop the cash.	2	2880
Dave confirms the pen to you.	1	2898
Sue sings the bread to you.	0	2615
You hand the book to Joe.	0	2512
Jim throws the hat to you.	0	2375
You hand Meg a paper.	7	3577
You kick the ball to Jack.	0	2529
Ruth gives the money to you.	0	2252
You give Lucy the key.	0	2232
You look at the cards with Mark.	0	2402
You sing John the cards.	1	2483
You deliver the pizza to Jenny.	0	2162
You and Ruth give the money.	10	3340
Joe chairs you the roast.	0	2442
You offer Sue the bread.	0	2196
Tim and you taste the ice-cream.	7	3849
You program the earring with Susan.	1	3813
You throw Nick the ball.	0	2531
You pass the pie to Andy.	0	2296
Lucy gives you the key.	0	2133
You touch the phone with Alex.	8	3684
Tom sleeps the tractor with you.	0	2699
Ellen awards a medal to you.	2	2916
You slide the cafeteria tray with Jo.	12	4295

You listen to the ground to Liz.	4	3576
Angela gives you a photo.	0	2531
Gill thinks you the marble.	1	2715
Anna passes the tissue to you.	0	2669
John drinks the house to you.	0	2486
You and Jim throw the hat.	2	2787
You and Diane buy the pencil.	1	2806
John sings you the cards.	2	2364
Sue offers you the bread.	0	2162
You dance the cookies Sam.	0	2206
Alan forges the chair to you.	1	3195
You check the key with Lucy.	4	2847
You offer Katie the spoon.	0	2176
Jack kicks the ball to you.	0	2260
You feed the ice-cream to Tim.	0	2355
You hand over the cash to Alex.	0	2109
You read a book with Joe.	0	1986
You ask the ball with Rick.	0	2618
Jo slides you the cafeteria tray.	1	3096
John throws the pen to you.	0	2330
Gill thinks the marble with you.	0	2551
Peter and you blow a kiss.	4	3118
You hand Paul the magazine.	1	2589
You offer the cake with Mary.	19	3567
You deal Mark the cards.	0	2573
You confirm the pen to Dave.	1	3025
You look at the medal with Ellen.	0	2280
Paul hands you the magazine.	1	2066
You offer the cake to Mary.	0	1918
Peter blows you a kiss.	0	1684
Alex gives the coins to you.	0	2188
You confess the tray to Julie.	1	2406
Alex hands over the cash to you.	1	2450
You smell the pie with Andy.	0	2299
Alan pours you the horse.	0	2311
Liz listens to the ground to you.	1	2914
You pass Sara the tray.	0	2102
You give Chris a drink.	0	2122
You sleep Tom the tractor.	0	2591
You and Lucy read the notebook.	0	2432
You drive the car to Steve.	0	2416
Evan plays the radiator with you.	4	3415
David confirms the pen with you.	4	2657
You ask the ball to Rick.	0	2682
Mark deals you the cards.	0	2246

Jane and you look at the marble.	2	2967
You sing the bread to Sue.	0	2260
Nick and you clean the ball.	1	2435
Katie offers you the spoon.	1	2173
Tom sleeps you the tractor.	0	1935
You hand over the wallet with Dave.	7	3244
You and Chris get a drink.	0	1987
Julie confesses the tray with you.	1	2525
Jack passes you the salt.	0	2332
You give Angela a photo.	0	2250
You look at the coins with Alex.	0	2222
You shout the cake with Mina.	0	2110
Rick asks the ball to you.	0	2435
You roll Jane the marble.	2	2240
You award a medal to Ellen.	0	2211
Paul offers the candy to you.	0	2469
You write Liz the ice-cream.	0	2111
Andy passes the pie to you.	0	2212
You toss the pencil to Diane.	0	2411
Meg hands you a paper.	2	2095
You hit the ball with Sally.	1	2815
You and Jack add salt.	3	2337
Evan plays the radiator you.	0	2466
Mina shouts the cake to you.	0	2222
You slide Jo the cafeteria tray.	2	2482
Liz writes the ice-cream with you.	1	2402
You throw the hat to Jim.	0	2386
Alex passes you the phone.	0	1883
You and Sue see the bread.	1	2479
Sally hits you the ball.	13	3186
You forge the chair with Alan.	3	2567
You wash the spoon with Katie.	1	2427
You drink the house to John.	0	2159
You and Mike drop a note.	4	2680
Lucy gives the notebook to you.	0	2514
Dave hands the wallet to you.	0	2152
You manage Ben the trees.	0	2527
Alan pours the horse with you.	1	2241
You pass the tissue to Anna.	0	2066
You blow Peter a kiss.	0	1851
You purchase the tray with Sara.	1	2649
Liz writes you the ice-cream.	0	2144
Nick throws you the ball.	0	1839
You hand the wallet to Dave.	0	2071
You buy the candy with Paul.	0	1977

Liz listens to the ground with you.	25	2973
You give the money to Ruth.	0	2248
Julie confesses the tray to you.	2	2311
You pass Alex the phone.	0	2141
You and Tony smell the cup.	2	2392
Mary offers the cake to you.	0	2353
You and Angela discuss the photo.	0	2193
You program the earring to Susan.	1	2302
You pass Mike a note.	0	1854
You think Gill the marble.	0	2218
You drive the car with Steve.	2	2554
Tony gives you the cup.	0	2400
You drink the house with John.	1	2086
Jenny delivers the pizza to you.	0	2428
You give the notebook to Lucy.	0	2319
Joe hands the book to you.	0	2101
You give the coins to Alex.	0	2272
You sing the bread with Sue.	0	2002
Anna and you purchase the tissues.	0	2597
Sam dances the cookies to you.	0	2082
You offer the candy to Paul.	0	2356
Joe chairs the roast with you.	0	2394
You deliver the pizza with Jenny.	0	2226
You pass Jack the salt.	0	1892
You forge the chair to Alan.	0	1769
You and Jack kick the ball.	0	1927
Tim feeds the ice-cream to you.	0	2666
Diane tosses the pencil to you.	1	2246
Meg and you look at the paper.	1	2344
You throw the pen to John.	0	2059
You play the radiator Evan.	1	2302
Chris gives you a drink.	0	1995
Alan pours you the horse.	0	1899
Susan programs the earring to you.	1	2242
Sara passes you the tray.	0	2096
You hit Sally the ball.	13	2832

Items split by type:

108 Sensible sentences

36 Toward sentences

18 Direct Object sentences

Sara passes you the tray.

Mark deals you the cards.

Alex passes you the phone.

Lucy gives you the key.

Katie offers you the spoon.

Tony gives you the cup.

Jane rolls you the marble.

Angela gives you a photo.

Meg hands you a paper.

Nick throws you the key.

Peter blows you a kiss.

Mike slips you a note.

Chris buys you a drink.

Jo slides you the cafeteria tray.

Sue shoots you the rubber band.

Sally hits you the base-ball.

Paul hands you the magazine.

Jack delivers you the table.

18 Dative Form sentences

Alex gives the coins to you.

Andy passes the pie to you.

Ellen awards a medal to you.

Joe hands the book to you.

Paul offers the candy to you.

Sue feeds the ice-cream to you.

Diane tosses the pencil to you.

John throws the pen to you.

Anna passes the tissue to you.

Lucy gives the notebook to you.

Jenny delivers the pizza to you.

Jack kicks the ball to you.

Steve drives the car to you.

Alex forks over the cash to you.

Ruth donates money to you.

Mary offers the cake to you.

Dave hands the wallet to you.

Jim throws the hat to you.

36 Away sentences

18 Direct Object sentences

You pass Sara the tray.

You deal Mark the cards.

You pass Alex the phone.

You give Lucy the key.

You offer Katie the spoon.

You give Tony the cup.

You roll Jane the marble.

You give Angela a photo.

You hand Meg a paper.

You throw Nick the ball.

You blow Peter a kiss.

You slip Mike a note.

You buy Chris a drink.

You slide Jo the cafeteria tray.

You shoot Sue the rubber band.

You hit Sally the base-ball.

You hand Paul the magazine.

You deliver Jack the table.

18 Dative Form sentences

You give the coins to Alex.

You pass the pie to Andy.

You award a medal to Ellen.

You hand the book to Joe.

You offer the candy to Paul.

You feed the ice-cream to Sue.

You toss the pencil to Diane.

You throw the pen to John.

You pass the tissue to Anna.

You give the notebook to Lucy.

You deliver the pizza to Jenny.

You kick the ball to Jack.

You drive the car to Steve.

You fork over the cash to Alex.

You donate money to Ruth.

You offer the cake to Mary.

You hand the wallet to Dave.

You throw the hat to Jim.

36 Non transfer sentences

18 2ND person plural sentences

Sue and you taste the ice-cream.

Diane and you buy the pencil.

John and you watch the pen.

Anna and you purchase the tissues.

Lucy and you read the notebook.

Tony and you smell the cup.

Jane and you look at the marble.

Angela and you discuss the photo.

Meg and you look at the paper.

Nick and you look at the ball.

Peter and you blow a kiss.

Mike and you slip a note.

Alex and you fork over the cash.

Ruth and you donate money.

Chris and you buy a drink.

Sue and you shoot the rubber band.

Paul and you hand the magazine.

Jim and you throw the hat.

18 2nd person singular sentences

You look at the coins with Alex.

You smell the pie with Jenny.

You look at the medal with Ellen.

You read the book with Joe.

You buy the candy with Paul.

You purchase the tray with Sara.

You look at the cards with Mark.

You speak on the phone with Alex.

You check the key with Lucy.

You wash the spoon with Katy.

You deliver the pizza with Jenny.

You kick the ball with Mike.

You drive the car with Steve.

You slide the cafeteria tray with Jo.

You hit the base-ball with Sally.

You deliver the table with Jack.

You offer the cake with Mary.

You hand over the wallet with Dave.

52 Nonsensical sentences

18 Toward

9 Direct Object sentences

Liz writes you the ice-cream.

John sings you the cards.

Gill thinks you the marble.

Sam dances the cookies to you.

Evan plays the radiator you.

Tom sleeps you the train.

Alan pours you the horse.

Joe chairs you the roast.

Tony bores you the rice.

9 Dative Form sentences

John drinks the house to you.

Sue sings the bread to you.

Mina shouts the cake to you.

Liz listens to the ground to you.

Dave confirms the pen to you.

Julie confesses the tray to you.

Rick interrogates the ball to you.

Susan programs the earring to you.

Alan forges the chair to you.

17 Away sentences

9 Direct Object sentences

You write Liz the ice-cream.

You sing John the cards.

You think Gill the marble.

You dance the cookies Sam.

You play the radiator Evan.

You sleep Tom the train.

You pour Alan the horse.

You chair Joe the roast.

You bore Tony the rice.

8 Dative Form sentences

You drink the house to John

You sing the bread to Sue

You shout the cake to Mina

You listen to the ground to Liz.

You confirm the pen to Dave.

You confess the tray to Julie.

You interrogate the ball to Rick.

You program the earring to Susan.

You forge the chair to Alan.

17 Non transfer sentences

8 2nd person singular sentences

You drink the house with John.

You sing the bread with Sue.

You shout the cake with Mina.

You confirm the pen with David.

You confess the tray with Julie.

You interrogate the ball with Rick.

You program the earring with Susan.

You forge the chair with Alan.

9 3rd person singular sentences

Liz writes the ice-cream with you.

John sings the cards with you.

Gill thinks the marble with you.

Sam dances the cookies with you.

Evan plays the radiator with you.

Tom sleeps the tractor with you.
Alan pours the horse with you.
Joe chairs the roast with you.
Tony bores the rice with you.

Appendix E: Ethical approval by C-REC for experiments conducted on young participants at Sussex University

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University of Sussex
School of Life Sciences Research Governance Committee

CERTIFICATE OF APPROVAL

Title of Project	Verb Comprehension: a Study of Spatial Representations
Principal Investigator	prof. Jane Oakhill
Student	Marika De Scalzi
Collaborators	
Duration of approval (not greater than 4 years)	36 months

This project has been given ethical approval by the School of Life Sciences Research Governance Committee.

NB. If the actual project start date is delayed beyond 12 months of the expected start date, this Certificate of Approval will lapse and the project will need to be reviewed again to take account of changed circumstances such as legislation, sponsor requirements and University procedures.

Please note and follow the requirements for approved submissions:
Amendments to protocol.

- Any changes or amendments to approved protocols must be submitted to the committee for authorisation prior to implementation.

Feedback regarding the status and conduct of approved projects

- Any incidents with ethical implications that occur during the implementation of the project must be reported immediately to the Chair of the committee.

The principal investigator is required to provide a brief annual written statement to the committee, indicating the status and conduct of the approved project. These reports will be reviewed at the annual meeting of the committee. A statement by the Principal Investigator to the Committee indicating the status and conduct of the approved project will be required on the following date(s):

December 2008, 2009, 2010……………………………………………………………………

Signed: ………….. ……Jennifer Rusted……………..
Chair of the Research Governance Committee

Date: …………22 July 2008…………….

University of Sussex

Life Sciences & Psychology Cluster based Research Ethics Committee

CERTIFICATE OF APPROVAL

Reference Number:	JOMDS0708
Title of Project:	Verb Comprehension: a Study of Spatial Representations
Principal Investigator:	. Jane Oakhill
Student:	Marika De Scalzi
Collaborators:	
Duration of Approval (not greater than 4 years)	12 months
Expected Start Date:*	February 2011

This project has been given ethical approval by the Life Sciences and Psychology Cluster based Research Ethics Committee (C-REC).

*NB. If the actual project start date is delayed beyond 12 months of the expected start date, this Certificate of Approval will lapse and the project will need to be reviewed again to take account of changed circumstances such as legislation, sponsor requirements and University procedures.

Please note and follow the requirements for approved submissions:

Amendments to protocol.

- Any changes or amendments to approved protocols must be submitted to the C-REC for authorisation prior to implementation.

Feedback regarding the status and conduct of approved projects

- Any incidents with ethical implications that occur during the implementation of the project must be reported immediately to the Chair of the C-REC.

The principal investigator is required to provide a brief annual written statement to the committee, indicating the status and conduct of the approved project. These reports will be reviewed at the annual meeting of the committee. A statement by the Principal Investigator to the C-REC indicating the status and conduct of the approved project will be required on the following date(s):

December 2011, 2012……………………………………………………………………………

Authorised Signature	Jennifer Rusted
Name of Authorised Signatory (C-REC Chair or nominated deputy)	**Jennifer Rusted**
Date	10-02-2011

Appendix F: Ethical approval by Sussex NHS Research Consortium for experiments conducted on older adults and memory impaired older adults

NHS

Sussex NHS Research Consortium

Please reply to: Research Consortium Office
Worthing Hospital
Lyndhurst Road
Worthing
West Sussex
BN11 2DH

Professor Jennifer Rusted
Professor of Experimental Psychology
Psychology Department
University of Sussex
Falmer,
Brighton
BN1 9QH

29 January 2008

Dear Professor Rusted,

RAMC ID: 0949/NOCI/2007
TITLE: Remembering to remember: the development of strategies to improve prospective memory performance in older adults and memory-impaired older adults.

Thank you for your application to the Research Approval and Monitoring Committee (RAMC) for approval for this study.

A sub-committee of the RAMC have considered this study. The documents considered were as follows:

- CV for Marika De Scalzi (signed and dated 29/01/08)
- Research Passport for Marika De Scalzi (signed and dated 29/01/08)

I am pleased to tell you that the study was approved, and so may proceed. This approval is valid in the following Organisations:

- Sussex Partnership NHS Trust

This approval is valid for the following researchers:

- Marika De Scalzi, PhD. Research Student, University of Sussex

Your RAMC approval is valid providing you comply with the conditions set out below:
1. You commence your research within one year of the date of this letter. If you do not begin your work within this time, you will be required to resubmit your application to the committee.
2. You notify the RAMC by contacting me, should you deviate or make changes to the RAMC approved documents.
3. You alert the RAMC by contacting me, if significant developments occur as the study progresses, whether in relation to the safety of individuals or to scientific direction.
4. You complete and return the standard annual self-report study monitoring form when requested to do so at the end of each financial year. Failure to do this will result in the suspension of RAMC approval.
5. You comply fully with the Department of Health Research Governance Framework, and in particular that you ensure that you are aware of and fully discharge your responsibilities in respect to Data Protection, Health and Safety, financial probity, ethics and scientific quality. You should refer in particular to Sections 3.5 and 3.6 of the Research Governance Framework.
6. You ensure that all information regarding patients or staff remains secure and strictly confidential at all times. You ensure that you understand and comply with the requirements of the NHS Confidentiality Code of Practice, Data Protection Act and Human Rights Act. Unauthorised disclosure of information is an offence and such disclosures may lead to prosecution.

Please contact the Consortium Office if you wish this approval to be extended to cover other Consortium Organisations; such an extension will usually be agreed on the same day. We also have reciprocal arrangements for recognition of Research Governance approval with some other NHS Organisations; such an extension can usually be arranged within ten working days.

Good luck with your work.

Yours sincerely,

Mrs Helen Vaughan
Senior Research Governance Officer

Email: helen.vaughan@wash.nhs.uk
Tel: 01903 285222 x 4190
Fax: 01903 209884