The development of short-term memory in children:
a cross-linguistic comparison and a study on Down syndrome

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Abstract

This thesis examines the emergence and use of short-term memory (STM) strategies in children, with respect to the working memory model (Baddeley & Hitch, 1974). Of interest are the developmental shifts observed in the use of coding and rehearsal strategies. The questions addressed refer to the extent to which STM development is affected by contextual factors, namely language characteristics or limitations in processing speed; how these factors affect the use of strategies; and how fixed, time-related factors (e.g. articulation rate, item length) interact with the maturation of strategies to determine STM capacity. It is suggested that children are able to use, or learn to use, STM strategies flexibly to adapt to such contextual factors. This affects the patterns of STM performance observed at different ages.

To explore this suggestion, a cross-linguistic study was conducted. Greek and English children were compared, as Greek words are on average longer than English words. The question addressed was whether this difference would be reflected in the patterns of STM performance of the two language groups. A study on STM in children with Down syndrome was also conducted, to explore how limitations in verbal abilities affect STM and strategy use.

Greek and English children aged 4 to 10 years were compared on a number of STM tasks. Dissociations between visuo-spatial and verbal tasks and effects of phonological similarity, visual similarity, and word length on recall of spoken words and pictures were examined. The developmental patterns of STM performance in the two language groups differed in the chronology of their emergence. Greek children relied on visual coding for longer than English children, who showed a shift towards a preference for verbal coding at an earlier age than Greek children. Children in both language groups seemed able to use strategies flexibly according to the length of the items to be remembered. Native language and differences in literacy acquisition were considered as possible causal factors for these differences.

The study of STM development in children with Down syndrome suggested a preference for visual coding in STM tasks. Children with Down syndrome may rely more on visual strategies, but they should be taught how to benefit from them in STM tasks.
This thesis is for my parents,

for Michel and Antiope,

and for Ketty.
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Introduction to the thesis

1. Background and subject of the thesis

This thesis examines the development of short-term memory (STM) with respect to Baddeley and Hitch's (1974) working memory model. The central question addressed is concerned with the factors determining the development of STM. As will be discussed, one of the principal components of working memory is the phonological loop, which is responsible for retaining speech-based information (Baddeley, 1986, 1990). The limited capacity of the phonological loop is time based, and thus determined by the size and temporal duration of the verbal material to be retained. According to the working memory model, therefore, item length and articulation rate play a major role in STM span.

The strategies applied for the encoding, maintenance, and retrieval of information are also important; among these, verbal rehearsal has received particular attention in previous research. Developmental research has focused on the emergence and use of mnemonic strategies, with an emphasis on the role of visual and verbal codes, as well as rehearsal, in memory development (e.g. see Henry, Turner, Smith, & Leather, 2000; Hitch, 1990; Palmer, 2000). As will be described, the evidence suggests a specific pattern of memory development, during which different strategies come into play. It seems that the emergence, efficiency, and awareness of these strategies follow a particular pathway. Although individual studies may not agree on the exact timing of developmental shifts in strategy use, overall, research suggests the emergence of a specific picture of memory development.

One question that arises is whether STM development really follows fixed and predictable pathways. By definition, strategies are mentally effortful, goal-directed processes, adopted to enhance performance in particular tasks (Bjorklund & Douglas, 1997). Efficient and successful strategies must be applied in a flexible manner, according to context, relevance to the task, and the resources available to
the individual. Studies on children's metacognition suggest that this flexibility increases with age and is often dependent on the child's own awareness of memory processes and knowledge of his or her memory skills. Indeed, it has been suggested that a plethora of strategies are available to the child but may compete with each other and may be used simultaneously to varying degrees. This variability in strategy use could account, in part, for individual differences in memory performance.

A closely related question addressed in this thesis is whether developmental patterns of STM are universal. The variability of strategy use within a population and even within the same child suggests that STM span does not depend solely on fixed biological factors such as capacity or speed of processing, but also on the context in which learning takes place, which brings various strategies into play. In other words, under different conditions, different resources may become more or less available; these opportunities or constraints may lead to deviations from the established developmental course of STM. For example, in immediate serial recall of words, the characteristics of a given language (i.e. item length, item phonemic complexity, item duration) may favour the choice of one particular strategy instead of another. This, in turn, would be reflected in the developmental memory profiles of individuals who speak this language. Evidence that language characteristics affect the development of STM span would strongly indicate that memory does not develop along a single route, but that there are alternative pathways to memory development.

This assumption would also have implications for populations where there are biological limitations to learning. Poor performance in STM tasks is common among individuals with learning difficulties in general, and to some subgroups with known aetiologies in particular. Limitations due to low intelligence, specific structural deficits, language difficulties, or other reasons may contribute to their memory difficulties. If there are alternative routes to learning, knowledge of the cognitive strengths and weaknesses of these individuals can help us understand their atypical developmental profiles and suggest the teaching of strategies suitable for optimal learning.
In this thesis, therefore, the question of strategy development and its relationship to language and cognitive constraints is addressed in two ways. First, the universality of strategic development is investigated by comparing the memory performances of children who speak different languages that differ substantially in word length and structure, namely Greek and English. Second, the flexibility of strategies and efficiency of new taught skills is examined in individuals with STM difficulties. These two approaches allow conclusions to be drawn on the nature of memory development, and more particularly on what is stable and universal and what is flexible and context-dependent in STM.

2. Method of investigation

To address these questions, particular populations and research designs were chosen. For the cross-linguistic experiments, English and Greek native speakers aged from 4 to 10 years were compared on a number of language and memory measures. The Greek language, which is the native language of the author, offered the opportunity to make comparisons related to STM span. The fact that Greek words are overall longer than English words—including the nouns that constitute the first vocabulary of a child—provided a starting point for making cross-linguistic comparisons relevant to the research questions. A cross-sectional design was used to observe memory development in the two populations being compared.

For the experiments on memory in individuals with learning difficulties, the population of children and adolescents with Down syndrome was chosen. The aetiology and biological basis of Down syndrome is now well documented, and research is progressing on the relationship of genetics to the cognitive profiles of this population. The cognitive development of individuals with Down syndrome has also been extensively studied, and much evidence is available on language and memory development. It is established that language and STM difficulties are central deficits in this syndrome, and the relationship between language and memory is a question of some importance. More particularly, it is known that difficulties in hearing, speech production, and mastery of grammar and syntax are common in this population, while a relative strength in visual processing has been suggested in many studies (see...
Chapter Five). Knowledge of the biological and language limitations present in this syndrome, as well as the STM strengths and weaknesses revealed in numerous studies, leads to the question of how this profile affects STM and strategy development and what are the most suitable strategies to be encouraged and taught.

Research strategies to explore this question included direct comparison of children with Down syndrome and typically developing children of comparable mental age, on a number of STM measures which allowed the observation of the use of strategies such as verbal and visual coding, and the use of spatial cues. In addition, on the basis of the visual processing advantage suggested for individuals with Down syndrome, the role of visual imagery instructions on STM performance was also investigated within this population.

3. Aims and main questions of the research

Together, findings from the studies planned could provide important information about:

1. The nature of STM and its development: what are the major factors determining STM span? Does STM development follow the same pathways in different contexts?
2. The nature of strategic development: how flexible is the choice and use of mnemonic strategies over development? To what extent is the potential to use strategies biologically based and to what extent does it depend on the available resources?
3. The relationships between language and STM: do language characteristics—or language difficulties—affect STM and the choice of mnemonic strategies?
4. The use of memory strategies in Down syndrome: are visuo-spatial coding and visual imagery beneficial in this population?
4. The structure of the thesis

The thesis is divided into two major sections, the first presenting the literature reviews and experiments related to the cross-linguistic study, the latter presenting the reviews and experiments related to the Down syndrome study. A final chapter draws together the findings from both sections.

In Chapter One, the literature on STM development is reviewed. Particular emphasis is given to the working memory model, its developmental applications, and the research that has investigated working memory in children. The relationship between STM and other cognitive processes, particularly language, is mentioned. The role of strategies and metamemory is discussed. Finally, the evidence that context may affect STM span and the use of strategies is reviewed. Cross-cultural, cross-linguistic studies and studies on bilinguals are presented and discussed with respect to the variability in strategy use.

Chapter Two presents the first experiment of the cross-linguistic study, in which English- and Greek-speaking children aged 4, 6, 8, and 10 years were compared on auditory and visual digit span and visuo-spatial span. The results are discussed with respect to the evidence for the role of item length and coding strategies in STM.

In Chapter Three, two more experiments are presented, in which the same groups of children were compared on word span tasks. The effects of phonological and visual similarity of items (Experiment Two), as well as word length (Experiment Three), and the effects of different presentation and response modalities on recall are discussed with respect to the existing evidence on coding and rehearsal strategies in children. Relationships between the STM measures and language measures are also discussed.

A general discussion of the cross-linguistic study follows in Chapter Four.

The second section of the thesis begins in Chapter Five, where Down syndrome is described and research on the STM difficulties of individuals with Down syndrome
and individuals with other learning difficulties is reviewed. The nature of the memory difficulties in Down syndrome is explored.

Chapter Six presents four experiments that explore STM in Down syndrome. The first two experiments (Experiments Four and Five) were carried out to replicate previous findings on digit spans and visuo-spatial spans, and the effects of phonological and visual similarity of test items on STM span. Following this, the third experiment (Experiment Six) explored the role of spatial cues on STM performance. Finally, Experiment Seven explored the ability of young individuals with Down syndrome to use visual imagery.

In Chapter Seven, the findings from the Down syndrome experiments are discussed.

Finally, an overall discussion and suggestions for future research are presented in Chapter Eight.
Chapter One

The development of STM in children

1.1. Introduction

This review will focus on the development of STM in children, with respect to the working memory model (Baddeley, 1986, 1990; Baddeley & Hitch, 1974). The term ‘working memory’ is associated with several models and, therefore, subject to various definitions (see Baddeley, 1996a, pp. 1-2). In this thesis it is considered as a system, or number of systems, responsible for the temporary storage and manipulation of information during cognitive tasks such as learning, reasoning, comprehension (Baddeley, 1990) and language acquisition (Baddeley, Gathercole, & Papagno, 1998).

The choice of the working memory concept for this thesis was based on several reasons. As will be seen, the model has proved powerful in accommodating findings from developmental STM studies (e.g. see Gathercole & Baddeley, 1993, for a review); even more importantly, it has provided a framework within which further studies on children’s STM performance and coding and rehearsal strategies could be conducted. The experiments reported in this thesis drew largely on the rationale and methodology of previous studies (e.g. Hitch, Halliday, Dodd, & Littler, 1989; Hitch, Halliday, Schaafstal, & Schraagen, 1988; Hitch, Woodin, & Baker, 1989); the issues they addressed were formulated with respect to the assumptions of the working memory model. The aim of the present studies, therefore, was to test a number of hypotheses against the assumptions of the model and possibly add further information about the operation of working memory.
Following a brief overview of the model and a description of its main components, studies on the development of working memory in children will be reviewed. An emphasis will be given on the evidence about the use of coding and rehearsal strategies, and their development. Related issues will be discussed, namely age and individual differences in STM performance and the contribution of factors such as processing speed and metamemory in STM capacity. Finally, a synthesis will be attempted, and models of STM development integrating a number of different factors will be discussed. As the focus of the cross-linguistic study is on the role of native language in STM performance, relevant cross-linguistic research will also be included.

1.2. Overview of the working memory model

As mentioned above, the working memory model postulates the existence of three main systems involved in the temporary storage of information:

(a) a central executive, which is viewed as a high-level control mechanism involved in the allocation of attention and the coordination of resources from short-term and long-term memory (Baddeley, 1996b);

(b) a phonological loop, whose operation is associated with the processing of auditory and verbal information, and

(c) a visuo-spatial sketch pad, involved in the processing of visual and spatial information.

Both the phonological loop and the visuo-spatial sketch pad are considered as ‘slave’ systems under the control of the central executive.

As these two slave systems are particularly relevant to the coding strategies studied in the next chapters, they are described in more detail below.
1.2.1. The phonological loop

The phonological loop consists of two components (although Hulme and Mackenzie (1992) argue against a fractionation of the loop): a phonological store, where speech-based information is entered and retained temporarily (for about two seconds), and an articulatory rehearsal mechanism, involved in the maintenance of the material in the phonological store through subvocal repetition of the items. This mechanism may also operate during encoding, by naming the items that enter the phonological store. In fact, visually presented items may enter the phonological loop if they are recoded verbally. As will be seen below, this process is optional and emerges later in development than phonological coding of verbal material, which does not require switching to a different modality.

A number of phenomena related to the function of the phonological loop are thought to tap on the operation of the phonological store and the rehearsal mechanism; they have also been used in research as indicators of the use of these components. The most widely used are the phonological similarity effect and the word length effect, which are described below.

1.2.1.1. The phonological similarity effect

This term describes the phenomenon that items which sound similar (Conrad, 1964), such as the letters P G V C T (Conrad & Hull, 1964), or the words mad, man, cat, mat, cap (Baddeley, 1966) are remembered with more difficulty than items that do not sound similar. The effect is considered to reflect confusion of the phonologically similar items when entering the phonological store (Baddeley, 1986) but also confusion during rehearsal (Hulme & Mackenzie, 1992).
1.2.1.2. The word length effect

Baddeley, Thomson, and Buchanan (1975) demonstrated that recall of short words is better than recall of long words. Strongly related to the effect and with STM span was speech rate; it also appeared that spoken duration of the items to be remembered, as measured by examining reading rates, was a better predictor of the effect than number of syllables. The effect was also abolished by articulatory suppression: when the participants were required to count aloud while trying to memorise visually presented words of varying length, word length did no longer have an effect on recall. These findings, which have been replicated in further research (see Baddeley, 1986), are considered to reflect limitations in the capacity of the phonological store, which is time based, and the articulatory rehearsal mechanism, which allows the items that are subject to decay to be refreshed. Thus, items that take longer to articulate are more subject to decay than items with a shorter spoken duration. This relationship leads to the well-known definition of STM span as the number of items that can be spoken in about two seconds (see Baddeley, 1986).

The dependence of STM span on temporal factors has also been demonstrated in cross-linguistic studies and studies in bilinguals. Ellis and Hennelly (1980) compared bilingual adults who spoke Welsh and English on digit spans in both languages. They found that spans for Welsh digits were shorter than spans for English digits, even though the dominant language of the participants was Welsh. They attributed this result to the difference in spoken duration between Welsh and English digit names, with Welsh digit names taking longer to pronounce. Moreover, this difference disappeared when articulatory suppression was used.

This pattern of longer digit names leading to shorter spans has been replicated in other studies, for various languages: Hoosain and Salili (1988) for Chinese, English, and Welsh; Chincotta & Underwood (1997a) in a cross-linguistic study on the visual digit spans of adults speaking Chinese, English, Finnish, Greek, Spanish, and Swedish, where articulatory suppression abolished the observed differences; Naveh-
Benjamin and Ayres (1986) contrasting digit spans and reading times of digits in Arabic, English, Spanish, and Hebrew; Stigler, Lee, and Stevenson (1986) showing digit span differences and digit spoken duration differences between Chinese and English adults and children; Zhang & Simon, 1985, contrasting Chinese and English STM for printed stimuli in bilinguals; Olazaran, Jacobs, and Stern (1996) contrasting visual and verbal STM in English and Spanish adults; Chincotta and Hoosain (1995) and Hoosain (1982) again showing a relationship between speech rate and digit span. The dependence of digit span on the language spoken has also been considered with respect to cross-linguistic differences in arithmetic skills (see Ellis, 1992).

There is, therefore, evidence from cross-linguistic comparisons that strongly suggests the temporal nature of the factors that determine STM span. As mentioned above, these results indicate the operation of verbal rehearsal, as indicated by the effect of articulatory suppression. However, it has also been demonstrated that word length can have an inverse effect on recall, as loss of phonological information may be more easily reconstructed for longer words than for shorter words (Cowan, Wood, Nugent, & Treisman, 1997).

1.2.1.3. Are temporal factors the only determinants of STM span?

The evidence presented above suggests a strong relationship between articulation time and STM span. However, there is also evidence that factors related to long-term memory also come into play. Hulme, Maughm, and Brown (1991) and Hulme, Roodenrys, Brown, and Mercer (1995) showed the effect of word familiarity on STM span; more evidence is, again, provided by cross-linguistic studies.

Chincotta and Underwood (1996, 1997b) compared dominant Finnish/Swedish bilingual children to bilingual children who spoke the two languages equally well on digit span, and found an effect of familiarity and practice with the language on STM performance. The superior role of dominant language to reading rate of digits was also shown in Spanish/English bilinguals (Chincotta & Underwood, 1997c; also see
da Costa Pinto, 1991). Greater fluency with numbers in one’s native language was also estimated by measuring reading times and recording eye fixations while reading numerals in Finnish/Swedish bilinguals; fluency predicted STM span differences in the two languages better than item length (Chincotta, Hyoenae, & Underwood, 1997). Finally, Chincotta and Underwood (1998) compared spoken word spans and nonword spans in bilingual children whose dominant language was either Finnish or Swedish, and in children who spoke the same language (Finnish or Swedish) both at home and in school. They found that nonword spans were better predicted by articulation rate, while word spans were better predicted by speech rate only in the groups that were equally fluent in the two languages. Language dominance had, again, a greater effect on STM span than word length.

1.2.2. The visuo-spatial sketch pad

The visuo-spatial sketch pad is, as mentioned above, the component of working memory devoted to the processing of visuo-spatial information. Its function in adults is believed to be complementary to that of the phonological loop (e.g. see Logie, 1995); in young children, as will be seen below, it is believed to play a major role in the retention of pictorial material. Research on the structure and function of the visuo-spatial sketch pad has been more fragmentary than research on the phonological loop, mainly because verbal coding appears to be the dominant process in STM tasks, masking the function of visual STM. As a result, the model of visuo-spatial working memory has developed more slowly and tends to be less detailed than the description of the phonological loop. For example, it is unclear whether the visuo-spatial sketch pad consists of separate systems, equivalent to the phonological store and the rehearsal mechanism, which are involved with the encoding and maintenance of visual and spatial information.

Evidence supporting the existence of a system where visual information enters via sensory input or activation of long-term representations is provided by the visual similarity effect on recall of visually presented material. The visual similarity effect
refers to poorer recall of visual items (letters or pictures) that resemble in form and/or spatial orientation, compared to recall of items which are similar in shape. As will be seen, visual similarity effects have been reported in young children (e.g. Hitch et al., 1988), indicating a prevalence of visual coding in younger ages. A visual similarity effect has also been detected in adults under articulatory suppression; in some experiments, the effect remains, though it is weaker, even without articulatory suppression (see Logie, 1995, pp. 71-73). These findings suggest that even adults use visual coding, which plays, however, a secondary role in STM.

An attempt has also been made to identify a mechanism responsible for the retention of visual/spatial material. Smyth and Scholley (1994) reported an effect thought to be analogous to the word length effect in a task which required serial recall of squares on a screen by tapping the sequence of the squares. Manipulating the distance between the squares, they showed that the time taken to move between the squares was inversely related to memory span, at least for relatively large displays. These findings were interesting in considering the role of kinaesthetic information in visuo-spatial working memory (also see Logie, 1995). However, these findings do not provide direct evidence about the existence of an active mechanism involved in the refreshing of visuo-spatial information.

Another issue yet unresolved in visuo-spatial working memory is related to the fractionation between visual and spatial components. As Farah (1988) discussed, visual and spatial processes are used simultaneously, making it difficult to observe dissociations between the two. Experiments using interference tasks thought to be purely spatial or purely visual (e.g. Baddeley & Lieberman, 1980; also see Baddeley, 1990) emphasize the function of the spatial component. Important information about the nature of the visuo-spatial sketch pad is provided by the work of Kosslyn (1980, 1994) in his model of mental imagery. Kosslyn’s work draws upon experimental and neuropsychological research to suggest a dissociation between visual and spatial components. He also suggests a number of sub-processes within the mental imagery
system which might help to understand the organisation of the sketch pad. In particular, image generation and maintenance, as explored and viewed in Kosslyn's work, could help to explain the activation of representations in the store component of the sketch pad, and the 'rehearsal' of these representations, respectively.

It seems, therefore, that the visuo-spatial sketch pad needs to be explored further. It seems that the sketch pad is involved in a number of processes, including visual imagery and writing (see Logie, 1995). For the purposes of the research reported in the next chapters, it is viewed as a system mainly involved in the visual encoding of pictorial information.

The structure and function of working memory outlined above are the framework for considering the developmental STM studies reported in the next section.

1.3. The development of STM in children

This section will focus on the issues in the development of STM related to the specific questions addressed in the thesis. In particular, the issues to be addressed are related to the evidence suggesting developmental shifts in the use of verbal and visual strategies. A number of factors that may affect these developmental shifts, namely processing speed, articulation speed, maturational processes related to strategy use, and metacognitive understanding, will also be considered.

1.3.1. Developmental changes in STM encoding

As will be discussed below, a number of developmental studies suggest that during development a transition occurs from reliance on a visual code for remembering visual material to reliance on a verbal code. This shift has been studied by examining phonological similarity, visual similarity, and word length effects in children. As mentioned above, these effects are thought to reflect the use of phonological coding, visual coding, and verbal rehearsal, respectively.
1.3.1.1. The phonological similarity effect in children

Conrad (1971) first observed that the phonological similarity effect on nonverbal recall for pictures (matching response) was not evident in children aged from 3 to 5 years. Hulme (1984), on the other hand, studied the recall of phonologically similar spoken words in children aged from 4 to 10 years, when a verbal response was required. He found that the effect was significant in children over 5 years, but not in 4-year-olds. These findings taken together suggest that the phonological similarity effect is not present in 4-year-olds, and that this absence of the effect does not depend on presentation modality. However, in a subsequent study, Hulme (1987) contrasted the recall of phonologically similar spoken words and pictures in children aged 4, 7, and 10 years, when a nonverbal response was required. The size of the effect increased in line with age. For visually presented material a smaller similarity effect was detected, which remained stable with increasing age.

Other studies, however, suggest a dependence of the effect on the modality in which the stimuli are presented. This dissociation has been supported by considering together the findings of studies showing that the phonological similarity effect on recall of spoken words is significant even in 4-year-olds (Hitch, Halliday, Dodd, & Littler, 1989; Hulme, 1987; Hulme & Tordoff, 1989), but emerges later for recall of pictures (Halliday, Hitch, Lennon, & Pettipher, 1990; Hitch & Halliday, 1983; Hitch, Woodin, & Baker, 1989). All these studies have shown that the phonological similarity effect on picture recall is significant in children aged 10 years, but not in children aged 5 years. Interpreted with respect to the working memory model, this pattern of results suggests that, at least in English-speaking children, phonological recoding of pictorial stimuli takes place at some point between the age of 5 and 10.

Another interesting finding was that, in the picture span tasks, naming the pictures upon presentation appeared to affect the results. For example, some studies have shown that the effect is not detected when the presentation of pictures is silent (Halliday et al., 1990) but is detected when the pictures are labelled overtly upon
presentation (Hulme, 1987). In contrast, Ford and Silber (1994) reported that overt naming of the pictures was not adequate to induce verbal recoding. Exploring this issue further is important, as it will provide suggestions on the requirements for the spontaneous use of a verbal strategy in young children.

Palmer (2000, Exp.1) addressed this issue in an experiment where she studied the phonological similarity effect on recall of spoken words and pictures in children aged from 3 to 7 years. She also contrasted silent presentation with forced labelling of the pictures. She found that children below the age of 7 did not appear to benefit from the overt labelling of the stimuli. Looking at individual differences in encoding within each age group, she also noted that the children who did show a tendency to benefit from picture naming were those that were deliberately using a verbal strategy. This suggests that overt naming of the pictures may not be sufficient to produce covert labelling.

Overall, the absence or small size of the effect in younger age groups is thought to reflect coding of visual material into a visual code, instead of recoding into a verbal code. The age at which this transition occurs appears to be between 5 and 7 years. However, as Palmer (2000) stresses, this transition is not abrupt but rather involves the gradual emergence of the ability to apply verbal strategies.

Further evidence supporting the reliance of younger children on visual information is provided by the visual similarity effect on recall of pictures.

1.3.1.2. The visual similarity effect in children

As mentioned above, the visual similarity effect is mainly detected in young children, although it can also be present in adults, especially under articulatory suppression which prevents them from verbally recoding the stimuli (see Section 1.1.2.). In very young children, however, it has been suggested that visual similarity effects on memory for pictures should be present even without articulatory
suppression, as this optional visual-verbal recoding does not occur automatically as in adults. Direct evidence to support this comes from several studies. Visual similarity effects have been reported for children aged 5 and below (Brown, 1977; Hayes & Shulze, 1977; Hitch et al., 1988, Exp. 1), but also, though weaker, for older children (Hitch, Woodin, & Baker, 1989). Interestingly, the effect is detected even though the children hear the names of the pictures on presentation, spoken by the researcher (Hayes & Schulze, 1977) or are told to label the pictures themselves (Hitch et al., 1988). It appears that visual similarity effect usually needs a sensitive measure (namely a fixed length procedure rather than a span procedure), to be detected (Hitch, Halliday, Dodd, & Littler, 1989). Finally, the preference of younger children for a visual code has been further established by visual interference experiments with 5 year-olds, compared to the more effective verbal interference for 10 year olds (Hitch et al., 1988, Experiments 3 and 4).

It is interesting that even 10-year-olds have been shown to be sensitive to visual similarity effects. It is true that the first experiment of Hitch, Woodin, and Baker (1989) showed that 10-year-olds were not sensitive to visual similarity unless they were prevented from verbal coding by engaging in articulatory suppression, when they also showed a recency effect for the last visually presented item (Exp. 2). However, the same study also showed that a mixed-modality interference task was more disruptive of the visual similarity effect than single-modality interference tasks (Exp. 3). Hitch, Woodin and Baker interpreted these findings as an availability of visual coding in 10-year-olds: although, at this age, verbal recoding has clearly taken over and masks the use of visual codes, it seems that some reliance on visual information is still present. Finally, the interference tasks suggested an independence of the visual similarity effect from visual recency (see also Hitch et al., 1988). It was suggested that, while the visual similarity effect is likely to reflect the decay of visual information about items (such as shape and orientation), visual recency may reflect the storage of information about the order in which a visually presented item is encountered during a memory task. Hitch et al. (1988) suggested the existence of
a passive component in visual working memory, where information is accessed via these visual and ordinal cues.

Again, Palmer (2000) studied children's individual differences in encoding by looking at visual and phonological similarity effects in each child separately. Her findings supported a gradual transition from early visual coding at about 4 years of age, to a mixed strategy (dual coding), to a shift towards verbal recoding at the age of 7 to 8 years.

1.3.1.3. Effects of word length in children

Age differences in the presence and size of the word length effect have been detected in various studies (e.g. Hitch, Halliday, & Littler, 1989, 1993; Hulme, Silvester, Smith, and Muir, 1986; Hulme, Thompson, Muir, & Lawrence, 1984). Findings regarding the age at which the word length effect emerges vary depending on presentation modality, response modality, and on whether the pictorial material is named or not upon presentation.

Like studies on phonological similarity effects in children, experiments on word length effects appear to be modality-dependent. While the effect on recall of spoken words has been detected from the age of 4 years (Hulme et al., 1984), it seems that it emerges later for pictures. For example, Allik and Siegel (1976) detected the word length effect for picture recall in 8- and 10-year-olds, but not in younger children. Hitch and Halliday (1983) found a similar pattern when they contrasted auditory and visual presentation in children aged from 4 to 11 years. In spoken word recall, they could detect the word length effect even in 4-year-olds; with picture recall, however, they showed that the effect was only clearly present at the age of 10.

Further studies appear to support this pattern (Halliday et al., 1990; Hitch, Halliday, Dodd, & Littler, 1989; Johnston, Johnston, & Gray, 1987), with the word length effect on picture recall emerging after the age of 7 or 8 years. The word length effect
was detected both when the children were presented with lists of a fixed length and when an STM span measure was recorded (e.g. Hitch, Halliday, Dodd, & Littler, 1989, Experiments 1 and 2).

However, Hulme et al. (1986) found a word length effect on recall of pictures even in 5-year-olds, and even when nonverbal recall was required. The effect appeared stable across the age range that was studied (5 to 11 years). Furthermore, the word length effect was abolished by articulatory suppression, suggesting the use of rehearsal. These findings seem inconsistent with the pattern described above, even though Hulme et al. noted that the detection of these effects in young children does not imply the use of a sophisticated rehearsal strategy from this early age. It could be that what may change with age is the automaticity of verbal recoding (p. 73).

This leads to a question related to the use of verbal strategies in young children: does the word length effect in young children imply that they rehearse at all? Even though it appears to be significant, at least for spoken words, it has been argued that young children do not engage in cumulative rehearsal until after the age of 7 (Baddeley et al., 1998; Gathercole, 1998). If this is the case, what may account for the detection of the word length effect in young children? One possibility is that, as in adults, verbal output produces the effect (Henry, 1991). The dependence of young children's STM span on time-related factors could also be attributed to search processes in STM (Cowan & Kail, 1996; Cowan, Keller, Hulme, Roodenrys, McDougall, & Rack, 1994). Clearly, exploring covert processes in STM and controlling for output effects would reveal a clearer picture about word length effects in children.

1.3.1.4. Verbal rehearsal and STM span in children

Further evidence which could be interpreted as indicating the use of rehearsal in children comes from measuring articulation times. Again, the relationship between articulation time and STM span seems robust and has been reported in several
studies. Nicolson (1981) demonstrated a linear relationship between speech rate and STM span in children aged 8 to 11 years. Hulme et al. (1984) replicated and extended these findings to 4-year-olds. As, invariably, STM span was found to be determined by the number of items which could be articulated in about two seconds, it was suggested that STM capacity itself remains stable with age; what changes is the functional capacity, determined by speech rate (see also Hitch, Halliday, & Littler, 1989; Hitch, Halliday, Dodd, & Littler, 1989; Hulme & Tordoff, 1989; Hulme et al., 1984). The studies with bilingual children reported in the beginning of this chapter also add support to this pattern.

Again, however, this relationship between STM span and speech rate has been contradicted. A temporal factor that may confound this relationship could be related to operational efficiency, as defined by Case, Kurland, and Goldberg (1982). Case et al. measured the time lag between hearing and repeating back a list of digits (repetition latency) in children, and found that they were strongly correlated. They supported this with further experiments on counting span and nonword repetition in adults, and concluded that what changed with age was general processing efficiency, and the ability to apply control processes on STM tasks.

While the hypothesis of Case et al. (1982) can be accommodated within the working memory model with respect to the function of the central executive (see Baddeley, 1986), evidence from the effect of articulatory suppression on recall seems to favour the suggestion of a change towards a verbal strategy over the course of development (see Baddeley, 1986; Hitch, 1990). Studies examining primacy effects and presentation rates in children may also provide evidence about rehearsal (see Hitch, 1990, for a brief review). However, as Hitch points out, even if these effects seem to suggest the use of rehearsal, the strategy is not necessarily present in a sophisticated form from an early age. Hitch (1990) refers to an automatic activation of articulatory motor programmes at a young age, as a response to spoken input. Similarly, Gathercole and Hitch (1983) support a gradual transition from overt naming of items to the use of cumulative covert rehearsal. This suggestion is also in line with the
argument for an increase in the sophistication and flexibility of rehearsal strategies over development (Guttentag, Ornstein, & Siemens, 1987) and with the discussion of Hitch, Halliday, Dodd, and Littler (1989) who noted that "the word length effect itself may reflect only a relatively unsophisticated component of the fully developed repertoire of rehearsal processes" (p. 360).

Further, there is evidence against the suggestion that young children rehearse. First, recording lip movements during STM tasks has shown that very few young children (aged about 5 years) show signs of verbal rehearsal (Flavell, Beach, & Chinsky, 1966). Second, if there are signs indicating this strategy, they are not consistent from one trial to the other and they do not seem to occur spontaneously (McGilly & Siegler, 1989). Moreover, the relationship between speech rate and STM span does not always seem to apply to younger children (e.g. Gathercole, Adams, & Hitch, 1994; Henry, 1994). As mentioned above, findings from bilingual studies also question the degree to which STM span is determined by item length, and suggest the contribution of long-term memory in STM span. Henry (1994) makes the same observation, on the basis of a lack of a relationship between STM span and speech rate when correlations between the two measures were examined for each child individually.

1.3.1.5. An alternative hypothesis about the emergence of verbal rehearsal in children

The patterns presented above support a gradual transition from visual coding to verbal recoding and the use of verbal rehearsal with increasing age. This pattern appears to be supported by the working memory model, according to which visual coding of nameable pictures is an optional process in adults, but verbal recoding of pictures is an optional—and more effortful—process in young children. An alternative suggestion was put forward by Penney (1989) who claimed that spoken input gains automatic access to a temporary 'echoic' store. Visual input, in contrast,
does not have access to an analogous store; it is, therefore, more necessary to use verbal rehearsal for visually presented items.

Henry et al. (2000) explored this hypothesis in young children aged from 4 to 10 years. They recorded the children's reported strategies, where possible, and they also studied word length effects for spoken words and pictures. Their first experiment showed a tendency for the youngest (4-year-old) children to show a word length effect for pictures, which did not, however, reach significance. Older children (aged 7 and 10) showed a word length effect for both presentation modalities when probed recall was required. In Experiment 2, nonverbal serial recall was required. Children aged 4 showed a significant word length effect for pictures, but not for spoken words, while the effect was, again, significant for both modalities in the older age groups. Henry et al. considered this finding with respect to the hypothesis of Penney (1989).

This finding is intriguing, given the consistency of previous experiments suggesting the reverse pattern. However, it requires further study as it raises an interesting question: what determines the choice of children's strategies over development? If the crucial factor is mental effort and general processing resources, then the word length effect for spoken input should emerge earlier, because it is an 'easier' task. If, however, the crucial factor is the rapid decay of visually presented information, then the more 'necessary' rehearsal of pictures should emerge first. It is interesting to consider how flexible young children are in choosing to apply a relatively effortful task in order to remember information subject to decay.

1.3.1.6. Synthesis of the findings on STM coding strategies in children

Altogether, the studies presented above suggest a shift from visual encoding to visual/verbal recoding, which takes place at about 7 to 8 years of age. However, this shift is not abrupt and reflects rather a preference for visual coding than a genuine
inability to use verbal coding. Rather, with increasing age more codes become available, leading to more efficient learning.

This pattern has several important implications. First, it provides further support to the assumptions of the working memory model about the function of the phonological loop: if verbal recoding of pictures is an optional route through which visual information enters the phonological loop, then it is not surprising that it emerges later in development—although, as was discussed, recent findings suggest the opposite. Second, this pattern also supports the argument of Hitch (1990) for the application of developmental fractionation in developmental research. Hitch claimed that dissociations like the ones reported above add evidence for a distinction between the components of working memory. He drew—with a note of caution—parallels between experimental dissociations in children and neuropsychological dissociations in adults. He also noted that children's and adults' memory systems should be very similar in organisation, and considered rehearsal as an example of gradual change over development.

On a more applied level, the patterns reviewed above suggest an increase in the quality of strategy use with increasing age. This qualitative change was not only evident with regard to rehearsal, but also with regard to the use of visual coding by older children. Hitch et al. (1988) mention that this transition towards verbal coding may be dictated by encouragement to use verbal strategies in school, especially through reading instruction. Interestingly, they formulate the question of whether the same patterns of modality effects would be observed in a non-Western culture with little, or different, formal education. This note is particularly interesting with respect to the present thesis, which considers the possible effects of native language on the modality patterns of children at different ages.

The dependence of STM span and the related modality effects on a number of factors (long-term representations, STM search, reading ability, etc.) suggests that item length and speed of articulation are far from being the only factors that determine
STM span. It is true that they have been very powerful in explaining a great part of the developmental research on STM. However, the role of other factors should also be considered. The word length/STM span equation should be the starting point for accommodating further factors (temporal as well as qualitative) in the model.

One such factor is metamemory, the knowledge and understanding of memory processes. Schneider (1999) reviews the development of metamemory in children and discusses causal models linking intelligence, metamemory, and strategic behaviour in recall. These models are interesting for their relevance to providing STM training, both for typically developing children and children with learning and STM difficulties (see chapter Five).

Kail (e.g. 1992, 1997) suggests more quantitative models to accommodate findings about children's performance in various memory tasks. Much of his work involved path analyses to explore relationships between age, processing speed, articulation rate, and STM span in children and adults. Path analyses may be useful in that they suggest causal relationships between a number of different measures. These relationships are interesting as they integrate the suggestions from the working memory perspective and the argument of Case et al. (1982) about operational efficiency. Kail and Park (1994) extended these findings to older children and adults, while Kail (1997) incorporated image generation rates into the model to predict spatial span.

To conclude, it is clear from the above that a number of factors contribute to STM span in children. So far the evidence suggests that time-related factors play a major role in determining the capacity of STM, and the increase of memory span with age. However, the dissociations reported above also highlight the importance of qualitative changes in children's STM performance. Models that incorporate quantitative findings on children's STM performance should be considered along with research on metacognitive understanding and children's strategy use.
1.4. Concluding remarks

As mentioned above, the findings reported here suggest a number of assumptions that are relevant to the chapters that follow. First, cross-linguistic research and developmental evidence showed that item length and articulation rate appear to be very powerful in explaining STM development in children. Second, the developmental shifts reviewed above seem to occur as children get more access to the strategies available to them, either as a result of formal education, or as a result of processing maturation and changes in the efficiency of the central executive with age, or even as a result of the increase in metacognitive understanding with age. It is important to note that these changes reflect a flexibility in the use of STM strategies which suggests that: (a) the same children may be able to apply different strategies according to task demands and the resources available to them; and (b) children from different cultures could show different patterns of performance, if their education or even their native language favours the use of some strategies and the reluctance to use others. These possibilities are further discussed in the chapters that follow.
Chapter Two

Experiment One: contrasting digit span and visuo-spatial memory span in Greek and English children

2.1. Introduction

The literature review in Chapter One presented evidence from cross-linguistic and bilingual studies for the role of item length and articulation time in determining STM span. Most of the studies reviewed contrasted memory spans for digits across different languages. It was concluded from this review that length of digit names in a language is inversely related to the length of auditory digit span, both in adults (e.g. Olazaran et al., 1996) and in children (e.g. Chincotta & Underwood, 1996; also see Ellis, 1992, for a review). More particularly, it appears that digit span in different languages depends on the time required to articulate the digits, as demonstrated in studies with bilinguals (e.g. Chincotta & Underwood, 1996; da Costa Pinto, 1991) and cross-linguistic studies (Naveh-Benjamin & Ayres, 1986). This dependence of digit span on item length and articulation rate agrees with the main assumption regarding the function of the phonological loop (e.g. see Baddeley, 1990). Further support for this is provided by studies which show that articulatory suppression abolishes differences in digit span (e.g. Chincotta & Hoosain, 1995; Chincotta & Underwood, 1997a), thus indicating that duration of rehearsal is the determining factor in digit span. This relationship between word length and memory span also supports a ‘weak’ form of linguistic relativity (see Naveh-Benjamin & Ayres, 1986): linguistic features such as word length seem to be related, at least to some extent, to cognitive processes thought to be universal, such as STM (see also Thorn & Gathercole, 1999).
However, the importance of factors other than word length and articulation time has also been acknowledged. These factors may or may not have an indirect effect on speech rate itself. For example, Chincotta and Underwood (1996) in their study with Finnish and Swedish bilinguals, showed that knowledge of the language, as determined by language of schooling, accounted for digit span differences between the two languages. It could be argued that familiarity with the language has an effect on speech rate, and thus on memory span (e.g. see Zhang & Simon, 1985).

However, in a subsequent study, Chincotta and Underwood (1997b) also demonstrated that in bilingual children who were not taught in their native language in school, articulation speed of the digits did not predict digit span. Indeed, as Chincotta et al. (1997) reported in another bilingual study, number fluency, as measured by recording eye movements and reading times of digits, seems to predict digit span better than articulation rate. Olazaran et al. (1996) also note that cultural differences, such as schooling, which may affect familiarity with numbers, could also contribute in different ways to differences in memory span. It can be concluded that the phonological loop hypothesis alone may not be adequate to account for all differences in memory span across languages.

The first issue addressed in the experiment reported here was based on the fact that Greek digits are on average longer than English digits by one syllable and by one phoneme (see Table 2.1).

<table>
<thead>
<tr>
<th>Greek digits</th>
<th>English digits</th>
</tr>
</thead>
<tbody>
<tr>
<td>e-na</td>
<td>one</td>
</tr>
<tr>
<td>dy-o</td>
<td>two</td>
</tr>
<tr>
<td>tri-a</td>
<td>three</td>
</tr>
<tr>
<td>tes-se-ra</td>
<td>four</td>
</tr>
<tr>
<td>pe-nte</td>
<td>five</td>
</tr>
<tr>
<td>e-kxi</td>
<td>six</td>
</tr>
<tr>
<td>e-pta</td>
<td>seven</td>
</tr>
<tr>
<td>o-cto</td>
<td>eight</td>
</tr>
<tr>
<td>en-ne-a or en-nia</td>
<td>nine</td>
</tr>
</tbody>
</table>

Mean number of phonemes: 3.72  Mean number of phonemes: 2.72
One of the questions addressed was whether differences in the number of syllables in digits between Greek and English are reflected by differences in digit span over development. To date, only one study has contrasted digit span in Greek and English adult speakers. Chincotta and Underwood (1997a) showed that digit span did not differ significantly between the two languages. However, it should be noted that in their study digits were presented visually on a computer screen, and that presentation rates also differed for the two groups, being 1 digit per second for the Greek group and 1 digit per 1.5 second in the English group. Although articulatory suppression had a significant effect on digit span in both groups, indicating that both groups used verbal rehearsal, it is possible that the Greek group also relied on visual coding, perhaps to a greater extent than English speakers.

One of the assumptions of the present experiment is that Greek speakers, speaking a language which, in terms of the working memory model, may impose constraints on their STM span, may opt for memory strategies, such as visual coding, for remembering verbal material. More particularly, the question addressed here was whether Greek children may adopt compensatory strategies to cope with long words in their language. If Greek children do rely on visual memory for longer and to a greater extent than English children, then this should be reflected in the memory spans of the two groups when a visual code is offered.

Therefore, the first question addressed was whether there was a disadvantage in the auditory digit span of Greek children compared with English children: shorter digit spans in the Greek group would be accounted for by the difference in length between English and Greek names of digits. If that was found to be the case, the second question addressed was whether Greek children were able to overcome this disadvantage when a visual code was available.

To explore these questions, auditory and visual digit span was contrasted in the two groups. The age groups chosen for the study were 4-year-olds, 6-year-olds, 8-year-olds, and 10-year-olds, as digit span increases steadily from about 3 items to about 6
items between the ages of 4 and 10 years (Chi, 1977). In addition, the two language groups were contrasted on Corsi blocks span, a task which measures nonverbal serial recall (from Milner, 1971(to be described in the Method section).

The Corsi blocks test has been used extensively in neuropsychological research (see Berch, Krikorian, & Huha, 1998) and in developmental research (e.g. Isaacs & Vargha-Khadem, 1989) and has been considered to be a nonverbal analogue of the digit span task (Milner, 1971). However, such an analogy may be misleading, as it is not clear which processes the Corsi test taps into. Double dissociations between Corsi span and verbal span have been reported in clinical populations (e.g. Hanley, Young & Pearson, 1991; Wang & Bellugi, 1994), in experiments using selective interference tasks (e.g. Smyth & Scholey, 1996), and in children aged from 5 to 8 (Pickering, Gathercole, & Peaker, 1998). Further, Della Sala, Gray, Baddeley, Allamano, and Wilson (1999) demonstrated double dissociations between Corsi span and visual pattern span: they claimed that pattern span is a more 'pure' measure of visual working memory, whereas the Corsi blocks test is a far more complex task that taps into spatial, sequential, and kinaesthetic abilities. Indeed, Groeger, Field and Hammond (1999) showed that adult performance in Corsi blocks was strongly predicted by motor span and measures of central executive function, and not by digit span.

Despite the controversy about the nature of the cognitive processes associated with the Corsi test, this task was used here to explore a further issue. This issue arose from the assumption that the Corsi test, besides involving motor planning processes, is primarily a nonverbal, visuo-spatial task. Mistry (1997) reviewed a number of studies that showed that in non-Western cultures children have developed better spatial memory skills than children in Western environments. Although there can be several explanations for this (see Section 2.3.6) it could be argued that children's memory abilities are flexible and can develop to adapt to a particular cultural context.
Conant, Fastenau, Giordani, Boivin, Opel, and Nseyila (1999) examined the relationships between visual and verbal STM tasks from the Kaufman Assessment Battery for Children (K-ABC) in a sample of 139 Zairian children, aged 6 to 13 years. Factor analysis revealed a dissociation between visual and verbal components, even in the oldest children of the group studied. This pattern contrasted findings from American children (Kaufman, Kaufman, Kamphaus, & Naglieri, 1984) where verbal and visual span tasks load on separate factors until about the age of 8, but become indistinguishable in older children; this shift is probably due to the use of verbal strategies for the visual tasks with increasing age. The authors offer possible explanations for these findings, associated with socio-cultural and schooling factors (to be discussed in Section 2.3.6).

Similarly, it could be argued that the characteristics of native language can also lead to particular patterns in children's STM performance. In particular, if Greek children have learned to rely on alternative, nonverbal codes for remembering information to compensate for possible memory difficulties due to word length, this may be reflected in longer Corsi spans and a prolonged dissociation of Corsi and digit spans compared to English children of the same age.

A note of caution is necessary here. From what is known so far about the nature of the processes involved in the Corsi task, it is not argued that a radical change in the cognitive structures of Greek children should be expected. The Corsi test is most likely to reflect abilities in coordinating information from different sources to remember sequences of items, location, and movements (see Della Salla et al., 1999). It is, therefore, strongly related to the function of the central executive (Groeger et al., 1999), whose operation is assumed to be universal and not dependent on language factors. Instead, the suggestion advanced here is that the superiority of Corsi span versus digit span observed in young children up to around the age of six (e.g. de Agostini, Kremin, Kurt, & Dellatolas, 1996) may be prolonged in Greek children compared to English children. This would not require a radical reorganisation of cognitive systems, but would rather reflect a preference for visuo-spatial processing as opposed to a reluctance to use verbal strategies.
To summarise, the following hypotheses were addressed in the present experiment:

H1/ If the number of syllables in the digit names plays a crucial role in determining digit span, then English children should have longer auditory digit spans compared to Greek children of the same age, and this difference should be significant at all ages.

H2/ If Greek children make use of visual coding for remembering verbal material when a visual code is available, this should be evident as at least equal visual digit spans compared to English children of the same age. However, this pattern may also depend on other factors, such as familiarity with numbers or schooling (see Chincotta & Underwood, 1997b, for effect of dominant language and digit decoding times on digit span).

H3/ Auditory digit span has been reported to be longer than visual digit span in English speakers (Conrad, 1964). In young children, in particular, auditory digit span should be an easier task than visual digit span, as the former does not require switching between different modalities, while the latter requires verbal recoding of the presented digit, either at presentation or during output. If Greek children have developed a general reliance on visual coding, and if their schooling favours acquaintance with numbers, then this should be evident as longer visual digit spans compared to auditory digit spans. This hypothesis, however, remains open-ended as it depends on many factors.

H4/ Greek and English children of the same age should have comparable Corsi spans, as this test is closely related to general cognitive performance rather than verbal skills, and should, therefore, be independent of language (see above).

H5/ If the Corsi blocks test reflects the function of the central executive and is, therefore, only related to maturational and intelligence factors that are independent of language, then English and Greek children should not differ in Corsi spans. If, on
the other hand, Greek children rely on nonverbal cues, such as the spatial elements of the Corsi task, for longer than English children, then they should have longer Corsi spans than digit spans until a later age than English children.

2.2. Method

2.2.1. Participants

In each language group (Greek and English) there were four age groups: 4-year-olds, 6-year-olds, 8-year-olds, and 10-year-olds.

Ninety-six children (24 from each age group) attending nursery or primary schools in Athens were recruited and tested either in school or at home, after parents' and teachers' consent was obtained. There was an equal number of boys and girls in each age group.

The mean ages of each Greek age group were: 4 years 4 months (range: 3 years 10 months to 4 years 10 months, SD=3.35 months); 6 years 4 months (range: 6 years to 6 years 11 months, SD = 3.02 months); 8 years 4 months (range: 8 years to 8 years 9 months, SD = 2.62 months); and 10 years 8 months (range: 10 years to 11 years 8 months, SD = 5.5 months).

Ninety-six English children (initially 24 in each age group) attending nursery or primary school in Surrey, were recruited and tested in school. Four children did not complete the testing as two 10-year-olds and one 6-year-old were unavailable during the testing sessions. One 6-year-old was also excluded from the study owing to very low performance, mostly through failing to follow the test instructions. This left a final sample of 92 children.

The mean ages of each English age group were: 4 years 4 months (range 3 years 10 months to 4 years 11 months, SD=5.59 months); 6 years 4 months (range 5 years 8
months to 6 years 6 months; SD=2.84 months); 8 years 2 months (range 7 years 8 months to 8 years 8 months, SD=3.10 months); and 10 years 1 month (range 9 years 8 months to 10 years 7 months, SD=3.41 months).

2.2.2. Matching

The two language groups were matched on chronological age, nonverbal ability, and vocabulary comprehension. To assess nonverbal general ability, the Raven's Coloured Progressive Matrices test (Raven, 1963) was administered. To assess receptive vocabulary, the short form of the British Picture Vocabulary Scale (BPVS; Dunn, Dunn, Whetton, & Pintilie, 1982) was administered to English children. As no comparable standardised test was available for assessing Greek receptive vocabulary, the BPVS was translated and modified for use with the Greek children. The modifications were necessary, because some of the picture items were inappropriate for Greek children either because they were likely to be unfamiliar to them or because, in translation, the name of a picture differed in difficulty and thus age of acquisition from its English equivalent. A full description of the changes made can be seen in Appendix A.

2.2.3. Measures and procedure

Each child was tested individually in a quiet room. The number of sessions varied for each child depending on levels of concentration and motivation. For older children, tests were often completed in one sitting whereas many of the younger children required up to four visits.

*Auditory digit span.*

Digit span was measured using a subtest of the British Ability Scales (BAS; Elliot, Murray, and Pearson, 1978). The researcher spoke the list of digits at a rate of one item per second, and the children were asked to repeat the items in the same order. Practice trials of two digits were given to make sure the children understood the task.
The number of digits to be memorised started at the list length specified in the test manual depending on the child's age, and increased across trials until the child failed all trials at a given length. There were five trials for every list length.

Scoring was carried out according to the instructions provided in the manual for the BAS. The raw score was the number of lists recalled in the same order. In addition to the test score, a span was recorded for each child, defined as the longest sequence recalled in correct order in three out of five trials at a given list length.

**Visual digit span.**

In the visual task, cards that reproduced the same sequences of digits that had been used in the auditory task were presented at a rate of one per second. Children from the two youngest age groups were asked to identify the numbers before testing. Two practice trials were provided to ensure that the children understood the task. Responses were scored, and a visual digit span calculated, following the procedure used for the auditory digit span task. The order of presentation of the two digit span tasks was counterbalanced.

**Corsi Blocks Test**

(as described in Isaacs and Vargha-Khadem, 1989). The apparatus used for this test consisted of a wooden board on which were fixed nine wooden 1.25 inch cubes, arranged irregularly. On the researcher's side, the cubes were numbered, so that they could be identified easily. The researcher tapped a sequence of blocks at a rate of one block per second. Starting with a sequence of two blocks, the child had to point, in the correct order, at the locations tapped by the researcher. Practice trials of two blocks were given to ensure the children understood the task. The procedure and scoring were the same as those used for the digit span tasks.
2.3. Results

2.3.1. Matching the groups

To assess whether the two language groups were equivalent in terms of nonverbal ability and vocabulary knowledge, separate analyses of variance (ANOVA) on the Raven's and BPVS measures were carried out. For each analysis, language and age group were treated as between-subjects factors. The means and standard deviations for the Ravens and BPVS scores can be found in Appendix A (Table A2).

The overall effect of native language on nonverbal ability was not significant, indicating that the two groups were overall matched on the Raven's test. However, the interaction between native language and age group was significant (F(3,180)=3.39, p=0.01). Separate analyses within each age group showed that this interaction was due to a significant difference in Raven's scores between the two 10-year-old groups (F(1,45)=5.41, p=0.025). The other age groups did not differ significantly in nonverbal ability.

The most plausible explanation for this difference between the oldest age groups is that the Greek children were significantly older than the English children (on average, older by 7 months). In age equivalent terms, this was a difference of 6 months at the 50th percentile (1982 standardisation of the Raven's test). This difference was no longer significant when the analysis was carried out again with age as a covariate. In subsequent analyses within the separate age groups, age was, therefore, used as a covariate.

Another ANOVA was carried out to assess whether the two language groups differed in vocabulary comprehension. Again, although the main effect of native language was not significant, there was a significant interaction between native language and age group (F(3,180)=5.03, p=0.002). Separate analyses within each age group showed that in this case, the age groups that differed significantly in their BPVS
scores were the 4-year-olds (F(1,46)=4.49, p=0.04) and the 10-year-olds (F(1,45)=5.80, p=0.02). When age was used as a covariate, this difference was abolished in the 10-year-old group, but not in the 4-year-old group. It was decided that this anomaly in the youngest age group could be ignored, as the difference was small and not significant in age equivalent terms in the 4-year-old group. Indeed, using the BPVS scores as a covariate in subsequent analyses did not alter the patterns of the results.

2.3.2. Comparing the two language groups on the tasks

To test the hypotheses stated in the introduction, two separate main analyses were carried out. This was necessary because only seven children in the 4-year-old group were able to identify all the printed digits correctly, and therefore mean visual digit spans were not calculated for this age group. Thus, the first analysis compared auditory digit span and Corsi span across all four age groups, while the second analysis compared all three span tasks across the three age groups who had completed all of them.\(^2\!\!^1\).

Figure 2.1 (graphs 2.1a and 2.1b) shows the overall mean memory spans for auditory digit span and Corsi span when all four age groups were used in the analysis (graph 2.1a) and for auditory digit span, visual digit span, and Corsi span when only the three oldest age groups were used in the analysis (graph 2.1b). More details about the means and standard deviations of the span measures are shown in Table 2.2.

\(^2\!\!^1\). The results reported were obtained using the span measures in the analysis. Analysis using the raw scores was also carried out; as it led to the same pattern of results, it is not reported here.
2.1a. Overall effects of task in the two language groups (all age groups).

2.1b. Overall effects of task in the two language groups (3 oldest age groups).

Figure 2.1. Overall effects of task in the two language groups (Greek and English).

Error bars represent the standard error of the mean.
Table 2.2. Mean memory spans for Greek and English children (standard deviations in parentheses).

<table>
<thead>
<tr>
<th>Group</th>
<th>Memory task</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Auditory digit span</td>
</tr>
<tr>
<td>Greek age 4</td>
<td>2.96 (0.62)</td>
</tr>
<tr>
<td>English age 4</td>
<td>3.25 (0.61)</td>
</tr>
<tr>
<td>Greek age 6</td>
<td>3.46 (0.72)</td>
</tr>
<tr>
<td>English age 6</td>
<td>4.23 (0.62)</td>
</tr>
<tr>
<td>Greek age 8</td>
<td>4.79 (0.78)</td>
</tr>
<tr>
<td>English age 8</td>
<td>5.29 (0.55)</td>
</tr>
<tr>
<td>Greek age 10</td>
<td>5.29 (0.86)</td>
</tr>
<tr>
<td>English age 10</td>
<td>5.96 (0.71)</td>
</tr>
<tr>
<td>Greek overall</td>
<td>4.12 (1.21)</td>
</tr>
<tr>
<td>English overall</td>
<td>4.68 (1.21)</td>
</tr>
</tbody>
</table>
As can be seen, on the whole English children had longer memory spans for spoken digits compared to Greek children, but shorter memory spans for visual digits and Corsi blocks. These differences were supported by a main effect of native language on auditory digit span (F(1,180)=30.67, p<0.001), which indicated that English children had longer auditory digit spans than Greek children at all ages, since the interaction between native language and age group was not significant. Conversely, Greek children had, on the whole, longer visual digit spans (F(1,134)=29.29, p<0.001) and Corsi spans (1,180)=42.33, p<0.001) than English children, but these differences did interact with age (F(2,134)=5.10, p=0.007 for visual digit span; F(3,180)=6.86, p<0.001 for Corsi blocks).

These interactions were further explored within each age group separately, using age as a covariate in the 10-year-old group. As Figure 2.2 (graphs 2.2a to 2.2d) shows, the two language groups differed significantly in visual digit span from age 8 onwards, with Greek children having the longer spans. At age 6, however, the two groups had similar visual digit spans. This pattern was supported by a significant effect of native language at age 8 (F(1,46)=36.70, p<0.001) and age 10 (F(1,44)=5.28, p=0.026).

Figure 2.2 also shows that Corsi spans were higher in the Greek group at ages 4, 8, and 10, but not at age 6. Indeed, when the same age groups across the two language groups were compared, Corsi blocks were significantly longer at age 4 (F(1,46)=5.08, p<0.001), age 8 (F(1,46)=59.48, p<0.001) and age 10 (F(1,44)=17.37, p<0.001), but not at age 6.

2.3.3. Contrasting auditory digit span and Corsi span

Figure 2.1 contrasts auditory digit span and Corsi span across all age groups in the Greek and the English sample. A clear double dissociation can be seen, with digit span being longer than Corsi span in the English group, and the opposite pattern for the Greek group. This pattern was also evident as an overall effect of task when the
Figure 2.2. Effects of task in each age group (Greek and English).

Error bars represent the standard error of the mean.
two tasks were contrasted in the two language groups \((F(1,180)=7.79, p=0.006)\). It was also evident as a significant interaction between task and language \((F(1,180)=88.23, p<0.001)\); a significant interaction between task and age group \((F(3,180)=15.03, p<0.001)\), and a significant three-way interaction between task, age group, and language \((F(3,180)=4.11, p=0.008)\). These interactions show not only that the difference between the two span measures had a different direction within each language group, but also that it varied with age in different ways in each language group. In other words, the difference between Corsi and auditory digit span followed different developmental pathways within each language group.

Indeed, Figure 2.2 (graphs 2.2a to 2.2d) shows that, while Corsi spans seem to be longer than digit spans in the two youngest Greek age groups, Corsi span is equal to digit span at ages 8 and 10. In contrast, the two youngest English groups seem to have similar Corsi and digit spans, but from age 8 onwards they have longer digit spans. This pattern was supported by t-tests contrasting auditory digit span with Corsi span within each age group and language group separately. In the Greek group, Corsi was, indeed, significantly longer than digit span at age 4 \((t(23)=3.98, p=0.001)\) and age 6 \((t(23)=4.00, p=0.001)\), but the difference was not significant from age 8 onwards. In the English group, however, the t-tests were not significant at age 4 and 6, but digit span was significantly longer than Corsi span at age 8 \((t(23)=9.70, p<0.001)\) and age 10 \((t(22)=7.00, p<0.001)\).

### 2.3.4. Contrasting auditory and visual digit span

Graph 2.1b also shows different overall patterns of auditory and visual digit span between the two language groups, in the three oldest age groups. In the Greek group, auditory and visual digit span did not differ on the whole; however, in the English group, spoken words were better remembered than printed digits. Indeed, the overall mixed ANOVA for the three oldest age groups revealed a significant interaction between task and native language \((F(2,268)=54.97, p<0.001)\). Planned comparisons showed that this interaction could be partly attributed to a difference
between auditory and visual digit span that was dependent on the language group \(F(1,134)=81.53, p<0.001\). Moreover, there was a significant interaction between task and age group \(F(4,268)=8.00, p<0.001\) which, again, could be partly attributed to an interaction between age group and the auditory-visual digit span difference \(F(1,134)=4.74, p=0.01\). The three-way interaction between task, native language, and age group was not significant.

These significant interactions were further explored. As Figure 2.2 shows, Greek 6-year-olds and 8-year-olds showed a tendency to have longer visual digit spans than auditory digit spans, while this effect was reversed to a trend for an auditory advantage at age 10. However, t-tests showed that none of these trends was significant; Greek children, therefore, remembered spoken digits and printed digits equally well at all ages. In contrast, English children showed a clear spoken digit advantage at all ages, as also supported by t-tests (6-year-olds: \(t(20)=4.25, p<0.001\); 8-year-olds: \(t(23)=8.31, p<0.001\); 10-year-olds: \(t(22)=8.90, p<0.001\)).

### 2.3.5. Summary of findings of Experiment One

The results of Experiment One are summarised below:

1. Auditory digit span was longer in the English group compared to the Greek group. This difference was significant in all age groups.

2. Greek and English children had similar visual digit spans at age 6. From age 8 onwards, however, Greek children had larger visual digit spans than English children.

3. Greek children had significantly longer Corsi spans than English children at ages 4, 8, and 10, but not at age 6.
4. The English and the Greek group showed very different patterns of results when Corsi span and digit span were contrasted. In English children, Corsi and digit span did not differ significantly at age 4 and 6. From age 8 onwards, digit span was longer than Corsi span. In contrast, Greek 4-year-olds and 6-year-olds had longer Corsi spans than digit spans. From age 8 onwards, Corsi blocks and spoken digits were equally well recalled.

5. When auditory digit span was contrasted with visual digit span, English children showed a modality effect for spoken digits over visually presented digits. This effect was evident from age 4, and remained stable until age 10. Greek children, on the other hand, did not show a modality effect. Their auditory and visual digit spans did not differ significantly, and this pattern remained stable at all ages.

2.3.6. Discussion of Experiment One

The findings of the experiment reported here support most of the hypotheses stated in the introduction. First, it seems that differences in the number of syllables between Greek and English digit names did produce a difference in digit span between the two language groups. This finding agrees with the cross-language and bilingual studies reported above, and supports hypothesis H1.

It should be noted that most experiments contrasting digit spans in different languages have found a relationship between articulation rate and digit span. It could be argued that phoneme spoken duration, rather than number of syllables, is a more robust predictor of memory span. However, it was also established that the digits in the two languages differed in the number of phonemes as well as the number of syllables. Therefore, although articulation rates were not recorded in this study, it seems that the difference in digit name length in terms of syllable number is the most straightforward explanation for the difference in digit span between the two languages.
Hypothesis H2 also predicted that, if Greek children made efficient use of visual coding, this should help them overcome differences in item length. Indeed, it was shown that Greek 6-year-olds had comparable digit spans to English children. Perhaps more surprisingly, at ages 8 and 10 they actually outperformed the English children in visual digit span. Could this difference reflect a visual strength in the Greek group, and if so, is this advantage inherent or learnt? It seems unlikely that Greek children would consciously opt to rely on visual coding for remembering digits. Greek digits may be longer than English digits, but they are still considered as relatively short words in the Greek language. It is possible, however, that Greek children generally tend to use visual coding when a visual code is available, either because they are generally reluctant to use verbal strategies, or because they have learned to do so in school. It could be, for example, that teaching of numbers and arithmetic is heavily based on visual strategies in Greek education, and that the performance of Greek children in digit span reflects the effect of education. If Greek children are better acquainted with recoding numbers compared to English children, this should offer them an advantage, especially after age 6 (year 1) when they will have mastered number decoding further. Research on educational programmes and practices in Greek schools seems necessary for answering this question more adequately.

This line of reasoning should also explain the lack of a modality effect in the Greek group when auditory and visual digit span were contrasted. Apparently Greek children relied on visual information, while the spoken digit advantage in the English group reflected their ability to use verbal strategies from an early age (see hypothesis H3). The present study did not provide evidence as to whether English children actually rehearsed the digits. It is unlikely that children used subvocal rehearsal before the age of 7 (e.g. see Gathercole, 1998), although, as Gathercole and Adams (1994) reported, rehearsal for spoken digits develops earlier than rehearsal for spoken nouns.
Finally, the findings from the Corsi spans are far more difficult to explain. In the introduction, the Corsi test was considered partly related to general processing resources that must operate independently of language, and partly to memory for spatial location, movements, and sequential memory. It is, therefore, unclear why Greek children should have longer Corsi spans compared to English children of the same age. It is even more unclear why this difference should be significant in all age groups, but not at age 6. Setting aside this anomaly in the pattern, it could be argued that English children may attempt to use verbal strategies for remembering the Corsi blocks, which, in turn, could negatively affect their performance. Although the children's strategies were not explored in this experiment, this possibility seems very unlikely. Even if children as young as 4 years were likely to engage in a verbal strategy for remembering the blocks, the relatively fast presentation rates should not encourage verbal labelling of the block positions. Another, more general explanation, could be that Greek and English children used different strategies during the Corsi task. It would be interesting to address this issue in future research.

Kail (1997) conducted a series of path analyses to build a model that linked various measures of memory span to more general abilities, such as articulation rate and speed of cognitive processing in children and adolescents aged from 8 to 20 years. He found that performance on spatial span tasks (Corsi blocks and pattern span) were strongly predicted by general factors such as age and processing skill, thus supporting the findings of Groeger et al. (1999). He also found that spatial span strongly predicted imagery skill. A quite speculative explanation suggested here is that Greek children may have developed visual imagery abilities (either as a spontaneous result of their language characteristics, or as a result of education, or both) that could account, in part, for their relatively high performance on the Corsi test. This possibility seems worth addressing in future research.

Finally, the patterns of relative Corsi and digit span development seem more straightforward. First, they seem to provide additional evidence supporting the idea that spatial span and verbal span involve separate mechanisms in memory and can,
therefore, be dissociated. A double dissociation, possibly due to linguistic
differences, was evident here. Second, hypothesis H5 regarding a difference in the
chronology of a developmental shift from longer Corsi spans to longer digit spans
also seems to be supported. It also seems that such a shift takes place gradually, with
Corsi blocks being better remembered than spoken digits at earlier ages, followed by
a stage when both are equally well remembered, possibly followed by spoken digits
being better remembered than Corsi blocks. Part of this pattern was shown in both
language groups, with Greek children starting from the first stage at age 4 and
reaching the intermediate stage at age 8; English children starting from the
intermediate stage at age 4 and reaching the spoken digit advantage at age 8. It is
tempting, therefore, to assume that Greek children follow the same developmental
route in Corsi and digit span development, with the only difference being in the
chronology of the transitions observed. This pattern also seems to agree with the
pathway proposed by Palmer (2000) where visual coding is followed by dual coding
which is, in turn, followed by verbal coding over development.

It is still unclear why a nonverbal memory task, tapping sequential memory, memory
for location, and memory for movements, should be easier than a digit span task and
why, if the two tasks are independent, there appears to exist a trade-off between the
two over development. One explanation is that the Corsi task requires imitation of
movements and memory for location, which can be thought as intrinsic processes.
Digit span, on the other hand, requires established long-term representations of
numbers, and is, from this point of view, a more elaborate task. It seems plausible
that the pattern suggested by Palmer (2000) mentioned above can be generalised to a
gradual shift from reliance on nonverbal skills to use of verbal skills. Obviously,
contrastting verbal tests with other, perhaps simpler, visual tasks, would help to
elucidate such developmental patterns.

The starting hypotheses of the present experiment predicted that the patterns
observed above might be attributed to language differences between the two groups,
namely differences in word length. However, it is unclear whether, and how,
language differences may lead to differences in modality effects in children of the same age that speak different languages. Could these language differences directly affect the spontaneous use of STM strategies in children? This would mean that native language affects the maturational processes related to STM strategy use, and therefore directly affects STM performance. Clearly, this suggestion requires further consideration.

There are, however, other explanations for this pattern. As mentioned above, Conant et al. (1999) found a prolonged dissociation between visual and verbal skills in Zairian children aged 6 to 13 years. The children they studied lived in a poor community and received poor reading and writing tuition in school. Conant et al. did not include a Western comparison group in their study, but commented on the difference between the pattern they observed in the Zairian sample and the findings from studies with American children. They suggested that this difference is very likely to be due to differences in reading and writing proficiency between American and Zairian children, and that these differences, in turn, may lead to differences in the use of verbal strategies in visual tasks. They also noted that the performance of Zairian children was not likely to be explained by more general factors, like malnutrition, that may affect brain maturation: they referred to some evidence from children in Laos, whose schooling and STM performance are similar to those of American children, even if their living conditions are comparable to Zairian children’s (Conant, Fastenau, Giordani, Boivin, Chounramany, Xaisida, Choulamountry, Pholsena, & Olness, 1997).

The suggestion of Conant et al. (1999) that reading instruction may affect the patterns of modality effects in STM tasks seems very plausible. As mentioned above, factor analytic studies with American children show that the shift from separate visual and verbal components to an equal loading of visual tasks on verbal and visual factors occurs at around the age of 7 to 8 years (Kaufman et al., 1984; also see Fastenau, Conant, & Lauer, 1998). This age coincides with the age when verbal recoding and rehearsal start to develop (e.g. Halliday et al., 1990; Hitch, Halliday,
Dodd, & Littler, 1989; Hitch et al., 1991). It also coincides with the period when acquisition of advanced reading skills and reading automaticity occur: for example, Ellis & Large (1988) in a longitudinal study with children aged from 5 to 7 years, demonstrated a transition from reliance of early reading ability on visual skills to more reliance on verbal skills. In another longitudinal study within the same age range, Ellis (1990) further supported this developmental shift, showing that reading acquisition further promotes both verbal and visual STM ability (see also Gathercole & Baddeley, 1993).

It seems, therefore, important that the development of reading and writing in Greek children be studied and compared to the literacy development of English children. There is evidence to suggest that the structural differences between the two languages lead to differences in reading processes, as shown in a cross-linguistic comparison of Greek and English adolescents (Chitiri & Willows, 1994), but further studies are needed to explore the relationships between language, education, and literacy from a cross-linguistic perspective.

Finally, further evidence is needed about modality differences between Greek and English children over the course of STM development. The next Chapter presents two more experiments that examine word spans in these two language groups.
Chapter Three

Development of encoding and rehearsal strategies
in Greek and English speakers

3.1. Introduction

As reviewed in Chapter One, the phonological similarity effect and the word length effect have been used to elucidate STM functions both in adults and in children. Both effects are established indicators of phonological recoding and rehearsal (Baddeley, 1966; Conrad & Hull, 1964; Hulme & Mackenzie, 1992), although the word length effect could also be due to output effects (Henry, 1991) or to some sort of verbal strategy not fully developed (Gathercole & Hitch, 1993). Similarly, the visual similarity effect is considered to reflect preference for visual coding (e.g. see Logie, 1995).

These effects can be informative about the emergence of STM strategies over the course of development. However, as discussed in Chapter One, detecting these effects in young children depends on the particular procedure used and task demands, such as presentation modality, response mode, and whether overt naming of presented stimuli takes place. In general, studies on the phonological similarity effect suggest that younger children tend to show a preference for visual coding compared to older children (Conrad, 1971; Hitch & Halliday, 1983; Hulme, 1984; Palmer, 2000), a pattern also supported by studies of the visual similarity effect (Hitch, Halliday, Schaaflstal & Schraagen, 1988; Hitch, Woodin & Baker, 1989). Similarly, findings on the word length effect suggest that older children are more likely to use verbal rehearsal than younger children (e.g. Hitch & Halliday, 1983; Hulme et al., 1986).
There seems, therefore, to be a developmental pattern suggesting a shift from visually based to phonologically based strategies for recall. However, even though this pattern is well documented, one can question the extent to which it varies across different populations. The findings on digit span and Corsi span presented in Chapter Two provided evidence that native language may influence the choice of memory strategies over the course of development. It was suggested that Greek children, having a language with on average longer words than English, would tend to use visual memory strategies more effectively and for a longer time compared to English children. A cross-linguistic study investigating the effects of phonological similarity, visual similarity, and word length would help to further elucidate these differences in strategy use.

Thus, the starting point of these experiments was that Greek nouns, including those that form part of the vocabulary of a 4-year-old child, are on average longer than English nouns in terms of the number of syllables and phonemes. To support this assertion, English words chosen at random from norms for age of acquisition, as well as from storybooks, were compared to their Greek equivalents on number of syllables. It was shown that Greek words are on average longer in terms of number of syllables and phonemes compared to English words. This comparison is reported in Appendix B.

Two experiments are reported in this chapter. Experiment Two investigates the effects of phonological and visual similarity on recall of spoken words and pictures in Greek and English children. The main question addressed is whether differences in word length and complexity are related to differences in the size of word spans, as well as in the timing of the above effects. Likewise, Experiment Three investigates the development of the word length effect in Greek and English children, again based on the assumption that linguistic differences would be reflected in differences in the onset of verbal rehearsal. The specific hypotheses related to each experiment are presented in the respective introduction sections.
3.2. Experiment Two: the development of phonological and visual similarity effects in Greek and English children

3.2.1. Introduction

As mentioned above, the aim of this experiment was to further elucidate the effect of language differences on the development of encoding strategies. Starting from the evidence that Greek nouns are on average longer than English nouns, memory spans for spoken words and pictures were compared in the two language groups; and phonological and visual similarity of the stimuli were also manipulated to detect possible differences in the emergence of these effects.

However, as opposed to digit span, where the items are equivalent in meaning in both languages, comparing word spans in different languages can present difficulties. Whereas in studies of digit span the only variable manipulated is digit length, in word spans other factors such as semantics, word frequency, word concreteness and imageability, may influence recall and possibly account for some of the differences between the two populations. In the present study, an attempt was made to keep such confounding factors to a minimum: stimuli were chosen from the same item pool for both language groups where possible, and norms and picture books were used as guides to match for word frequency (see also Method section). However, some caution is still needed when interpreting the results of word span experiments.

In Experiment Two, the following specific hypotheses about the memory performances of the two language groups were formulated.

H1/ English children would be expected to have longer spoken word spans for the control words compared to Greek children, as the set of stimuli used in the Greek group were longer by one syllable. Although the effects of word length on recall are further explored in Experiment Three, superior word spans for the control words in
the English group would also provide some evidence about the role of word length in recall.

H2/ Assuming that a gradual transition from visual coding to verbal recoding occurs over the course of development (e.g. Palmer, 2000) and that this transition should develop later in the Greek group than in the English group, the following can be predicted:

At a younger age, both Greek and English children would rely on visual memory for remembering the pictures. In this case, word length should be irrelevant (except for its possible effect during verbal output). As both groups would be reluctant to use verbal memory for remembering pictures, Greek children should have at least equal picture spans to English children’s.

At the age when English children would begin to use verbal strategies for remembering pictures (possibly after age 7; e.g. see Cowan & Kail, 1996; Gathercole & Hitch, 1993) they should have an advantage over Greek children of the same age, who should not yet have developed this ability. Therefore, English children should have superior picture spans from age 7 onwards. At the age when Greek children would begin to use verbal strategies for remembering pictures, both language groups would be expected to benefit from the additional verbal code. However, given the difference in word length in this experiment, English children should still have superior picture spans.

H3/ The effects of presentation modality on recall in the two language groups are more difficult to predict. The relevant studies to date also provide conflicting evidence (see Chapter One). On one hand, recall of spoken words should be superior to picture recall, as verbal recall of spoken words does not require recoding to another modality, and is, therefore, more effortless. On the other hand, pictorial presentation offers the advantage of an additional code, at least at the age when
children can use both verbal and visual coding. For these reasons, modality effects are approached here as a more open-ended issue.

However, a general prediction that can be made about the relative performance of the two language groups is that the patterns of change in the modality effects observed in the two language groups should differ, at least chronologically. In other words, if English children develop their verbal memory skills at an earlier age compared to Greek children, then any effect of modality observed in the English group should occur later in the Greek group. Alternatively, the two language groups could exhibit entirely different effects of modality, depending on their particular strengths; in general terms, English children should benefit from verbal information more, or earlier than, Greek children.

H4/ The phonological similarity effect on recall of spoken words should emerge at the same age in both language groups.

H5/ For recall of pictures, Greek children would be likely to be sensitive to phonological similarity at an older age than English children, as the latter should be able to opt for phonological recoding of pictures at a younger age.

H6/ Finally, more direct evidence for visual encoding in Greek children would be provided through the visual similarity effect: it should persist to an older age in Greek children, than in English children.

All the above hypotheses are based on the assumption that word length and complexity may affect, to some extent, the choice of memory strategies over development. A more general question to be explored refers to the degree to which memory performance may differ across different languages. The bulk of research on working memory development suggests that memory span is determined by fixed, universal factors that depend on brain maturation and intelligence: processing speed, speech rate, and the capacity of the phonological loop can account for developmental
patterns of memory as well as for individual differences in memory performance. However, as discussed in Chapter One, studies of children's strategies as well as cross cultural research suggest that there are some degrees of freedom in how memory processes develop: factors such as schooling, task context, and environmental demands can affect, at least to some extent, the emergence of particular performance patterns. The present experiments would hopefully indicate if language poses such environmental demands and, if so, to what extent it affects memory development.

3.2.2. Method

3.2.2.1. Participants

The same children who took part in Experiment One also participated in Experiment Two. Studying age groups between 4 and 10 years, with a two-year difference between the age groups, should reveal evident changes in the development of encoding strategies and word length effects.

3.2.2.2. Stimuli

Two variables were manipulated: phonological similarity and visual similarity of words and pictures. Words were selected from three sample sets, with seven stimuli in each set: (1) phonologically similar set (2) visually similar set—drawings of elongated objects that are pictorially similar and have the same orientation along their long axis and (3) a control set. As this set contained phonologically dissimilar words whose shapes/orientations also were dissimilar, it served as a control for both auditory and visual conditions.

In the Greek group, the words included in each set were selected from children's books to ensure that even the youngest children were familiar with them. All the words had two syllables, as this is practically the shortest length of most Greek
concrete nouns. The Greek words and their English translations are given in Table 3.1. For the visual condition, 10 x 15 cm cards with black and white line drawings representing the words were used. These visual stimuli can be seen in Appendix C.

Table 3.1. Greek stimuli used for the phonological and visual similarity study, and their English translations.

<table>
<thead>
<tr>
<th>Phonologically similar</th>
<th>Visually similar</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>balla</td>
<td>ball</td>
<td>sfyri</td>
</tr>
<tr>
<td></td>
<td></td>
<td>hammer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>skyllos</td>
</tr>
<tr>
<td></td>
<td></td>
<td>dog</td>
</tr>
<tr>
<td>gala</td>
<td>milk</td>
<td>ftyari</td>
</tr>
<tr>
<td></td>
<td></td>
<td>spade</td>
</tr>
<tr>
<td></td>
<td></td>
<td>spiti</td>
</tr>
<tr>
<td></td>
<td></td>
<td>house</td>
</tr>
<tr>
<td>skala</td>
<td>ladder, stairs</td>
<td>chtena</td>
</tr>
<tr>
<td></td>
<td></td>
<td>comb</td>
</tr>
<tr>
<td></td>
<td></td>
<td>koukla</td>
</tr>
<tr>
<td></td>
<td></td>
<td>doll</td>
</tr>
<tr>
<td>tsanta OR saka</td>
<td>bag or satchel</td>
<td>skoupa</td>
</tr>
<tr>
<td>(N.B. Either word was acceptable; both are phonologically confusable)</td>
<td></td>
<td>broom</td>
</tr>
<tr>
<td></td>
<td></td>
<td>dentro</td>
</tr>
<tr>
<td></td>
<td></td>
<td>tree</td>
</tr>
<tr>
<td>kaltsa</td>
<td>sock</td>
<td>kleidi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>key</td>
</tr>
<tr>
<td></td>
<td></td>
<td>psomi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>bread</td>
</tr>
<tr>
<td>gata</td>
<td>cat</td>
<td>stylo</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pen</td>
</tr>
<tr>
<td></td>
<td></td>
<td>vrysi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>tap</td>
</tr>
<tr>
<td>lambda</td>
<td>lamp</td>
<td>pipa</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pipe</td>
</tr>
<tr>
<td></td>
<td></td>
<td>heri</td>
</tr>
<tr>
<td></td>
<td></td>
<td>hand</td>
</tr>
</tbody>
</table>

For the selection of the control stimuli used in the English group, both children's books and vocabulary norms for age of acquisition (Morrison, Chappell, & Ellis, 1997) were consulted, to ensure that the words were familiar even to the youngest age group. The word sets were also matched for rated imageability, frequency and familiarity. The phonologically similar set was the same as the one used by Conrad (1971); the visually similar set was the same as the one used in the Hitch, Woodin, & Baker (1989) study. The items were one-syllable words, and their equivalent black-and-white line drawings, again displayed on 10 x 15 cm cards. Where possible,
words selected for the Greek group were also selected for the English group, even if they were included in a different stimulus set. The words used in the English group are shown in Table 3.2, and the respective line drawings can be found in Appendix C.

Table 3.2. English stimuli used for the phonological and visual similarity study (from Conrad, 1971; Hitch, Woodin, & Baker, 1989, respectively).

<table>
<thead>
<tr>
<th>Phonologically similar</th>
<th>Visually similar</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>rat</td>
<td>key</td>
<td>shirt</td>
</tr>
<tr>
<td>bat</td>
<td>spade</td>
<td>door</td>
</tr>
<tr>
<td>cat</td>
<td>hammer</td>
<td>milk</td>
</tr>
<tr>
<td>bag</td>
<td>fork</td>
<td>car</td>
</tr>
<tr>
<td>man</td>
<td>broom (or brush)</td>
<td>pig</td>
</tr>
<tr>
<td>hat</td>
<td>pen</td>
<td>chair</td>
</tr>
<tr>
<td>tap</td>
<td>nail</td>
<td>clock</td>
</tr>
</tbody>
</table>

3.2.2.3. Design and procedure

Each child was tested individually in a quiet room. All the cards were first shown to the child to make sure that they could name all the objects correctly. If a child could not name some of the pictures or named them wrongly, the researcher said the correct name and the procedure was repeated until the child named all the pictures correctly. To ensure the children understood the demands of the task, training trials were given for both presentation conditions, using two training words.

A span measure procedure was used, as it would allow direct comparison of the memory performance of different age groups, as opposed to a fixed length procedure which would require presenting the different age groups with different list lengths (see Hitch, Woodin, & Baker, 1989). The experimental conditions started with a sequence of three for the youngest age group, four for the two middle groups, and five for the oldest group. If a child failed in two out of three trials at the lowest list length, the researcher went backwards and administered a shorter list, until a basal
span measure was achieved. Half the children received the auditory condition first, and half the visual condition first. The order of sets (phonologically similar, visually similar, control) was randomised.

In the auditory presentation condition, the researcher spoke a sequence of words randomly selected without replacement from each list, at a rate of one word per second. Three trials were offered in each list length. The child had to repeat back the list in the correct order. Testing was discontinued after a child failed two trials out of three at a given list length. A span measure was established as the list length for which the child was successful on at least two trials.

The same procedure was applied for the visual condition, except that the stimuli were pictures. The cards were presented to the child one at a time, and each card was turned over before the next picture was presented. When all the pictures in the list were presented and turned over, the child had to repeat back their names. Upon presentation, the pictures were not named by the researcher, but the children were free to name them if they wanted. A span measure was established as in the auditory presentation condition.

3.2.3. Results

Table 3.3 shows descriptive statistics of the word spans for each language group and age group separately. To explore the differences in memory performance between the two language groups, an overall mixed 2x2 ANOVA was carried out with presentation modality (spoken words versus pictures) and phonological and visual similarity as within subjects factors and age group and language group as the between subjects factors. This was followed by separate ANOVAS and planned comparisons to explore simple effects of modality and stimulus similarity. Only the results relevant to the specific research questions are reported here.
Table 3.3. Mean word spans for the phonological/visual similarity experiment in Greek and English children (standard deviations in parentheses).

<table>
<thead>
<tr>
<th>Group</th>
<th>Condition</th>
<th>Phonological similarity</th>
<th>Visual similarity</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Spoken words</td>
<td>Pictures</td>
<td>Spoken words</td>
</tr>
<tr>
<td>Greek age 4</td>
<td></td>
<td>2.25</td>
<td>(0.44)</td>
<td>2.71</td>
</tr>
<tr>
<td>Greek age 6</td>
<td></td>
<td>2.62</td>
<td>(0.50)</td>
<td>3.25</td>
</tr>
<tr>
<td>Greek age 8</td>
<td></td>
<td>2.83</td>
<td>(0.56)</td>
<td>3.88</td>
</tr>
<tr>
<td>Greek overall</td>
<td></td>
<td>2.66</td>
<td>(0.54)</td>
<td>3.59</td>
</tr>
<tr>
<td>English age 4</td>
<td></td>
<td>2.46</td>
<td>(0.64)</td>
<td>3.52</td>
</tr>
<tr>
<td>English age 6</td>
<td></td>
<td>2.96</td>
<td>(0.62)</td>
<td>3.52</td>
</tr>
<tr>
<td>English age 8</td>
<td></td>
<td>3.21</td>
<td>(0.61)</td>
<td>4.12</td>
</tr>
<tr>
<td>English age 10</td>
<td></td>
<td>3.65</td>
<td>(0.71)</td>
<td>4.78</td>
</tr>
<tr>
<td>English overall</td>
<td></td>
<td>3.02</td>
<td>(0.74)</td>
<td>3.85</td>
</tr>
<tr>
<td>English age 10</td>
<td></td>
<td>3.65</td>
<td>(0.71)</td>
<td>4.14</td>
</tr>
<tr>
<td>Greek age 10</td>
<td></td>
<td>2.92</td>
<td>(0.41)</td>
<td>4.29</td>
</tr>
<tr>
<td>Greek overall</td>
<td></td>
<td>2.66</td>
<td>(0.54)</td>
<td>3.59</td>
</tr>
<tr>
<td>Greek age 4</td>
<td></td>
<td>2.25</td>
<td>(0.44)</td>
<td>2.71</td>
</tr>
<tr>
<td>English age 4</td>
<td></td>
<td>2.46</td>
<td>(0.64)</td>
<td>2.96</td>
</tr>
<tr>
<td>Greek age 6</td>
<td></td>
<td>2.62</td>
<td>(0.50)</td>
<td>3.25</td>
</tr>
<tr>
<td>Greek age 8</td>
<td></td>
<td>2.83</td>
<td>(0.56)</td>
<td>3.88</td>
</tr>
<tr>
<td>English age 8</td>
<td></td>
<td>3.21</td>
<td>(0.61)</td>
<td>4.12</td>
</tr>
<tr>
<td>Greek age 10</td>
<td></td>
<td>2.92</td>
<td>(0.41)</td>
<td>4.29</td>
</tr>
<tr>
<td>Greek overall</td>
<td></td>
<td>2.66</td>
<td>(0.54)</td>
<td>3.59</td>
</tr>
</tbody>
</table>
3.2.3.1. Testing hypotheses H1 and H2: word span differences between the two language groups

To test hypotheses H1 and H2, the word spans of the two language groups were compared. Figure 3.1 contrasts the overall word spans of the two language groups, for both spoken words and pictures. Only words from the control set were used for this comparison, to directly explore memory spans in both presentation modalities without interference from stimulus similarity effects.

As can be seen in Figure 3.1, English children generally achieved longer spans for both spoken words and pictures compared to Greek children. This difference was supported by a significant main effect of native language on recall when the two language groups were compared on span for the control words (F(1,180)=14.34, p<0.001) and an absence of a significant interaction between presentation modality and native language. As supported by the non-significant three-way interaction between presentation modality, native language, and age group, the direction of this difference remained stable in all age groups, English children having superior spoken word and picture spans at all age levels.

3.2.3.2. Testing hypothesis H3: effects of presentation modality

Examining the effects of presentation modality allowed the exploration of the general prediction made in hypothesis H3, namely that differences in modality effects between the same age groups of different native language should reflect differences in the use of encoding strategies. Of interest here was the effect of presentation modality on the recall of the control words that were both phonologically and visually dissimilar. Figure 3.1 contrasts recall of spoken words versus pictures in the Greek and the English group. As can be seen, Greek children recalled spoken words and pictures equally well. This pattern was supported by the lack of a significant modality effect when recall of spoken and pictorial stimuli were
3.2a. Greek similarity effects

3.2b. English similarity effects

Figure 3.2. Overall phonological and visual similarity effects on recall of spoken words and pictures in the two language groups (Greek and English).

Error bars represent the standard error of the mean.
contrasted, and was stable across age groups, as supported by the absence of a significant interaction between presentation modality and age.

In the English group, however, as Figure 3.1 also shows, spoken words were better recalled than pictures: F(1,88)=7.14, p=0.009. Again, this effect did not interact with age. Therefore, English children showed an advantage for remembering spoken words even at age 4, while the Greek group did not display a significant modality effect at any age level.

3.2.3.3. Testing hypotheses H4 and H5: effects of phonological similarity on recall

Figure 3.2 (graphs 3.2a and 3.2b) contrasts recall of words in all three conditions (phonological similarity, visual similarity, control) and both presentation modalities (spoken words versus pictures) in the two language groups. This analysis explored hypotheses H4 and H5 regarding the emergence of the phonological similarity effect on recall of spoken words and pictures, in both language groups. As can be seen from the distance between the top and bottom lines of the graphs, an overall effect of phonological similarity was apparent for spoken words and pictures in both language groups (F(1,92)=361.14, p<0.001 for the Greek group; F(1,88)=176.50, p<0.001 for the English group).

Of more interest were the interactions between phonological similarity, presentation modality, and age group, within each language group, which are shown in Figure 3.3 (graphs 3.3a to 3.3d). As can be seen in graphs 3.3a and 3.3b, in the Greek group phonological similarity seemed to have an effect on recall of spoken words in all age groups, becoming more pronounced with age. For the recall of pictures, phonological similarity only appeared to become important from age 6 onwards, and again the effect increased with age.
3.1. Comparing the two language groups on spoken words and pictures (control set). Error bars represent the standard error of the mean.
3.3a. Greek similarity effects on spoken word recall

3.3b. Greek similarity effects on picture recall

3.3c. English similarity effects on spoken word recall

3.3d. English similarity effects on picture recall

Figure 3.3. Effects of similarity on spoken word and picture recall for each age group (Greek and English).

Error bars represent the standard error of the mean.
This pattern was supported by planned comparisons conducted in the Greek group, which showed a significant interaction between phonological similarity and presentation modality \((F(1,92)=13.50, p<0.001)\), as well as between phonological similarity and age \((F(3,92)=24.62, p<0.001)\); the three-way interaction between presentation modality, phonological similarity, and age approached but failed to reach significance \((F(3,92)=2.53, p=0.062)\). To further explore this interaction, simple effects of phonological similarity for spoken words and pictures were examined within each age group separately, confirming that, for picture recall, the effect emerges at age 6 in the Greek group \((p<0.001\) from age 6 onwards).

In the English group, the effect of phonological similarity seemed to be significant from age 4 onwards, both for pictures and spoken words (see graphs 3.3c and 3.3d). However, the effect seemed to be larger for spoken words than for pictures, especially in the two youngest age groups. This was confirmed by a significant interaction between phonological similarity and presentation modality \((F(3,88)=21.10, p<0.001)\), and between phonological similarity and age \((F(3,88)=6.49, p=0.0001)\), while the three-way interaction approached significance \((F(3,88)=2.45, p=0.069)\).

3.2.3.4. Testing hypothesis H6: visual similarity effects

Graphs 3.2a and 3.2b also depict the presence of visual similarity effects, as the distance between the right top and the middle lines, in the Greek and the English group respectively. Of interest here was the effect of visual similarity on recall of pictures, which allowed the exploration of hypothesis H6. As seen in the graphs, there seemed to be an overall visual similarity effect on recall of pictures for both language groups. To explore whether this pattern reflected any significant simple effects of visual similarity of pictures, an ANOVA was carried out with age and native language as the between-subjects factors and testing material (dissimilar versus similar pictures) as the within-subjects factor. This revealed a simple effect of visual similarity on picture recall \((F(1,180)=9.93, p=0.002)\), but no interactions
between type of material, age, or language group were significant. This would suggest that both language groups were sensitive to visual similarity of pictures at all age levels. However, as graphs 3.3b and 3.3d show, this effect was no longer detectable in any of the age groups when the analysis was repeated for each age group separately. This would probably indicate that both language groups were sensitive to visual similarity of pictures, but that the effect was too weak to be detected in relatively small samples.

3.2.4. Summary of results of Experiment Two

The findings of Experiment Two are outlined below.

1. On the whole, English children at all ages achieved significantly longer spans than Greek children, both for spoken words and pictures.

2. Greek children recalled spoken words and pictures equally well. This absence of a significant modality effect was evident in all age groups. English children, in contrast, had longer spans for spoken words than for pictures, again at all age levels.

3. A phonological similarity effect on recall of spoken words was apparent from age 4 in both language groups.

4. A phonological similarity effect on picture recall seemed to emerge at age 4 in the English group, and at age 6 in the Greek group.

5. The present experiment revealed a significant overall effect of visual similarity on recall of pictures, even if the effect was not detectable within each age group separately.
3.2.5. Discussion of Experiment Two

The findings related to the language differences in memory span for spoken control words were not unexpected, given the difference in word length between the sets of stimuli used for each language group. Thus, hypothesis H1 was confirmed; these findings also agreed with the results of the digit span experiment.

Also in line with hypothesis H2 was the finding that English children had longer picture spans than Greek children. This difference did not interact with age, but the underlying reasons for the superior spans in the English group might vary at each age level (predictions formulated in hypothesis H2 above). As mentioned above, when a visual code is offered, this should represent an advantage for both language groups according to dual coding theory (Paivio, 1986). On the other hand, as a verbal response was required, the visual presentation task was more difficult as it required recoding of the pictures to the verbal modality. The findings should therefore reflect a trade-off between: (a) differences in word length—which would offer an advantage to English children, (b) more effort required for recoding visually presented material, which would pose a challenge to both language groups, especially at younger ages, and possibly (c) visual coding, which would offer an advantage to both groups, especially at younger ages, but for a longer time in the Greek group. If both groups benefited equally from visual coding, then the word length differences would still favour the English group. This was indeed the case.

Greek children appeared to rely on visual encoding when effects of presentation modality were examined (see hypothesis H3). Even the youngest English children appeared to be better at recalling spoken words than pictures. Even the youngest Greek children, in contrast, did not seem to recode visual information (as shown by a lack of a phonological similarity effect for pictures), and so performed equally well in both pictures and spoken words. This pattern agreed with the general prediction stated in hypothesis H3, namely that English children should benefit from verbal information more, or earlier than, Greek children.
Further evidence about coding strategies in the two groups was provided by the phonological similarity effect. In line with previous research (Hulme, 1984, 1987) this was found to be significant from age 4 in both language groups, for recall of spoken words, thus supporting hypothesis H4. For visually presented material, the findings from English children also agree with Hulme’s study (1987), which also showed a phonological similarity effect at age 4. As discussed in the literature review, this finding does not agree with other studies that place the phonological similarity effect on picture recall at later ages (e.g. Conrad, 1971; Baddeley et al., 1998; Hitch & Halliday, 1983). It can be argued that overt naming of the pictures during presentation may encourage verbal processing and account for the effect at age 4. In the present experiment, although, unlike Hulme’s study, the researcher did not name the pictures, even the youngest children spontaneously named them. This could partly account for the detection of the effect at such a young age.

Of more interest was the finding that Greek children appeared to be sensitive to phonological similarity on recall for pictures at a later age—age 6—compared to English children. This age coincided with the age of emergence of a phonological similarity effect reported by Longoni and Scalisi (1994) in Italian children. However, as Longoni and Scalisi did not include an English group in their study, it is not possible to directly compare patterns of possible cross-linguistic differences. The findings reported here also supported the initial hypothesis H5 that, possibly due to linguistic differences, Greek children should show a preference for visual coding that would persist until a later age. However, it should be noted that practically all the Greek children, like English children, named the pictures spontaneously upon presentation, even at age 4. Therefore it is puzzling that there should be a difference in the chronology of the phonological similarity effect, as both groups spontaneously produced auditory input upon presentation of the pictures. As Palmer (2000) suggests, overt naming of the stimuli may not, after all, be adequate for producing a phonological similarity effect; this requires more elaborate attentional processes that require the maintenance of temporarily activated representations of the stimuli (see
also Ford & Silber, 1994, for a lack of a phonological similarity effect in the presence of overt labelling of pictures).

Indeed, as Palmer (2000) also suggests, what changes with age is not so much the ability to use verbal recoding, but rather the ability to use it appropriately and successfully as a verbal strategy. In Chapter One it was stressed that young children do have the ability to name pictures or rehearse words: they are reluctant to apply these verbal abilities as goal-oriented strategies, a characteristic known as production deficiency. It is possible that Greek 4-year-olds, even having named the pictures, did not rely on verbal memory for recall and thus did not confuse the phonologically similar words.

The overall significant effect of visual similarity appeared to be present in all age groups and for both language groups, but in fact was not detectable when each age group of a native language was analysed separately. This indicates that a small visual similarity effect must be present (see hypothesis H6) but would require larger samples or a more sensitive procedure in order to be detected. Indeed, visual similarity effects have only been found in studies where a fixed length procedure has been used (Hitch et al., 1988; 1989b) but not when a span procedure has been used (Hitch, Halliday, & Littler, 1989).

On the whole, therefore, the results seem to point towards differences in the chronology and possibly the types of strategies used by the two language groups. From the phonological similarity findings, it appears that although the two groups follow the same developmental pattern in the types of encoding they rely on, in Greek children this pattern is slightly shifted towards a later age. The modality effects and comparisons of spans for control words also indicate that the two language groups may differ in the efficiency with which they use visual and verbal information over development; the English children clearly show a verbal advantage from the youngest age tested, while the Greek children appear to benefit more from visual cues, especially at a younger age.
These findings agree with the hypothesis that Greek children would display a visual advantage in STM, and that this advantage would be evident until a later age than in English children. However, as with the findings from the Corsi blocks task, one should be cautious in assuming that these findings support a causal relationship between linguistic differences and STM performance. More direct evidence which links memory performance to word length should be provided from studying the word length effect and the development of verbal rehearsal in the two groups. Experiment Three explored these effects in the two language groups.

3.3. Experiment Three: effects of word length and the development of rehearsal in Greek and English children

3.3.1. Introduction

The previous experiments examined the developmental course of verbal coding in Greek and English children and explored the possible codes children may use to retain information in STM. The main assumption was that linguistic differences between English and Greek native speakers might be reflected in different coding strategies during development. In particular, it was suggested that differences in the average word length in Greek and English may lead to a choice of different STM strategies in the two populations during development. These differences would be most likely reflected in a longer reliance of Greek children on visual strategies, as their language comprises longer words; English children would be more likely to adopt verbal strategies from an earlier age compared to Greek children.

The findings of Experiments One and Two seem to support this hypothesis. Greek children appeared to have longer visuo-spatial spans than digit spans until age 6, and equivalent verbal and visuo-spatial spans until age 10 at least, while a verbal span advantage was evident in English children from age 8. Findings from the word span tasks also indicated an earlier advantage for recall of verbal material in English children, which was not apparent in Greek children. There was also evidence that
the effect of phonological similarity on recall of pictures, which indicates verbal recoding of pictorial material, emerges slightly later in Greek children compared to English children.

However, even if these findings confirm the presence of differences in memory strategies between the two populations, they do not provide direct support of the link between word length differences and the choice of memory strategies. One could argue that these findings are not necessarily attributable to language differences, but rather to more general cultural differences such as schooling. More direct evidence would be provided if word length as such was manipulated as an experimental variable, and its effect on memory span was studied in the two language groups. In other words, it is important to establish whether the two language groups would adopt different strategies for remembering words of increasing length. More particularly, of interest here would be the age at which verbal rehearsal of pictorially presented material emerges. The present experiment, therefore, explores the effect of word length and its relationship to verbal rehearsal in the two language groups.

As several researchers (e.g. Baddeley, 1986; Hulme et al., 1986; also see Kail, 1990) suggest, the emergence of rehearsal in childhood is a gradual process: it is the efficiency of rehearsal strategies rather than their actual use that changes with age, especially when material is presented visually. Visual material leaves room for more strategies, as it may involve recoding into a different modality (see Cowan & Kail, 1996). If, as suggested, the use of verbal recoding and rehearsal of visual material is an optional strategy that is dependent on the individual's available resources, differences in the effect of word length for pictures should be evident between Greek and English children: more particularly, Greek children should opt for alternative means of remembering the longer words of their language. Rehearsal should finally be adopted, as verbal labelling and articulation improve with age; but this should occur at a later age compared to English children.
Some researchers have argued that an effect of word length on picture recall may be attributed to verbal output rather than rehearsal (see Cowan, Day, Saults, Keller, Johnson, & Flores, 1992; Henry, 1991). In this experiment, therefore, a condition of nonverbal recall of pictures was included, to control for contributions of verbal recall to the word length effect. If the effect was significant for verbal recall, but not for nonverbal recall, at the same age, this would indicate that word length operated at the verbal output stage.

Therefore, the word length effect should be expected to emerge first for recall of spoken words. For visual material, word length effects would emerge relatively later if the recall response were verbal. If word length does have a detectable effect at the stage of verbal recall without rehearsal occurring, then the effect should be expected to emerge later for a nonverbal than for a verbal response. If, however, verbal rehearsal was required for a significant word length effect to be observed, then the chronology of the effect should not differ between the two response conditions.

In addition to direct comparisons of the two language groups, each group could also be studied separately to examine how memory performance changes with increasing word length. Such separate analysis would be necessary, as different sets of words were used for each language group. Moreover, most Greek nouns designating everyday objects known to young children range from 2 to 5 syllables, while in English they range from 1 to 3 syllables. This means that direct comparisons between Greek and English could only be made for the 2- and 3-syllable words, included as stimuli in the experiment reported.

Furthermore, it could be argued that differences in the use of memory strategies would be encountered even within the same individual, depending on the difficulty and demands of the memory task. More particularly, one would expect younger children, whose rehearsal strategies are not yet fully developed, to memorise words in different ways, depending on word length. Shorter words should be rehearsed more easily than longer words. For longer words, rehearsal could be less efficient, or
even avoided, if the option of visual encoding was offered. This pattern would be evident as: (1) a dependence of effects of modality on word length: possibly an advantage for spoken word recall if words are shorter, but a picture advantage if words are longer; (2) a change of these modality effects with age: with increasing age, verbal rehearsal would take over even for longer words, leading to an overall verbal advantage; (3) a difference in the timing of these effects between the two language groups, with Greek children adopting rehearsal strategies later than English children.

However, the above pattern could be confounded by additional factors besides rehearsal: dual coding would contribute towards a picture advantage, while visual/verbal recoding would make picture recall more difficult. Moreover, it is possible that, at least at the early stages of rehearsal development, verbal rehearsal would be disrupted more by spoken words than by pictures, leading to better recall of pictures. As the final pattern observed would be a composite of all these factors, it was difficult to make clear predictions about the effects of modality on recall of short and long words.

In summary, the present experiment was designed to explore:
1. how word length affected recall at different presentation and response modalities;
2. how effects of presentation and response modality on recall changed with age;
3. whether the above effects were dependent on native language;
4. whether the above effects changed with word length within the same language group; in other words, whether the same child adopted different strategies for remembering words of increasing length.

To explore these questions, nouns familiar to children as young as 4—the youngest age group studied—were chosen, consulting children’s books. In the English group, these nouns are from 1 to 3 syllables long. In the Greek group, however, they are from 2 to 5 syllables long. Word sets for each language group were constructed to explore whether, and how, children use different resources for remembering shorter
and longer words that are part of their everyday vocabulary. This should provide some understanding of how young children actually cope with memory constraints when learning their own language.

More specifically, the following hypotheses were formulated either as clear predictions, or as more general questions and suggestions to be explored.

If differences in word length between the two languages are related to differences in the development of memory strategies, then the following should be expected:

H1: Language group differences in spoken word span.
When the length of the spoken words used as stimuli in each language group are equal, Greek and English children should not differ significantly in recall of spoken words.

H2: Language group differences in picture span (verbal response).
As mentioned with regard to Experiment Two (hypothesis H2), the relative performance of the two language groups on verbal recall of pictures would represent a trade-off between verbal recoding, dual coding, and a possible additional verbal advantage in the English group. Thus, the same predictions that were formulated in Experiment Two also apply here, and are formulated below as a general hypothesis: 'The gradual transition from visual coding to verbal recoding should occur earlier in the English group'.

This, in turn, suggests that, at a younger age (i.e. age 4), Greek and English children should rely primarily on visual memory for remembering the pictures, and thus would have equal picture spans. With increasing age, however, verbal strategies should gradually take over. As this transition should occur earlier in the English group, English children should be able to benefit from dual coding from an earlier age compared to Greek children, and should, therefore, have longer picture spans.
This difference should eventually be abolished at the age when Greek children are also able to use verbal recoding efficiently.

**H3: Language group differences in picture span (nonverbal recall).**
A similar pattern should be expected for nonverbal recall of pictures, except that in this case visual/verbal recoding is not required, but optional. Thus, the suggestions formulated in hypothesis H2 should also apply to nonverbal recall, but in this condition, English children should begin to use verbal coding possibly later, and Greek children possibly even later. The observed pattern, therefore, should be the same as predicted in hypothesis H2 above, but shifted towards a later age.

**H4: Language group differences in the patterns of presentation modality effects.**
Given the interplay between dual coding, difficulties with verbal recoding, and efficiency of verbal rehearsal, it is difficult to make clear predictions about effects of presentation modality on recall within each language group. Experiment Two showed that Greek children recalled spoken words and pictures equally well at all ages, while a spoken word advantage was reported for the English group at age 4; no significant modality effects were apparent from age 6 onwards. Thus, the same pattern should be expected here.

**H5: Language group differences in the patterns of response mode effects.**
As for the effects of response modality, nonverbal recall (pointing response) should be better than verbal recall in both language groups, as the former condition does not require recoding in a different modality, or involvement of verbal strategies. This difference should decrease with age, as verbal recoding would become more efficient with age, thus making verbal recall of pictures automatic even when not required. It should, however, decrease sooner in English children than in Greek children.

**H6: Language group differences in the chronology of the word length effect.**
An effect of word length on recall of spoken words should be apparent from as early as age 4 in both language groups (see literature review in Chapter One).
For picture span with verbal recall, however, the effect should emerge later than for spoken words in both language groups. It should also be observed later in Greek children than in English children.

The effect of word length on picture recall with a nonverbal response was used here to control for contributions of response modality to the effect. Therefore, it should occur at the same time as the effect on picture verbal recall, only if it is attributed to verbal rehearsal.

3.3.2. Method

3.3.2.1. Participants

The same children who took part in experiments One and Two also participated in this study.

3.3.2.2. Stimuli

For the Greek group, word sets ranging from 2 to 5 syllables were used, while word sets ranging from 1 to 3 syllables were used in the English group. There were 7 items in each set. The words that belonged in each set are shown in Tables 3.4 and 3.5.

Within each language group, the word sets were matched for imageability, rated frequency, and rated familiarity using the ratings reported in Morrison et al. (1997). In the English group, the word sets were also matched for objective age of acquisition. Finally, the words used in each language group were also matched for the measures mentioned above, although it should be stressed that, due to cultural differences, different ratings might apply in the Greek word sets. The line drawings used for the visual presentation conditions in the two language groups can be found in Appendix C.
### Table 3.4. Greek stimuli used for the word length experiment, and their English translations.

<table>
<thead>
<tr>
<th>2 syllables</th>
<th>3 syllables</th>
<th>4 syllables</th>
<th>5 syllables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greek</td>
<td>English</td>
<td>Greek</td>
<td>English</td>
</tr>
<tr>
<td>melo</td>
<td>apple</td>
<td>baloni</td>
<td>balloon</td>
</tr>
<tr>
<td>papia</td>
<td>duck</td>
<td>gourouni</td>
<td>pig</td>
</tr>
<tr>
<td>tyri</td>
<td>cheese</td>
<td>roloi</td>
<td>clock</td>
</tr>
<tr>
<td>blouza</td>
<td>T-shirt</td>
<td>trapezi</td>
<td>table</td>
</tr>
<tr>
<td>blouza</td>
<td>fish</td>
<td>vivlio</td>
<td>book</td>
</tr>
<tr>
<td>psari</td>
<td>shoe</td>
<td>pontiki</td>
<td>mouse</td>
</tr>
<tr>
<td>porta</td>
<td>door</td>
<td>pontiki</td>
<td>mouse</td>
</tr>
<tr>
<td>mati</td>
<td>eye</td>
<td>papoutsi</td>
<td>shoe</td>
</tr>
</tbody>
</table>

Mean number of phonemes=4.57; SD=0.43; range=4-5

Mean number of phonemes=5.86; SD=0.38; range=5-6

Mean number of phonemes=8.29; SD=0.95; range=7-10

Mean number of phonemes=9.57; SD=0.53; range=9-10

### Table 3.5. English stimuli used for the word length experiment.

<table>
<thead>
<tr>
<th>1 syllable</th>
<th>2 syllables</th>
<th>3 syllables</th>
</tr>
</thead>
<tbody>
<tr>
<td>duck</td>
<td>onion</td>
<td>banana</td>
</tr>
<tr>
<td>shoe</td>
<td>balloon</td>
<td>umbrella</td>
</tr>
<tr>
<td>hand</td>
<td>jumper</td>
<td>elephant</td>
</tr>
<tr>
<td>book</td>
<td>apple</td>
<td>dinosaur</td>
</tr>
<tr>
<td>ball</td>
<td>letter</td>
<td>telephone</td>
</tr>
<tr>
<td>bus</td>
<td>rabbit</td>
<td>bicycle</td>
</tr>
<tr>
<td>fish</td>
<td>table</td>
<td>newspaper</td>
</tr>
</tbody>
</table>

Mean number of phonemes=3.00; SD=0.58; range=2-4

Mean number of phonemes=4.43; SD=0.79; range=3-5

Mean number of phonemes=6.00; SD=1.53; range=3-7

Although the selection of words was based on the number of syllables, the number of phonemes was also considered. This was done to ensure that: (a) the two and three syllable sets, on the basis of which the two language groups were directly compared on word span, contained the same mean number of phonemes in the two languages; (b) increasing number of syllables was accompanied by increasing number of
phonemes in each language group. Indeed, one-way ANOVAS showed that the two and three syllable sets used in the two language groups did not differ significantly in the number of phonemes. Within each language group, simple comparisons between sets of words on the number of phonemes showed that the words that differed in the number of syllables also differed in the number of phonemes (p<0.05). Details about the number of phonemes in each word set are shown in Tables 3.4 and 3.5.

3.3.2.3. Design and procedure

The procedure followed was the same as in Experiment Two, with the addition of a pointing response condition when the words were presented visually. In this case the children had to point, in the correct order, at the stimuli to be recalled, on a board where all seven items from a set were present. Therefore, a modality condition with three levels (auditory presentation/verbal response, visual presentation/verbal response, and visual presentation/pointing response) was manipulated.

Thus, each child was presented with the following conditions:
1. Spoken words - verbal response
2. Pictures - verbal response
3. Pictures - pointing response

Four sets of words of increasing length were used at each modality condition for Greek children: 2 syllables, 3 syllables, 4 syllables, and 5 syllables. This resulted in 3 modality conditions x 4 word lengths = 12 conditions. For the English group, three sets of words of increasing length were used at each modality, resulting in 3 modality conditions x 3 lengths = 9 conditions.

Presentation modality (visual versus auditory) was counterbalanced. Within the visual presentation condition, type of response (verbal versus pointing) was also counterbalanced. The order of word sets was randomised.
3.3.3. Results

Table 3.6 shows descriptive statistics of the word spans at each length for each language group and age group separately. To explore the differences in memory performance between the two language groups, an overall mixed ANOVA was carried out with presentation/response modality condition (spoken words/verbal response, pictures/verbal response, pictures/pointing response) and number of syllables (2 and 3 syllables) as within subjects factors and age group and language group as the between subjects factors. The results of this analysis are reported in Table 3.7.

Two further ANOVAS were carried out within each language group separately, as different word sets were used: four sets of words of increasing length for the Greek group and three sets of words for the English group. In these ANOVAS, modality and word length were the within subjects factors and age group was the between subject factor. The results of these analyses are also reported in Table 3.7.

As can be seen, different parts of these three analyses are related to the research hypotheses formulated above, and thus were further explored. The relevant parts of this main ANOVAS will, therefore, be referred to in the Results sections to follow. These were followed by further ANOVAS and planned comparisons to explore simple effects of modality and length. Only the results relevant to the specific research questions are reported here.

^1 Only 2- and 3-syllable words could be included in the overall ANOVA, as these were the word lengths used in both language groups.
### Table 3.6. Mean word spans for the word length experiment in Greek and English children (standard deviations in parentheses).

<table>
<thead>
<tr>
<th>Group</th>
<th>Condition</th>
<th>1 syl</th>
<th>2 syl</th>
<th>3 syl</th>
<th>4 syl</th>
<th>5 syl</th>
<th>1 syl</th>
<th>2 syl</th>
<th>3 syl</th>
<th>4 syl</th>
<th>5 syl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greek age 4</td>
<td>Spoken words, verbal response</td>
<td>-</td>
<td>2.96</td>
<td>2.42</td>
<td>2.21</td>
<td>2.17</td>
<td>-</td>
<td>3.00</td>
<td>2.83</td>
<td>2.83</td>
<td>2.88</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.36)</td>
<td>(0.66)</td>
<td>(0.59)</td>
<td>(0.38)</td>
<td></td>
<td>(0.29)</td>
<td>(0.48)</td>
<td>(0.48)</td>
<td>(0.34)</td>
</tr>
<tr>
<td>English age 4</td>
<td>Pictures, verbal response</td>
<td>3.00</td>
<td>2.54</td>
<td>2.25</td>
<td>-</td>
<td>-</td>
<td>2.67</td>
<td>2.17</td>
<td>2.96</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.51)</td>
<td>(0.51)</td>
<td>(0.53)</td>
<td></td>
<td></td>
<td>(0.56)</td>
<td>(0.38)</td>
<td>(4.07)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greek age 6</td>
<td>Pictures, pointing response</td>
<td>-</td>
<td>3.33</td>
<td>3.04</td>
<td>2.79</td>
<td>2.62</td>
<td>-</td>
<td>3.08</td>
<td>2.96</td>
<td>2.92</td>
<td>2.96</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>(0.56)</td>
<td>(0.55)</td>
<td>(0.66)</td>
<td>(0.58)</td>
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<td>(0.41)</td>
<td>(0.36)</td>
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<td>(0.20)</td>
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<tr>
<td>English age 6</td>
<td></td>
<td>3.95</td>
<td>3.43</td>
<td>2.90</td>
<td>-</td>
<td>-</td>
<td>3.71</td>
<td>3.14</td>
<td>3.05</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.67)</td>
<td>(0.60)</td>
<td>(0.54)</td>
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<td>(0.56)</td>
<td>(0.57)</td>
<td>(0.67)</td>
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<tr>
<td>Greek age 8</td>
<td></td>
<td>-</td>
<td>4.21</td>
<td>3.17</td>
<td>3.71</td>
<td>2.79</td>
<td>-</td>
<td>3.75</td>
<td>3.46</td>
<td>3.38</td>
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<td></td>
<td></td>
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<td>(0.51)</td>
<td>(0.48)</td>
<td>(0.50)</td>
<td>(0.59)</td>
<td></td>
<td>(0.68)</td>
<td>(0.66)</td>
<td>(0.65)</td>
<td>(0.73)</td>
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<tr>
<td>English age 8</td>
<td></td>
<td>4.50</td>
<td>3.83</td>
<td>3.67</td>
<td>-</td>
<td>-</td>
<td>3.92</td>
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<td>3.46</td>
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<td>(0.66)</td>
<td>(0.76)</td>
<td>(0.76)</td>
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<td></td>
<td>(0.65)</td>
<td>(0.65)</td>
<td>(0.59)</td>
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</tr>
<tr>
<td>Greek age 10</td>
<td></td>
<td>-</td>
<td>4.71</td>
<td>3.96</td>
<td>3.42</td>
<td>3.00</td>
<td>-</td>
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<td>3.54</td>
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<tr>
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<td>(0.69)</td>
<td>(0.69)</td>
<td>(0.50)</td>
<td>(0.59)</td>
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<td>(0.55)</td>
<td>(0.66)</td>
<td>(0.55)</td>
<td>(0.70)</td>
</tr>
<tr>
<td>English age 10</td>
<td></td>
<td>5.48</td>
<td>4.61</td>
<td>3.91</td>
<td>-</td>
<td>-</td>
<td>4.78</td>
<td>4.22</td>
<td>3.65</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.79)</td>
<td>(0.72)</td>
<td>(0.79)</td>
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<td>(0.60)</td>
<td>(0.74)</td>
<td>(0.57)</td>
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<tr>
<td>Greek overall</td>
<td></td>
<td>-</td>
<td>3.80</td>
<td>3.15</td>
<td>3.03</td>
<td>2.65</td>
<td>-</td>
<td>3.64</td>
<td>3.20</td>
<td>3.02</td>
<td>2.98</td>
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<td>(0.88)</td>
<td>(0.81)</td>
<td>(0.81)</td>
<td>(0.62)</td>
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<td>(0.85)</td>
<td>(0.63)</td>
<td>(0.54)</td>
<td>(0.56)</td>
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<tr>
<td>English overall</td>
<td></td>
<td>4.23</td>
<td>3.60</td>
<td>3.18</td>
<td>-</td>
<td>-</td>
<td>3.76</td>
<td>3.36</td>
<td>3.29</td>
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<td></td>
<td></td>
<td>(1.12)</td>
<td>(0.99)</td>
<td>(0.94)</td>
<td></td>
<td></td>
<td>(0.96)</td>
<td>(1.01)</td>
<td>(2.13)</td>
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</table>
Table 3.7. Results of the three main ANOVAS: (1) overall 2x2 mixed ANOVA (native language x age x modality x length, (2) overall Greek ANOVA (modality x length x age) (3) overall English ANOVA (modality x length x age)

<table>
<thead>
<tr>
<th>Main effects and interactions</th>
<th>Overall 2x2 ANOVA</th>
<th>Overall Greek ANOVA</th>
<th>Overall English ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main effect of presentation/response modality</td>
<td>F(2,360)=5.41, p=0.005</td>
<td>F(2,184)=8.38, p&lt;0.001</td>
<td>F(2,176)=8.00, p&lt;0.001</td>
</tr>
<tr>
<td>Main effect of word length</td>
<td>F(1,180)=69.34, p&lt;0.001</td>
<td>F(3,276)=116.87, p&lt;0.001</td>
<td>F(2,176)=51.21, p&lt;0.001</td>
</tr>
<tr>
<td>Main effect of age</td>
<td>F(3,180)=118.194, p&lt;0.001</td>
<td>F(3,92)=86.20, p&lt;0.001</td>
<td>F(3,88)=72.65, p&lt;0.001</td>
</tr>
<tr>
<td>Main effect of language group</td>
<td>ns</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Interaction: age x language group</td>
<td>ns</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Interaction: modality x length</td>
<td>F(2,360)=3.19, p=0.042</td>
<td>F(6,552)=7.34, p&lt;0.001</td>
<td>F(4,352)=3.35, p=0.01</td>
</tr>
<tr>
<td>Interaction: modality x language</td>
<td>ns</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Interaction: modality x age</td>
<td>ns</td>
<td>F(6,184)=7.72, p&lt;0.001</td>
<td>ns</td>
</tr>
<tr>
<td>Interaction: length x language</td>
<td>F(1,180)=6.95, p=0.009</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Interaction: length x age</td>
<td>F(3,180)=11.06, p&lt;0.001</td>
<td>F(9,276)=19.79, p&lt;0.001</td>
<td>F(6,176)=4.86, p&lt;0.001</td>
</tr>
<tr>
<td>Interaction: modality x age x language</td>
<td>ns</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Interaction: modality x length x age</td>
<td>ns</td>
<td>F(18,552)=3.90, p&lt;0.001</td>
<td>ns</td>
</tr>
<tr>
<td>Interaction: modality x length x language</td>
<td>ns</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Interaction: length x age x language</td>
<td>ns</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Interaction: modality x length x age x language</td>
<td>F(6,360)=2.51, p=0.021</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

3.3.3.1. Testing hypotheses H1, H2, and H3: comparing the two language groups on STM spans for spoken words and pictures

Figure 3.4 displays the word spans of 2- and 3-syllable words (collapsed together) for each language group, at each separate condition of presentation and response modality. As can be seen, Greek and English children did not appear to differ in word spans in any condition.
3.4. Comparing the two language groups on word span for each modality. Error bars represent the standard error of the mean.
This pattern was supported by the lack of a significant main effect of language, and the lack of a significant interaction between modality and language (see ANOVA results in Table 3.7.). As can be seen, the interaction between native language and age was also nonsignificant, indicating that Greek and English word spans were similar at all ages 32.

**3.3.3.2. Testing hypotheses H4 and H5: modality effects in the two language groups**

The two groups were studied separately for effects of presentation and response modality on recall. As mentioned above, the reason for carrying out separate analyses for each language group was that words of four different lengths (2, 3, 4, and 5 syllables) were given in the Greek group, while the English children were tested on three sets of words (1, 2, and 3 syllables). The following analyses allowed the exploration of hypotheses H4 and H5.

**Greek group**

Graph 3.5a shows the overall mean word spans at each length and for each presentation/response condition for the Greek group. As can be seen, on the whole the Greek group appeared to perform better on recall of spoken words when the words were shorter (2 syllables).

---

3^2 However, two interactions reported in Table 3.7. should also be considered here, namely the significant interaction between language group and word length, and the four-way interaction between age, language, modality and word length. These were further explored by conducting three separate mixed ANOVAs for each presentation/response modality: spoken words, verbal recall of pictures, and nonverbal recall of pictures. Some interactions in these ANOVAs were significant, as, for example, the three-way interaction between word length, native language, and age on recall of spoken words (F(1,180)=4.52, p=0.004). Since such interactions indicated that the language group differences were dependent on word length as well as age, as was suggested in the initial hypotheses, they were further explored by language comparisons within each age group and for each word length. However, further analysis revealed small effects that occurred at age 8 and age10. These effects were no longer significant at age 10 when age and Raven's scores were treated as covariates; as reported in Chapter Two, the 10-year-old groups were not perfectly matched on chronological age. The findings at age 8 reflected relatively small effects that could be attributed partly to the large degrees of freedom and partly to sampling problems; for this reason it was decided not to report them here.
3.5a. Greek overall word length effects

3.5b. English overall word length effects

Figure 3.5. Overall word length effects for each condition in the two language groups (Greek and English).

Error bars represent the standard error of the mean.
This difference between recall of spoken words and recall of pictures disappeared for 3- and 4-syllable words, and was reversed to an advantage for picture recall at the longest word length. Verbal recall of pictures was better than nonverbal recall at all lengths.

This pattern was confirmed when a mixed ANOVA with modality (3 levels) and word length (4 levels) as the within-subjects factors and age group as the between-subjects factor was carried out (see Greek ANOVA in Table 3.7). Of interest here was the significant interaction between presentation/response modality and age, as well as the significant interaction between modality and word length, and the three-way interaction between modality, length, and age. These interactions suggested that any modality effects would be dependent on word length (as shown in graph 3.5) and age.

Analysis of simple effects of modality at each word length further supported the pattern observed in Figure 3.5. For 2-syllable words, a significant difference was found between spoken words and verbal recall of pictures (F(1,95)=5.85, p=0.018) and between spoken words and nonverbal recall of pictures (F(1,95)=19.10, p<0.001), with better recall of spoken words. There were no significant differences between conditions for 3- and 4-syllable words. For 5-syllable words, however, there was a significant difference between spoken words and verbal recall of pictures (F(1,95)=19.74, p<0.001) and between spoken words and nonverbal recall of pictures (F(1,95)=4.26, p=0.042), with pictures being better remembered than spoken words. Finally, as also shown in graph 3.5a, planned comparisons of an overall difference between the two response conditions (verbal versus nonverbal) suggested that verbal recall was better than nonverbal recall (F(1,95)=13.61, p<0.001) and this difference did not interact with word length.

The significant interaction between modality and age was also further explored. Graphs 3.6a to 3.6d show the mean word spans for each modality, at each word length, in each age group separately. Planned comparisons were also carried out to explore the significance of differences between conditions; any significant effects (p<0.05) are shown in Table 3.8.
Figure 3.6. Greek word length effects for each condition, in each age group.
Error bars represent the standard error of the mean.
Table 3.8. Modality effects in the Greek group (significant at p<0.05).

<table>
<thead>
<tr>
<th>Modality effects</th>
<th>Age 4</th>
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<td>Difference between spans for</td>
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<tr>
<td>1. Spoken words (S)</td>
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<td>P&gt;S</td>
<td>P&gt;S</td>
<td>P&gt;S</td>
<td>S&gt;Pv</td>
<td>-</td>
<td>-</td>
<td>Pv&gt;S</td>
<td>-</td>
<td>-</td>
<td>S&gt;Pv</td>
<td>S&gt;Pv</td>
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<td>2. Pictures, verbal recall (Pv)</td>
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<td>1. Spoken words (S)</td>
<td>S&gt;Pp</td>
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<td>S&gt;Pp</td>
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<td>Pp&gt;S</td>
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<td>Pp&gt;S</td>
<td>S&gt;Pp</td>
<td>Pp&gt;S</td>
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<td>2. Pictures, pointing response (Pp)</td>
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<td>1. Pictures, verbal recall (Pv)</td>
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Verbal response > pointing response, at all lengths
Inspection of the graphs and the significant results displayed in Table 3.8 show the following pattern of performance for the Greek group: at age 4, Greek children appeared to be better at verbal recall of spoken words than nonverbal recall of pictures if the words were shorter (2 syllables)—see graph 3.6a. When recall of pictures was verbal, there was no difference between spoken word recall and picture recall if the words were short (2 syllables), but there was an advantage for pictures when the words were longer than 2 syllables. Finally, verbal recall of pictures was better than nonverbal recall at all word lengths.

At age 6 (see graph 3.6b) a verbal advantage was evident for the shortest words used in the task (2 syllables). Spoken words were better recalled than pictures, regardless of whether a verbal or a manual response was required. No significant differences were found between spans for 3- and 4-syllable words. However, for 5-syllable words, the longest words used in the set, pictures—with both verbal and nonverbal recall—were better recalled than spoken words. There was no significant difference between the verbal and nonverbal recall condition.

At age 8, however, the results seemed more complicated, and it was not possible to discern differences in performance between shorter and longer words (see graph 3.6c). For example, verbal recall of pictures was better than recall of spoken words for 2- and 5-syllable words, with no significant differences for 3- and 4-syllable words.

Nonverbal recall of pictures was better than recall of spoken words for 3-and 5-syllable words, but the direction of this difference was reversed for 4-syllable words. Again, there was no significant difference between verbal and nonverbal recall of pictures.

Finally, the oldest age group (graph 3.6d) displayed a more consistent pattern, with overall higher spans for spoken words compared to pictures. Recall of spoken words was significantly better than both verbal and nonverbal recall of pictures, but only for 3- and 4-syllable words. For the shortest and the longest words, no significant differences were detected.
English group

Graph 3.5b shows that the English children recalled spoken words better than pictures at lengths of 1 and 2 syllables. For 3-syllable words, however, no difference between recall of spoken words and pictures was significant. In addition, as opposed to the Greek group, spans did not differ significantly between the two response conditions (verbal versus nonverbal), and the effect remained non-significant at all word lengths.

A mixed ANOVA was carried out for the English group, with presentation/response modality (3 levels) and word length (1-, 2-, and 3-syllable words) as the within-subjects factors and age group as the between-subjects factors (see English ANOVA in Table 3.7). A significant overall effect of modality as well as a significant interaction between modality and word length confirmed the pattern observed in graph 3.5b. However, the interaction between modality and age group as well as the three-way interaction between modality, length, and age group were not significant, indicating that, in the English group, all age groups displayed the same pattern of modality effects.

The interaction between modality and word length was further explored in analysis of modality effects for each word length separately. These analyses supported the pattern observed in graph 3.5b. For 1-syllable and 2-syllable words, there was a significant difference between spoken words and verbal recall of pictures (F(1,91)=18.17, p<0.001; F(1,91)=7.88, p=0.006, for 1 and 2 syllables respectively). There was also a significant difference between spoken words and nonverbal recall of pictures at these lengths (F(1,91)=35.93, p<0.001; F(1,91)=8.76, p=0.004, for 1 and 2 syllables respectively). There were no significant modality effects on recall of 3-syllable words.

Summarising the effects of modality

On the whole, the findings suggested that both language groups had a verbal advantage for recall of shorter words (1 to 2 syllables). With increasing word length, this advantage was no longer significant, but was reversed to give better recall of
pictures for recall of 5-syllable words in the Greek group. In this language group, however, such effects were not constant across age groups but changed with age. Although some individual effects within each age group, particularly in the two oldest groups, were difficult to interpret, most significant effects indicated a gradual progression from visual encoding to verbal encoding for longer items. For example, the picture superiority effect emerged at 3 syllables for 4-year-olds, but at 5 syllables at age 6, disappearing at age 10. The superiority of verbal recall over nonverbal recall of pictures was also significant in the youngest age group only. These findings are further discussed in section 3.3.4.

3.3.3.3. Testing hypothesis H6: effects of word length in the two language groups

Returning to the overall mixed ANOVA which compared the two language groups on 2- and 3-syllable words (see 2x2 ANOVA in Table 3.7): the significant two-way interaction between word length and native language as well as the four-way interaction between word length, presentation modality, age, and native language, suggested that for each presentation/response condition, the word length effect developed in different ways in the two language groups. To explore this further, also taking into account that different sets of stimuli were used in the two language groups, the effects of word length were analysed in each language group separately (see Greek and English ANOVAS in Table 3.7). Graphs 3.5a and 3.5b show how word spans varied with word length in each presentation/response condition, within each language group.

Greek group
As can be seen in graph 3.5a, overall, word span appeared to decrease with increasing number of syllables, in all modalities. However, the slopes of these changes seemed to vary across modalities and along number of syllables: for example, the slope for the effect of word length on recall of spoken words was steeper than the slope that designated the effect of word length on both verbal and nonverbal recall of pictures, which suggested a more gradual change with number of
syllables, and thus a less pronounced word length effect. This dependence of the word length effect on presentation/response modality was also suggested by the significant interaction between word length and modality in the Greek three-way ANOVA (Table 3.7).

Further to this ANOVA, analysis of simple effects of word length for each modality separately, also confirmed the presence of a significant word length effect on recall of spoken words \( (F(3,276)=76.37, p<0.001) \), on verbal recall of pictures \( (F(3,276)=38.71, p<0.001) \), and on nonverbal recall of pictures \( (F(3,276)=40.83, p<0.001) \). Thus, the effect of word length was significant for all presentation/response conditions, but stronger for spoken words (see overall Greek means in Table 3.6).

Given the significant interaction between word length, modality, and age in the Greek group, the effects of word length were examined within each age group separately. Graphs 3.6a to 3.6d show the word spans for each number of syllables, in each age group respectively. As can be seen, the effect of word length on recall of spoken words was evident in all age groups; this was also confirmed by a significant simple effect of word length on spoken word recall \( (F(3,69)=13.33, p<0.001) \) in the 4-year-old group; \( F(3,69)=9.94, p<0.001 \) in the 6-year-old group; \( F(3,69)=31.00, p<0.001 \) in the 8-year-old group; \( F(3,69)=33.04, p<0.001 \) in the 10-year-old group).

Interestingly, there seemed to be a cut-off point beyond which the slope of the graph leveled out, indicating that the word length effect ceased to be significant when words were longer. This cut-off point appeared to increase with age: in the two youngest age groups, the slope leveled out beyond a word length of 3 syllables (see graphs 3.6a and 3.6b), while in the two oldest age groups the word spans appeared to decrease even at a length of 5 syllables. Pair-wise comparisons which contrasted spans for words of increasing length (differing in length by one syllable) confirmed that, in the 4-year and 6-year-old group, only 2-syllable and 3-syllable word spans differed significantly \( (F(1,23)=10.15, p=0.004) \) for the 4-year-old group; \( F(1,23)=5.24, p=0.032 \) for the 6-year-old group; the spans for 3, 4, and 5-syllable
words did not differ significantly. However, in the two oldest age groups, all pairs of word spans that were contrasted differed significantly from each other (8-year-olds: F(1,23)=54.66, p<0.001 for difference between 2- and 3-syllable words; F(1,23)=10.15, p=0.004 for 3- and 4- syllable words; F(1,23)=39.20, p<0.001 for 4- and 5- syllable words; 10-year-olds: F(1,23)=12.67, p=0.002 for 2- and 3- syllable words; F(1,23)=11.60, p=0.002 for 3- and 4- syllable words; F(1,23)=5.37, p=0.03 for 4- and 5- syllable words).

Graphs 3.6a to 3.6d also show the effects of word length on both verbal and nonverbal recall of pictures. As can be seen, word spans did not appear to decrease with increasing word length in the two youngest age groups (graphs 3.6a and 3.6b), suggesting the absence of a significant word length effect when pictures were recalled either verbally or nonverbally. Indeed, analysis of simple effects showed that the word length effect was not significant in these two age groups when pictures were recalled. As graphs 3.6c and 3.6d indicate, however, the effect became apparent at age 8 and was even clearer at age 10. With the exception of an anomaly in the 8-year-old age group, where word span increased for 4 syllable words, picture spans seemed to decrease with increasing number of syllables. This was confirmed by a significant effect of word length on verbal picture recall (F(3,69)=4.60, p=0.005 for the 8-year-olds; F(3,69)=41.91, p<0.001 for the 10- year olds) and nonverbal picture recall (F(3,69)=13.14, p<0.001 for the 8-year-olds; F(3,69)=47.24, p<0.001 for the 10-year-olds).

Again, it can be seen that the graphs appeared to level out after a certain number of syllables, indicating that the effect was no longer detectable beyond that length. Thus, pair-wise comparisons showed that, in the 8-year-old group, only the spans for 2- and 3- syllable words differed significantly (F(1,23)=6.75, p=0.016), while in the 10-year-old group, the spans for 2- and 3- syllable words (F(1,23)=38.86, p<0.001) and 3- and 4- syllable words (F(1,23)=11.86, p=0.002) differed significantly. In both age groups, the word length effect for nonverbal recall appeared to be significant for up to a length of 4 syllables (8-year-olds: F(1,23)=5.70, p=0.026; F(1,23)=12.83,
p=0.002; 10-year-olds: F(1,23)=56.35, p<0.001; F(1,23)=13.0, p<0.001, for differences between 2- and 3- syllable words and 3- and 4- syllable words respectively).

Therefore, in the Greek group, the effect of word length was significant even in the youngest age group when spoken words were recalled. For both verbal and nonverbal recall of pictures, however, the effect emerged in the 8-year old group. Moreover, it seemed that, beyond a certain word length, the word length effect reached a sort of 'saturation point' and word spans no longer decreased with increasing number of syllables. This point increased with age and, within a given age group, was higher for recall of spoken words (5 syllables) than for recall of pictures (3 or 4 syllables).

English group

Turning to the English group, graph 3.5b shows an overall pattern of significant word length effects in all modalities, similar to the Greek group. The main three-way ANOVA (see English ANOVA in Table 3.7) revealed a significant main effect of word length as well as a significant interaction between word length and age and an interaction between modality and word length. To examine the effects of word length within each modality condition, this interaction was further explored with analysis of simple effects. As graph 3.5b shows, there was a clear word length effect on recall of spoken words (F(2,176)=103.89, p<0.001), a less pronounced, but still significant, word length effect on verbal recall of pictures (F(2,176)=3.90, p=0.022) and a significant word length effect on nonverbal recall of pictures (F(2,176)=38.18, p<0.001). However, for both verbal and nonverbal recall of pictures, the overall effect of word length seemed to be significant only up to 2 syllables, beyond which recall did not decrease with increasing number of syllables (see graph 3.5b, also pairwise comparisons: the effect was significant for the difference between 1 and 2 syllables (verbal picture recall: F(1,88)=4.49, p=0.0006; nonverbal picture recall: F(1,88)=3.01, p=0.034), but nonsignificant for differences between 2 and 3 syllables).
Of interest was the three-way interaction between word length, modality, and age. Although, in the English group, this interaction was not significant (see Table 3.7), graphs 3.7a to 3.7d suggest that the word length effect was sensitive to modality in different ways in each age group. Thus, although the word length effect on recall of spoken words was significant in all age groups (simple effects of word length on spoken word recall were all significant at p<0.001 in all age groups), for recall of pictures the effect seemed to change with age. In the 4-year-old group, the effect was significant neither for verbal nor nonverbal recall of pictures, but emerged in both response modalities at age 6, being significant at p=0.001 from that age onwards.

Closer inspection of the graphs also indicated the presence of a word length point beyond which the effect was no longer significant, as was the case in the Greek group. Indeed, planned comparisons showed that the effect of word length on recall of spoken words was significant both when 1- and 2-syllable word spans and 2- and 3-syllable word spans were compared, and this effect was significant in all age groups (with the exception of the 8 year old- group, where the difference in span between 2- and 3- syllables was not significant). For verbal and nonverbal recall of pictures, the findings were more complicated. For verbal recall of pictures, the "cut-off" point beyond which the word length effect was no longer significant was at 2 syllables up to age 6 (p<0.001). At age 8, however, only the difference between 2-syllable and 3-syllable words was significant (F(1,23)=7.27, p=0.013), while the difference between 1- and 2- syllable words was not significant. Finally, in the 10-year-old group, the word length effect was significant for at least up to 3 syllables (p<0.001). Finally, for nonverbal recall of pictures, overall the word length effect emerged at age 6, being significant for a length of at least 3 syllables.
Figure 3.7. English word length effects for each condition, in each age group. Error bars represent the standard error of the mean.
Summarising the word length effects

The two language groups did, therefore, differ in the age when the word length effect for picture recall emerged, but did not differ in the timing of the same effect on recall of spoken words\(^3\). This partly supported hypothesis H6; however, in contrast to the initial prediction, the effect emerged at the same time for verbal and nonverbal recall of pictures in both language groups. The effects of word length in each language group are summarised in Table 3.9.

Table 3.9. Effects of word length (WLE) on recall for each condition in the two language groups.

<table>
<thead>
<tr>
<th></th>
<th>GREEK</th>
<th>ENGLISH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4 years</td>
<td>6 years</td>
</tr>
<tr>
<td>Spoken words</td>
<td>WLE (only up to 3 syllables)</td>
<td>WLE (only up to 3 syllables)</td>
</tr>
<tr>
<td>Pictures, verbal recall</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pictures, pointing response</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>ENGLISH</td>
<td>4 years</td>
<td>6 years</td>
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<tr>
<td>Spoken words</td>
<td>WLE</td>
<td>WLE</td>
</tr>
<tr>
<td>Pictures, verbal recall</td>
<td>-</td>
<td>WLE (only up to 2 syllables)</td>
</tr>
<tr>
<td>Pictures, pointing response</td>
<td>-</td>
<td>WLE</td>
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</tbody>
</table>

The chronological difference in the emergence of the word length effect between the two language groups was also supported by calculating the slope of the word length regression line for each participant separately, and carrying out the ANOVAS with the slope as a dependent variable. It was confirmed that the two language groups differed in the age at which the slope changed significantly. The same pattern was also revealed when the correlations between word span and word length were used as a dependent variable within each language group.
3.3.3.4. Summary of results of Experiment Three

To summarise the findings of Experiment Three:

1. The two language groups did not differ significantly on recall of spoken words.

2. The two language groups did not differ significantly on either verbal or nonverbal recall of pictures.

3. The effects of presentation and response modality on recall varied with word length and age, in quite different ways in each language group.

4. The effect of word length on verbal recall of spoken words was significant from age 4 in both language groups.

5. The word length effect on both verbal and nonverbal recall of pictures was detected from age 6 in English children; and from age 8 in Greek children.

6. Simple comparisons of word spans for words of increasing length showed that increasing word length had an effect on recall up to a particular word length; and that this particular word length increased with age. This was evident in both language groups.

3.3.4. Discussion of Experiment Three

On the whole, the findings of Experiment Three suggest group differences in the development of modality effects and word length effects on STM span. Whether these differences are substantial, and whether they can be attributed to linguistic differences, is debatable.
The summary of results presented in Section 3.3.3.4 presents findings that often seem inconsistent with the initial predictions, and difficult to interpret. As will be discussed below, it is apparent that the initial hypotheses may be only partly supported, and that further theoretical support is necessary for making sense of the results. The following suggestions may be helpful in interpreting the apparently confusing findings regarding the performance of the two language groups at different ages.

The first suggestion is based on the very definition of strategies: that they are goal-directed, effortful behaviours that require mental attention (see Bjorklund & Douglas, 1997). The efficiency and appropriateness of their use gradually changes with age; at some point they become automatic and require minimum executive resources. Young children are more likely to apply some fragmentary, primitive kind of strategies (see Palmer, 2000). In some cases, these strategies may even disrupt performance.

The second assumption is that the effects of word length and phonological similarity on recall may indicate the use of verbal strategies for recall, but do not allow the differentiation between effective and less effective use of strategies. For this reason, similar patterns of performance observed in different groups of children tested do not necessarily mean that the underlying memory strategies used are the same. For example, Greek and English children of the same age may both exhibit a word length effect, but this does not mean that they are using verbal rehearsal in the same way or with the same efficiency. Indeed, Palmer (2000) acknowledged and largely resolved this problem by including children’s self-reports on any strategies they used during memory tasks.

Finally, an assumption which has also been formulated as a basis of the present research, and has been implicit in the research hypotheses, refers to the flexibility with which children choose to use different resources according to their abilities and the task difficulty. For instance, it is suggested that the same child may opt to use
verbal rehearsal for shorter words, but be more reluctant to use the same strategy for longer words. Again, this flexibility may increase with age. Flexibility was shown with increasing age, but also within the same individual, with regard to visual and verbal coding strategies (e.g. Brown, 1977; Della Sala, Logie, Marchetti, & Wynn, 1991; Palmer, 2000).

Obviously, as the above assumptions relate to internal processes that cannot be measured easily, they can only be tentative. It should be remembered that examining the effects of phonological similarity and word length in a cross-linguistic study is only a first step towards exploring possible differences in the memory processes of groups that speak different languages. If these assumptions can provide a convincing explanation for the results, this does not mean that they actually apply; but rather that they should be the starting point of further experiments that would be designed to test their validity.

The findings are discussed below with respect to the hypotheses formulated in the introduction:

3.3.4.1. Hypotheses H1 to H3: language group comparisons of STM span

In these hypotheses it was suggested that Greek and English children should not differ significantly in recall of spoken words. Greek and English children should differ on recall of pictures only at those stages during development where English children make better use of verbal information than Greek children. English children should develop their verbal memory skills earlier than Greek children. Both groups should also begin to use verbal information earlier for verbal recall of pictures, and later for nonverbal recall.

Were these predictions supported? Comparison of the two language groups on memory span for the control words seemed, on the whole, to support the assumption that the number of syllables is the chief determining factor for memory span: both
groups performed equally well on recall of words that had the same number of syllables. Thus, hypothesis H1 was supported.

More surprising was the finding that the two groups did not differ on picture spans, and that this pattern was stable across ages and at both word lengths. Again, this pattern could be accounted for by underlying factors that could not be directly identified solely on the basis of word span comparisons. Palmer (2000) suggests a gradual developmental transition from visual encoding to dual coding and finally verbal coding. If Greek children show extended developmental stages in the use of these strategies compared to English children, then one would expect English children to have longer picture spans at all age groups (hypotheses H2 and H3). However, as Palmer (2000) points out, even within each age group there may be variability in the choice of coding strategies. It is possible that the pattern observed here reflected a trade-off between visual strengths in Greek children and verbal strengths in English children, and that the small, inconsistent effects observed in the separate age groups represent this variability.

3.3.4.2. Hypotheses H4 and H5: modality effects

Effects of modality in the two language groups also provided some evidence that Greek children may choose to benefit more from visual coding compared to English children of the same age. The modality effects also agree with the assumptions stated above, the most interesting observation being that modality effects seemed to change as a function of word length within the same language and age group.

Thus, in Greek 4-year-olds, shorter words (2 syllables) were equally well remembered as pictures recalled verbally, and better remembered as pictures recalled nonverbally. From 3-syllable words and beyond, however, there was a picture advantage over spoken words, for both a verbal and a nonverbal response. This reflects the preference of young Greek children for visual information. At age 6, again, a spoken word advantage observed for 2-syllable words disappeared for 3-
syllable and 4-syllable words, and was reversed to a picture advantage for the longest (5-syllable) words. This pattern may reflect use of verbal skills for the shortest words, followed by dual coding for longer words and a greater reliance on visual information for the longest words.

The pattern observed in the 8-year-old Greek group is, however, more complicated (see Tables 3.6 and 3.8). It is not clear why this group displayed a picture recall advantage for shorter (2-and 3-syllable) words, and a spoken word advantage for 4-syllable words, followed by a picture advantage for the longest words. In contrast, in the 10-year-old group the pattern observed is more meaningful, with the exception of a lack of a spoken word advantage that should be detected for 2-syllable words. However, a spoken word advantage was observed for 3-syllable and 4-syllable words, and was no longer detected for the longest (5-syllable) words, indicating that, in this age group, dual coding seems necessary only for remembering the longest words.

Thus, besides a few deviations in the two oldest age groups, a pattern can be observed regarding effects of presentation modality on STM span: Greek children seemed to use a verbal strategy more successfully if the words were shorter than when the words were longer; with increasing word length, they used visual resources as well, so no modality effect was detected; and with the longest words, they seemed reluctant to use verbal strategies and relied mostly on visual information, hence the picture advantage. Moreover, with increasing age, as their rehearsal strategies became more efficient, they appeared to use verbal strategies for longer words, too. This supports the assumption that the same child might choose to use different strategies according to task difficulty: the task difficulty, here, being determined by the length of words to be remembered. This pattern also seems to agree well with Palmer’s (2000) suggestions regarding the flexibility of coding strategies in children.

A similar pattern was also observed in the English group: a spoken word advantage was observed for 1-syllable and 2-syllable words; but no significant modality effect
was detected for the longest (3-syllable) words used in that group, again indicating use of both visual and verbal information for remembering longer words. It can be assumed that, if even longer words were used in this group, children would be more reluctant to rehearse, and this would be evident as a picture advantage, as was the case with Greek children. However, in contrast to Greek children, this pattern was observed in all ages: quite surprisingly, English children did not appear to use solely verbal rehearsal for longer words as they grew older. It is possible that this would be evident if longer words were used in this group.

What is also interesting is that the similarities in the patterns of modality effects between the two language groups were not observed for the same length of words: the pattern observed in English children for effects of modality on recall of 1- and 2-syllable words was observed in the Greek group for 2- and 3-syllable words—the shortest words that could be used in each age group. This suggests that it may not be absolute word length that determines the perceived difficulty of a memory task, and hence the choice of strategies used; it could rather be that factors such as familiarity with word length may determine the likelihood of a verbal strategy being used at a particular age. Alternatively, as will be discussed below, the differences in modality effects at a given word length between the two language groups may be attributed to the fact that spoken duration, rather than number of syllables, is more likely to affect children's choices on using verbal rehearsal.

Do the above effects agree with hypothesis H4? It was predicted that the patterns observed in Experiment Two should be replicated in this experiment, at least for 1-syllable words in the English group and 2-syllable words in the Greek group. There should be a superiority of spoken word recall versus verbal recall of pictures in the English 4-year-old group; and a lack of a modality effect in all other English age groups, as well as in all Greek age groups. This, however, was only partly observed in the present experiment. Greek children remembered spoken words and pictures equally well, but only at ages 4 and 10. The spoken word advantage for 1-syllable words was observed in all English age groups, and was not confined to the 4-year-
old group. As the procedure of the memory tasks as well as the length of the words used were the same, such differences between the findings of the two experiments should not occur. In addition, as noted in the Method sections, although different sets of words were used in each task, they were selected to be of comparable frequency. Therefore, no plausible explanation for this discrepancy in the results can be offered here.

Turning to the effects of response modality on recall (hypothesis H5), they were similar in the two language groups, except at age 4. Greek 4-year-olds were better at verbal than nonverbal recall of pictures, at all word lengths. From that age onwards, there was no significant difference between the two modalities. No significant difference between the two response modalities was found in the English group either, and this was evident in all English age groups. According to hypothesis H5, nonverbal recall of pictures should be better than verbal recall at younger ages; with increasing age, the difference should no longer be significant. However, the opposite was found in Greek 4-year-olds, although they would be expected to benefit more from a purely visual task, which would not require recoding into another modality.

One explanation for this could be provided if the nature of the two tasks (verbal versus nonverbal response) is considered. Both tasks required recall of the items in serial order. In the verbal response condition, the cards remained upside down, in the order they were presented, in front of the child. In the nonverbal response, in contrast, all the pictures were presented on a board and a pointing response was required. In the verbal response task, therefore, the turned-over cards can be used as spatial cues for recall, while in the nonverbal task this option is not offered. It is possible that young Greek children use spatial coding, in addition to visual coding; this may account for their differences in performance between the two tasks.

Besides this effect against hypothesis H5, the lack of a significant difference between verbal and nonverbal recall in the two language groups (from age 6 in the Greek group and from age 4 in the English group) seems to support the prediction that,
beyond a certain age, the two conditions should not differ. Moreover, the prediction that this reversal of the response mode effect should occur earlier in English than in Greek children can also be supported, at least in part: to confirm that such a reversal of the effects of response mode occurs in English children, children younger than 4 years should be tested.

Interestingly, there was clear evidence that the modality effects observed interacted with word length. With a few exceptions in the Greek 8-year-old group, a trend for a spoken word advantage for shorter words and a visual advantage for longer words was observed. Furthermore, this pattern interacted with age: the older the children, the more likely they were to display a spoken word advantage for words of the same length.

Ishikawa and Nobe (1998) conducted a cross-linguistic experiment where they compared the spoken word and printed word spans of adults that were native speakers of Chinese, Japanese Kanji, and English. They found that, while all language groups used verbal rehearsal in both conditions, as evidenced by the effect of articulatory suppression on recall, modality effects differed from one language group to the other. An auditory advantage was found for the English and the Chinese native speakers, but a visual advantage was reported for the Japanese speakers. In addition, modality effects were reversed to a visual advantage within each language group when list length was increased and familiarity with the phonological structure of the stimuli was decreased. The findings of the present experiment seem to agree with these findings in adults, in that people’s encoding strategies can be adapted to cope with task difficulty; task difficulty can be determined by word length in children, and word phonological complexity in adults.

3.3.4.3. Hypothesis H6: word length effects

The findings related to effects of word length on recall can be easily related to the initial predictions. An effect of word length on spoken word recall was apparent
from age 4 in both language groups, thus confirming hypothesis H6. This suggests that both language groups used verbal rehearsal, even at age 4. It is, however, argued that the word length effect on recall of spoken words does not reflect verbal rehearsal at this early age (e.g. see Gathercole & Hitch, 1993), but rather the effect of an automatic triggering of articulatory programmes (also see Hitch, 1990). The effect of word length could also be attributed to output effects (e.g. Cowan et al., 1992; Henry, 1991). It can be supposed, therefore, that children are starting to use some primitive form of rehearsal, which, for spoken words, depends solely on word length.

In contrast, an effect of word length on recall of pictures was evident from age 6 in the English group, but from age 8 in the Greek group, also agreeing with hypothesis H6, which predicted a difference in the chronology of the effect between Greek and English children. Moreover, the effect emerged at the same time for verbal and nonverbal recall on pictures, suggesting that it was not likely to be attributed to an influence of word length during verbal output, and thus resolving the issue addressed in hypothesis H6. However, this possibility of a contribution of verbal output to the word length effect cannot be entirely excluded, as it is possible that some children named the pictures aloud even in the nonverbal recall condition.

One potentially interesting finding was observed when simple comparisons were made between spans of words that differed by one syllable. This observation was mostly apparent in the Greek group; it seemed that the effect of word length could not always be accounted for by differences in recall between all sets of word lengths. Rather, at younger ages, word spans differed only when shorter words were compared to each other; however memory spans did not differ between longer words, for example between 4- and 5-syllable words. With increasing age, differences in recall between longer words became apparent. Inspection of the means showed that this pattern could not be explained by floor effects. A very tentative explanation for this could be that the detection of a word length effect may not simply reflect the use of a verbal strategy, but also the choice to rely on a verbal
strategy. For example, a significant difference between recall of 2- and 5-syllable words could mean that both sets of words are rehearsed, thus recall is better for the shorter words, as the phonological loop hypothesis predicts. Alternatively, however, it could mean that shorter words are rehearsed and longer words are not, or, at least, that longer words are not rehearsed in the same way and as successfully. This suggestion also seems to be supported by the fact that this pattern was most evident for verbal recall of pictures, where an alternative, or complementary, option to rehearsal is offered. It may also be more dramatic in Greek children, where a wider range of word lengths was studied.

As predicted, therefore, the two language groups differed in the chronology of the word length effect. The pattern predicted by the working memory model, where the timing of the word length effect depends on presentation modality, with the effect being detected earlier for spoken words than pictures (e.g. Hitch, Halliday, Dodd, & Littler, 1989), was also supported. On the whole, the pattern observed for both Greek and English children in both experiments, with phonological recoding emerging a little earlier than verbal rehearsal, supports the suggestion of Gathercole & Hitch (1993) that verbal rehearsal develops gradually from overt labelling of the stimuli to covert sequential repetition of the stimuli.

As noted above, this means that some caution is needed when concluding that the word length effects observed here can be attributed to 'mature' rehearsal; in this respect, it would be wiser to refer to 'verbal processing' instead of 'rehearsal'. As Gathercole and Hitch (1993) suggest, the word length effects observed in young age groups may reflect the spontaneous mapping of phonological representations to articulatory plans, rather than the strategic repetition of the word lists. As was observed in Experiment Three, this occurred even when no verbal response was required. In any case, what is important here is that, strategic or not, this verbal processing is evident with a time difference in the two language groups.
It should also be noted that the findings reported here may agree, in general, with the literature on word length effects, but not with the recent findings of Henry et al. (2000, Exp. 2). As discussed in Chapter One, the results of the study by Henry et al. appeared to support the hypothesis of Penney (1989) that verbal rehearsal develops earlier for pictures than for spoken words, because more effortful processes are required for retaining pictures in STM. However, the reverse pattern was observed here.

3.5. Concluding remarks of Experiments Two and Three

Both experiments were designed as a first step towards exploring the possible relationships between native language and STM development. As this issue and the related research questions were formulated with respect to the working memory model, the starting point of this research was the question of whether word length alone can account for all aspects of the development of memory span, and how the role of strategy change during development may be integrated within the model.

The developmental research conducted over the 80’s and early 90’s with respect to the working memory model revealed developmental shifts in modality effects and word length effects that strongly stress the role of strategy use during development. In addition, the role of strategy efficiency during development has been stressed by several researchers (e.g. Kail, 1990). The aim of the present study was to offer a basis for integrating the concept of flexibility in strategy use with the assumptions of the working memory model.

Do the findings reported in this chapter allow us to evaluate the role of strategies in development? Comparing the effects of modality and word length on recall at each age group suggested differences between the two language groups that were often too complicated to interpret. Perhaps the most straightforward finding was the evidence that Greek children exhibit a phonological similarity effect on picture recall, and a word length effect on picture recall, at a later age compared to English children. This finding alone seems to support the general claim made in the
Introduction that linguistic differences may lead to differences in the patterns of memory span development. To begin with, such differences were not expected to be dramatic. It was assumed that memory structures and mechanisms should be universal and not context-dependent; but that at least their timing could be influenced by external factors, one of which could be native language.

Experiment Three, in particular, was designed to directly explore the possible effect of one language attribute—word length—on the development of memory span. Indeed, the findings of this experiment revealed intricate relationships between native language, age, and word length, which suggested two ideas. First, that native speakers of different languages exhibited different patterns of modality effects and word length effects, at least in terms of chronology; and second, that even within the same language and age group, these effects were related to word length.

The first conclusion could be challenged on the grounds that other factors, such as cultural differences or differences in reading instruction (see Chapter Two), could account for the differences observed between the two language groups. Moreover, although the words used in each language group were chosen to be matched for frequency, the fact that they could not be matched simultaneously on length as well as meaning requires some caution. It could be argued, for example, that semantic features or even phonological features other than word length, may account for the findings.

The most obvious among these possible confounding factors is the spoken duration of a word. In the Greek language, number of phonemes is generally linearly related to phoneme duration, as each phoneme has always the same spoken duration in all words. In English, however, words that have the same number of syllables do not necessarily take the same amount of time to pronounce (e.g. ‘tap’ is a shorter word than ‘cake’). To control for such differences, measures of articulation rate and spoken duration of each word should be recorded. For this reason, the findings
concerning direct comparisons of the two language groups should be treated with caution.

The second finding regarding the use of different strategies within the same language and age group, offers some support to the suggestion that the perceived difficulty of a task does guide, to some extent, the choice of strategies to be used—or not to be used. It was suggested, with regard to the findings on relationships between modality effects and word length, as well as word length effects, that children can adapt their behaviour during a memory task according to task demands. Such a demand here was related to word length. As the perceived task difficulty changes with age, so do the effects observed in memory tasks.

Therefore, although several alternative explanations can be offered for the effects observed, the two main conclusions considered together seem to support a tendency of Greek children: (1) to rely on visual information for longer than English children, (2) to use visual information in flexible ways, especially for words that they considered to be longer and therefore more difficult to remember. It should be noted that this flexibility is not considered to be idiosyncratic to Greek children; it was also observed in English children, but was more manifest in that language group where task demands, word length-wise, were more pronounced.

In addition, it should be stressed that the choice to use one strategy does not exclude the use of other strategies. Verbal and visual strategies, along with other strategies such as elaboration, grouping, or associations, are likely to be used at the same time to different degrees and with a different degree of success (see Bjorklund & Douglas, 1997). The aim of the child is to use all the available resources in order to solve the task with minimal effort; possibly without metacognitive awareness of the efficiency of the resources used. This could explain the complexity of the relationships between age, word length, and native language, observed in Experiment Three.
Obviously, the above suggestions need further exploration. As stressed several times throughout this chapter, examining the effects of phonological similarity and word length in a cross-language context is only a first attempt towards exploring the idea that language attributes may account for some aspects of memory span development. Further studies should consider the possible contribution of other phonological features, mainly phoneme duration; semantic features; and cultural factors besides language. More sensitive measures of strategy use in children are also required to further explore the issue of whether word length, native language, and memory development are related. Suggestions for further research are given in the next chapter.
Chapter Four

Discussion of the cross-linguistic study

4.1. Synthesis of the findings of Experiments One, Two and Three

The three experiments carried out for the cross-linguistic study consisted of comparing Greek and English children aged from 4 to 10 years on a number of STM span tasks. Of particular interest were the effects of presentation modality on recall in the two language groups. These findings are brought together below, and considered with respect to the questions formulated in the Introduction.

Experiment One showed that English children had larger auditory digit spans than Greek children of the same age, and this difference was evident in all age groups. As discussed, this finding agreed with results from other studies (e.g. Ellis & Hennelly, 1980; Hoosain & Salili, 1988; Naveh-Benjamin & Ayres, 1986) and supported the role of item length as a critical factor in working memory.

The same difference was observed for spoken words and pictures in Experiment Two, with English children having larger spans. This was not surprising, as the words on recall of which the language groups were compared differed by one syllable, with Greek words being longer. When, however, the comparison word sets were equaled for length in the two language groups (Experiment Three), this difference was abolished.

However, there was also evidence that factors other than word length came into play: English children had shorter spans than Greek children from age 8 and beyond, and this difference was attributed to possible differences in familiarity with printed numbers. This finding also agrees with evidence from bilingual studies suggesting the role of fluency in STM performance (e.g. Chincotta & Underwood, 1996, 1997c) and especially with the study by Chincotta et al. (1997) which contrasted number
fluency—as measured by reading times of digits—with articulation time—as measured by reading times of numerals.

Thus, the above findings demonstrate the direct effects of item length on recall. However, of more interest were the findings related to the different coding strategies used by the two language groups. In particular, there was evidence for a greater reliance of Greek children on visual coding, in contrast to English children of the same age who relied more on verbal coding. This pattern was expressed as:

(a) larger Corsi spans of the Greek group compared to the English group;
(b) a verbal advantage for digits in the English group, but no modality effect on digit recall in the Greek group;
(c) recall of spoken digits being equal to or better than recall of Corsi blocks in English children, and the reverse for Greek children, interpreted as a prolonged pattern of the visuo-spatial-verbal dissociation in the Greek group compared to the English group;
(d) a spoken word advantage in the English group, but a lack of a modality effect in the Greek group (Experiment Two);
(e) a gradual change in the direction of the modality effect from a picture advantage towards a spoken word advantage, as a function of increasing word length, in both language groups (Experiment Three);
(f) a change in the association between a particular word length and the direction of the modality effect as a function of increasing age—with the picture advantage being shifted towards longer words with increasing age—apparent in the Greek group but not in the English group (Experiment Three).

The dependence of these modality effects on age agree with the model of coding strategy development suggested by Palmer (2000). She proposed that visual coding alone precedes dual coding, which is succeeded by verbal coding as verbal strategies become more efficient with age. This pattern was, indeed, also observed here in both language groups, but with a time lag of about two years between the two. In addition to the findings cited above, this time lag was also evident as:
(a) A chronological difference between the two language groups in the emergence of the phonological similarity effect on picture recall, as the effect was detected earlier in English children;

(b) A chronological difference between the two language groups in the emergence of the word length effect on picture recall, again with the effect observed earlier in the English group.

On the whole, therefore, the findings from all three experiments supported a difference in the use of verbal and visual strategies in the two language groups. It also appeared that the patterns of performance were very similar in the two language groups; what differed was the age at which they were observed. Does this mean that verbal processing in Greek children is delayed, or even non-efficient, in comparison to English children? Two findings, observed in both language groups, suggest that this is not the case; instead, as Mistry (1997) points out, a preference of children for a particular strategy does not mean that they are not able to use another.

The first finding suggested that what children did during the word span tasks was to switch coding strategies according to the difficulty of the task: the longer the words to be remembered, the more likely they were to avoid using verbal strategies. This was most evident in the Greek group, where a wider range of word lengths was used; furthermore, the Greek children opted for verbal strategies in order to remember increasingly longer words, as they grew older.

The second finding requires to be explored further, as it raises questions about what the word length effect really reflects. Besides the obvious explanation, that it reflects the time-limited capacity of the phonological loop, could it also reflect a differential use of verbal processing for short and long words, at least in children? A word length effect observed or recall of 1- and 3-syllable words, for example, means that longer words take longer to articulate and are, therefore, less well remembered. Alternatively, it could mean that 1-syllable words are rehearsed, while 3-syllable words are not. The finding that both language groups showed a word length effect up to a particular word length, and that this length limit increased with age, seems to support this alternative explanation.
The flexibility observed in these two findings agrees with results from studies indicating the simultaneous presence of visual and verbal strategies in the same individual, in adults (e.g. Brandimonte, Hitch, & Bishop, 1992) and in children (Hitch, Woodin, & Baker, 1989; Palmer, 2000). The presence of a visual component in strategy use at all ages was also suggested in Experiment Two, by an overall significant visual similarity effect. As discussed, the effect could not be detected in individual age groups. Hitch and his colleagues suggest that the visual similarity effect may be masked by the stronger contribution of verbal strategies to STM span.

This flexibility also suggests that even very young children are able to allocate different resources and inhibit others according to task demands: apply verbal strategies to remember shorter words, and visual strategies to remember longer words. Thus, the differences between the two language groups cannot be interpreted as a delay in the maturation of verbal strategies in Greek children, but as a functional use of the resources available to this group; this ability is related to the function of the central executive (e.g. see Baddeley, 1996).

Again, the question arises of whether the cross-linguistic differences in STM performance really are the direct result of differences in word length. This issue cannot be resolved solely on the basis of the results of these experiments. As discussed in Chapter Two, a strong alternative possibility is related to differences in literacy skills between the two language groups, which, of course, may reflect linguistic differences. In other words, educational programmes related to the teaching of reading and writing, exposure to visual material in school, or even explicit teaching of learning strategies may differ between the two countries. This possibility should be considered in future research (see below).

Whatever the underlying factors that may account for the cross-linguistic differences, the experiments presented in this thesis led to several interesting conclusions with regard to the development of short-term memory: STM capacity is not simply time-related, but also controlled by the ability to use strategies in a flexible manner; even more interestingly, young children seem to possess this ability.
4.2. Suggestions for further research

The study reported in this thesis was a starting point towards revealing possible differences in the development of STM ability in children. Such differences were shown, and were interpreted within the framework of the working memory model. As discussed elsewhere, the underlying reasons for these differences could be found in differences in literacy acquisition. Future experiments, therefore, should include a measure of reading ability as well as more detailed analysis of reading strategies when comparing STM performance in the two languages. Information about differences in the curriculum should also be considered.

The possibility that children spontaneously adapt their use of STM strategies to language constraints remains plausible. To further explore this, more STM comparisons between the two languages should be conducted. Below are suggestions for the follow-up of the experiments reported here.

(a) As discussed in Chapter Two, the Corsi test involves various processes, making it difficult to interpret the pattern observed in Experiment One. A further experiment could contrast verbal, visual, and spatial span in the two languages, selecting tests that allow a distinction between visual and verbal abilities (e.g. pattern span; see Della Sala et al., 1999, or a selection of verbal and spatial memory tasks from the K-ABC: see Conant et al., 1999). Comparing the language groups on such tasks, and examining the relationships between performance and reading ability would provide useful information about developmental differences related to native language or literacy. Recording children’s strategies, either through questionnaires or by using interference tasks or error analysis would also provide information on whether and when visual and spatial tasks begin to involve verbalisation strategies.

(b) The modality effects related to auditory and visual digit span could be studied further, taking into account numeracy skills and familiarity with numbers. A direct measure of this could be the time taken to read printed digits. This could be contrasted to the time taken to articulate the names of the digits, as in Chincotta et al.
(1997). This contrast would elucidate the role of time factors (articulation rate) and long-term factors (number knowledge) in digit span.

(c) Verbal strategies should be studied qualitatively within each language group. The word length effect alone does not necessarily imply use of rehearsal. Measuring articulation rates, and including articulatory suppression in the studies would provide more direct evidence about the use of rehearsal. Measuring articulation rates also provides more robust evidence about linguistic differences that may affect memory span.

(d) Studying differences in coding strategies between the two languages should include a more sensitive measure of visual similarity. However, visual similarity effects are not the only way of showing the involvement of visual coding. The performance of the children in Experiment Two suggested that they switched between visual and verbal strategies according to word length. This flexibility should be further studied in other contexts, both in English and Greek children. For example, rated word frequency or age of acquisition could substitute word length to study modality effects. If such effects were observed, this would support the idea that coding strategies are selectively applied according to task difficulty.

(e) The pattern of the word length effects observed in Experiment Three should also be further explored, to investigate the possibility that children may use verbal rehearsal for shorter words, but not for longer words when they are presented as pictures. This could be done by using articulatory suppression, which abolishes the word length effect. If the children use a rehearsal strategy for short but not for long words, then articulatory suppression used during short word recall only, but not during recall of long words, should completely abolish the word length effect. If, however, they use verbal rehearsal for both sets of words, then the effect would not be abolished; it would be attributed solely to recall of the long words. A control condition with no articulatory suppression, which would produce the word length effect, should be included.
(f) Developmental differences between the two languages would be shown more clearly if a longitudinal study were conducted. Again, a consideration of educational factors would be necessary. The developmental changes in STM could also be studied along with vocabulary development.

(g) Finally, testing the two language groups on a variety of STM measures would allow the building of a model of STM development. Kail (1997) used structural equation modelling to explore the relationships between age, general processing speed, and various measures of STM span as well as articulation rate and imagery skill. It would be interesting to conduct a similar analysis in a cross-linguistic study, and possibly add factors related to native language or literacy.

4.3. Concluding remarks

The cross-linguistic experiment provided evidence about the possible role of native language in STM performance in children. It also explored ways in which children cope with factors which, according to the working memory model, may impose constraints on memory performance. As mentioned in the Introduction to the thesis, another way to explore this issue is to study children with Down syndrome, for whom there is evidence for STM and language difficulties. This approach is discussed in the second part of the thesis, which begins in the next chapter.
Chapter Five

Short-term memory in Down syndrome

5.1. Overview of the Chapter

As mentioned before, the main aim of this thesis was to identify possible effects of contextual factors on the use of STM strategies in children. In the previous chapters, native language was considered as one of the factors that may impose constraints on STM span, and thus affect the course of memory development. In the second part of the thesis, learning difficulties will be considered as another factor that may affect STM. This possibility will be explored in people with Down syndrome, a population with specific language and memory difficulties. As will be seen, individuals with Down syndrome experience difficulties in verbal STM tasks, while there is adequate evidence to suggest that their visual processing skills are relatively intact. The central question addressed will be, therefore, whether this dissociation between visual and verbal STM observed is, or can be, exploited in strategy use to compensate for verbal memory difficulties. Exploring this question will not only illuminate further the nature of the memory difficulties in Down syndrome, but also provide information about the malleability of STM mechanisms over development.

This review will, therefore, focus on the STM development of young individuals with Down syndrome, with an emphasis on their visual memory abilities. Following a brief description of the syndrome and its associated characteristics, the evidence that Down syndrome is characterised by a specific deficit in verbal as opposed to visuo-spatial memory will be discussed within the framework of the working memory model (Baddeley, 1986, 1990). Related issues will be addressed, namely: whether the memory impairments observed in this population are the result of a specific, "syndrome-related" deficit, or rather associated with their global learning
difficulties; what is the relationship between their hearing and speech difficulties and their memory; and how the potential areas of strength could be further explored and enhanced through teaching memory strategies.

5.2. Down syndrome: incidence, aetiology, and description

5.2.1. The genetic basis of Down syndrome

Down syndrome is one of the most common conditions of learning difficulties, having an incidence of about 1 in 1000 births (Steele, 1996) and constituting about 30% of the population of people with severe mental retardation (Smith & Philips, 1981). It also is the most common form of learning difficulties associated with a chromosomal abnormality (Simonoff, Bolton, & Rutter, 1998). In particular, Down syndrome is caused by a trisomy, an extra copy of all or part of chromosome 21. This trisomy is usually present in all the cells of an individual with Down syndrome, but in about 1-4% of the cases—thought to be milder cases—only a portion of the cells are trisomic, a condition called mosaic trisomy 21 (Gibson, 1978; Thuline & Pueschel, 1982).

In about 95% of the cases, trisomy 21 is caused by nondisjunction of chromosome 21 during cell division, leading to an extra copy of the whole chromosome. Nondisjunction is strongly associated with maternal age, as the incidence of the condition increases from about 0.9 per 1000 live births in mothers under the age of 33 to 38 per 1000 live births in mothers older than 44 years (Trimble & Baird, 1978; also see Lilienfeld, 1969). It is less clear whether nondisjunction can occur in paternal germ cells (e.g. Erickson & Bjerkedal, 1981; Olshan, Bard, & Teshke, 1989).

About 4-6% of the cases with Down syndrome are due to translocation of a part of chromosome 21 (Scully, 1973). In this case Down syndrome may be inherited; the heritability of the condition depends on the nature of the translocation. Studies on
translocation have contributed to the mapping of the genes that may be associated with the phenotypic profile of Down syndrome (e.g. Patterson, 1992). However, although several physical conditions associated with Down syndrome have been related to specific loci on chromosome 21 (e.g. Epstein, 1990), the relationship between learning difficulties and the genetic profile of Down syndrome remains unclear. It is possible that the mechanism responsible for causing learning difficulties in Down syndrome originates from a general imbalance in gene—and protein—dosage (Epstein, 1986, 1989).

The above brief account of the genetic basis of Down syndrome leads to two general conclusions that are particularly relevant in the present discussion regarding the STM abilities of these individuals. First, it can be suggested that the memory difficulties of people with Down syndrome have a biological basis. Whether these difficulties are directly related to a specific neurological profile and possibly to a specific genotype, or are secondary to other cognitive difficulties such as language, is less clear. Nevertheless, what is important here is the suggestion that the cognitive profile of individuals with Down syndrome has a fixed component that is very likely to impose constraints to their development.

Second, the genetic variability observed in Down syndrome is reflected in the wide range of abilities observed in this population. This variability is further enhanced by the contribution of environmental factors, as in typically developing individuals. For example, the mental age of individuals with Down syndrome ranges from the moderately to the severely retarded range (IQ = 25-55) but can also extend to the mildly retarded and even to the normal range (Simonoff et al., 1998), reaching a maximum mental age of 7 to 8 years (Gibson, 1978). A wide range of abilities is also evident in language (Fowler, 1995), with some single cases of exceptional language development (Rondal, 1995; Vallar & Papagno, 1993).

The first conclusion suggests, therefore, that the STM difficulties of individuals with Down syndrome may be attributed to biological factors that impose a disadvantage
in this population. However, the second conclusion implies that the severity of this disadvantage varies from one individual to the other; and perhaps more importantly, that it may be alleviated through environmental intervention.

5.2.2. Cognitive profile of individuals with Down syndrome

Down syndrome is characterised by several physical characteristics and associated conditions. These include a characteristic facial appearance and a number of medical conditions that occur with a high prevalence in this population; congenital heart disease, motor problems, ophthalmic disorders, and hearing loss are the most common (see Roizen, 1996, for a review). The present section will only present those problems that are or may be associated with cognitive abilities, particularly language and memory.

5.2.2.1. General cognitive ability

Down syndrome is associated with general learning difficulties, expressed as a progressive decline of IQ over the course of development (Hodapp & Zigler, 1990). In other words, the difference between chronological age and mental age increases from childhood to adolescence. As mentioned above, there is a great variability in general cognitive ability in Down syndrome, with IQ mostly ranging between 25 and 55 (Simonoff et al., 1998). As with typically developing children, general cognitive ability in Down syndrome depends on the interaction between heritable and environmental factors, namely parental IQ and education (e.g. Loehlin & DeFries, 1987). As Carr (1992) notes, environmental intervention in Down syndrome can lead to increases in IQ, even during adulthood.

The progressive decline of IQ in Down syndrome suggests that the developmental approach is applicable in this population (see Cicchetti & Beeghly, 1990). According to the developmental approach (Zigler, 1967), learning difficulties reflect a delay in development, but do not differ in quality to typical development. In particular, this
view accepts the following hypotheses: first, that individuals with learning difficulties follow the Piagetian sequences in development. Second, that not only the stages of development but also its structure is common in typically developing children and children with learning difficulties. And third, that the performance of individuals with learning difficulties on cognitive tasks is influenced by personality and motivational factors, which are shaped by their life experiences (Hodapp, Burack, & Zigler, 1998; Zigler, 1971). Based on these principles, the developmental approach considers learning difficulties in a continuum with typical development.

Thus, people with Down syndrome experience learning difficulties that can be accounted for by a general developmental delay. On a biological level, this is reflected by a slowness in processing speed, a generally immature nervous system, and a markedly reduced size and weight of the brain (see Coyle, Oster-Granite, & Gearhart, 1986). However, it is not clear how gross anatomical abnormalities in the nervous system result in learning difficulties, or how a generally slow rate of development accounts for the specific cognitive profile observed in the syndrome. Specific cognitive characteristics are presented in the next section.

5.2.2.2. Specific cognitive processes

Although the developmental approach seems adequate to account for learning difficulties in Down syndrome, it can also be complemented by a neuropsychological perspective which considers specific patterns of strengths and weaknesses in cognitive functions. As Pennington and Bennetto (1998) point out (p.106), what differs in learning difficulties is not only the level of ability, but also the structure of cognitive processes. The developmental approach should, therefore, be able to explain neuropsychological mechanisms in children with learning difficulties as well as in typically developing children.

As will be seen below with respect to the memory difficulties of individuals with Down syndrome, there seems to exist a specific cognitive profile with dissociations
within the STM system. Similarly, dissociations unique to Down syndrome can also be found within other cognitive domains, namely language. These relative strengths and weaknesses are briefly presented below.

A general dissociation between verbal and nonverbal abilities has often been reported in Down syndrome (e.g. Fowler, 1990; Miller, 1987). This disparity between language abilities and nonverbal abilities has also been contrasted with the reverse pattern observed in Williams syndrome (Mervis & Bertrand, 1997).

However, the language difficulties experienced by individuals with Down syndrome are not generalised, but focused on problems in phonological skills (e.g. Kumin, 1994), articulation (e.g. Hulme & Mackenzie, 1992), vocal imitation (e.g. Dunst, 1990) and expressive language, especially syntax (e.g. Fowler, 1998). Conversely, receptive language, semantics, and pragmatics are relatively spared (Fowler, 1998).

These specific difficulties could be accounted for by anatomical, perceptual and motor problems that are associated with Down syndrome. Thus, articulatory problems could be attributed to the characteristic structure of the mouth and vocal tract, that restricts tongue movements (Hulme & Mackenzie, 1992) as well as to difficulties in planning and executing motor programmes (e.g. Frith & Frith, 1974; Wishart, 1988). Hearing difficulties, strongly associated with Down syndrome (see Marcell & Cohen, 1992; Marcell, 1995) could also account for phonological problems. However, research does not seem to support a relationship between hearing difficulties and language development in Down syndrome (Miller, Leddy, Miolo, & Sedey, 1995). Finally, as Fowler (1998) suggests, phonological difficulties might, in turn, account for problems in syntactic skill.

The above outline of the linguistic profile of Down syndrome suggests that general developmental delay as well as conditions that are specifically associated with Down syndrome can selectively affect particular cognitive domains. As will be discussed, this interplay between general and specific cognitive difficulties is important for identifying strengths in cognitive processing and for considering the ability of
individuals with Down syndrome to use these strengths beneficially. This issue, however, will be addressed with respect to STM, which is reviewed below.

5.3. Exploring STM difficulties in Down syndrome

5.3.1. Studying STM in individuals with learning difficulties

It has been well documented that people with learning difficulties have memory deficits, particularly in STM, that are central to their cognitive problems. Belmont and Butterfield (1969) concluded that STM relates directly to intelligence and that people with mental retardation have notable difficulties in retaining information in STM. They rejected forgetting rate as a possible explanation and suggested that inadequate encoding strategies, as well as difficulties in retrieval, might account for poor STM performance. Specific STM difficulties in auditory serial recall have also been associated with learning difficulties (e.g. Marinosson, 1974). It has been suggested that general difficulties in executive functions which affect the use of strategies can account for these STM difficulties: the role of mental effort and language skills in the acquisition of information has been discussed with respect to learning difficulties (see Bebko & Luhaorg, 1998).

However, as has been mentioned above, there is also evidence for a distinct memory profile in Down syndrome. To explore whether individuals with Down syndrome show a specific pattern of STM performance that is peculiar to this population or, rather, have similar STM to individuals with general learning difficulties, many studies have included a control group of individuals of learning difficulties with mixed or unknown aetiologies. Identifying differences in STM performance between Down syndrome and other groups with learning difficulties is important for designing educational and memory training programmes with specific targets.

As will be seen, a plethora of studies on memory in Down syndrome have explored effects of modality on STM performance. A number of studies have detected
differences in performance between subtests of psychometric scales (e.g. Marcell & Armstrong, 1982). Other studies have focused on verbal and visual STM tasks, such as digit span and Corsi span (e.g. Jarrold & Baddeley, 1997). Phonological and visual similarity effects and word length effects have been studied to explore working memory in Down syndrome (e.g. Broadley, MacDonald, & Buckley, 1995). Finally, training studies have contributed in identifying and improving specific STM weaknesses. This research is reviewed below.

5.3.2. Exploring STM in Down syndrome by using psychometric tests

5.3.2.1. Effects of modality

As mentioned above, a number of studies have tested the performance of people with Down syndrome on a range of psychometric scales. One of the older studies of this kind was carried out by Bilovsky and Share (1965) who tested people with Down syndrome on the Illinois Test of Psycholinguistic Abilities (ITPA). Using two memory subtests from the scale, they found a particular deficit in auditory sequential memory as compared to visual memory. Rohr and Burr (1978) carried out a similar study using the same test. Again, the children with Down syndrome presented a consistent pattern of performance, with the worst performance on verbal/auditory subtests and better performance on the visual test. They were also found to be impaired in auditory/verbal tasks as compared to children with other learning difficulties.

However, as Marcell and Armstrong (1982) point out, the ITPA auditory and visual memory subtests differ in the complexity of instructions, kind of stimuli (digits and abstract designs), rates of presentation, modality of required response, and required processing of information (sequential and simultaneous). These may be confounding factors when studying the effect of input modality on performance. Marcell and Armstrong administered the same subtests when controlling for these variables. They first administered the ITPA test to children with Down syndrome, replicating
the visual superiority findings of previous studies. This pattern of performance was
the same for different age groups within the Down syndrome sample.

Visual and auditory digit span tasks from the Wechsler Intelligence Scale (WISC-R)
were then administered to children with Down syndrome and to typically developing
children matched for mental age. The typically developing children were better at
the auditory condition, while performance was equal for visual and auditory
presentation in the Down syndrome group. The results did not depend significantly
on sequential recall.

Although, unlike previous ITPA studies, there was no visual superiority for the
Down syndrome group, nevertheless the lack of a modality effect showed a difficulty
in retaining auditory material, which was independent of the sequential nature of the
task. Possible explanations for this were discussed by Marcell and Armstrong,
including greater susceptibility to auditory distraction in Down syndrome, storage
difficulties in echoic memory, rapid decay of information stored in echoic memory,
or failure to rapidly retrieve information from echoic memory.

Studies using items from the Stanford-Binet (SB) test have also indicated the
possible strengths and weaknesses of people with Down syndrome. Silverstein,
Legutki, Friedman, and Takayama (1982) compared a group of institutionalised
people with Down syndrome with a group of institutionalised people with other
learning difficulties, matched on mental age and age of admission at the institution,
on items selected from the SB scale. Overall, people with Down syndrome
performed better in tasks that depend on visuo-motor ability, while they were
relatively impaired in verbal tasks. However, as Silverstein et al. (1982) point out,
the subtests also differ in the nature of their instructions and required responses;
visuo-motor ability tasks require modelling of the researcher's actions (block
building, drawing) while verbal tasks rely heavily on language ability and require a
verbal response (digit span, categorisation tasks). It is therefore difficult to conclude
which factors account for the differential performance of the Down syndrome group.
A more recent version of the SB scale (SB4) was used by Bower and Hayes (1994) to assess a range of abilities, including STM, in children and adolescents with Down syndrome and children and adolescents with nonspecific intellectual disabilities matched on CA, IQ, gender, and socioeconomic status. Overall, individuals with learning difficulties scored lower on STM measures than on other tasks (verbal, visual and quantitative) indicating that memory deficits are a core area of weakness in learning difficulties. Lower STM measures were obtained for the children with Down syndrome as compared to the general learning difficulties group, with significantly lower performance by the former on auditory tasks, digit span and memory for sentences, and similar performance for the two groups on the visual tasks (bead memory and memory for objects). However, within the Down syndrome group, no significant differences were found between performance on visual and auditory tasks. As Bower and Hayes note, this may be due to the small number of participants rather than a real absence of modality effect on memory.

Another study that focused on the general processing abilities of children with Down syndrome was carried out by Pueschel, Gallagher, Zartler, and Pezzullo (1987), using the K-ABC. Pueschel et al. administered the simultaneous and sequential processing scales of the K-ABC to children with Down syndrome and two control groups. The first control group consisted of typically developing children which were the younger siblings of children in the Down syndrome group, while the second group consisted of typically developing children who were unrelated to the children in the Down syndrome group. All groups were matched on mental age. Both control groups performed better than the Down syndrome group on both the sequential and simultaneous scales, but in none of the groups were there any differences in performance between sequential and simultaneous processing. However, more detailed analysis of the data for specific subtests showed that children with Down syndrome performed better on visual-vocal (Gestalt closure) and visual-motor (hand movement) tasks than on auditory-vocal (digit span) and auditory-motor (word order) tasks, again suggesting an auditory weakness in this population.
5.3.2.2. Sequential versus nonsequential processing of information

As was seen in the previous section, many studies have also addressed the question of whether the memory deficits of people with Down syndrome reflect a more global difficulty of processing information in serial order. This issue has been tackled in further studies. As mentioned above, Pueschel et al. (1987) contrasted simultaneous with sequential processing in children with Down syndrome but did not find any significant differences (see also Pueschel, 1988). Varnhagen, Das, and Varnhagen (1987) tested individuals with Down syndrome and individuals with general learning difficulties on auditory and visual span for letters, auditory serial recall for words, and memory for designs. Although the Down syndrome group had poorer auditory serial recall than the learning difficulties group, memory for order of the items did not differ in the two groups.

More recently, Kay-Raining Bird and Chapman (1994) further explored the assumption that the auditory deficit depends on the sequential nature of recall. They tested children with Down syndrome and typically developing children, matched on mothers' educational level and on performance on the Bead Memory and Patterns Analysis subtests of the SB4. The tests administered were a narrative task from the Peabody Picture Vocabulary Test-Revised (PPVT-R), an auditory digit span task from the ITPA, and the bead memory task plus the pattern analysis test from SB4. In addition, the Test of Auditory Comprehension of Language - Revised (TACL-R) was administered, and measures of speech rate were also recorded.

Of particular interest were the effects of order recall on performance of the Down syndrome group. Overall, however, ordering errors were the same for the two groups. The Down syndrome group remembered less information than the comparison group on the narrative task; they achieved lower scores on the auditory digit span task, but performed equally well on the bead memory task—as expected, since they were initially matched on this measure to the control group; but their lower performance in the verbal tasks was not a function of errors in order of the
items. Within the Down syndrome group, a visual memory superiority effect for the bead memory task was found, while the control group performed equally well on the visual and auditory task. Finally, although the control group had longer bead memory spans than the Down syndrome group, ordering errors were similar when sequencing performance analysis was carried out for whole bead, or for bead colour. For bead shape, however, the Down syndrome group made in fact fewer errors than the controls.

In addition, when correlations between tasks were computed, the only significant relationships were found between auditory spans, visual spans, and amount recalled in the narrative task, for the Down syndrome group only. However, when cognitive level and speech rate were partialled out, only the relationship between auditory span and story recall remained significant. This indicated a relationship between memory and expressive language abilities in this group.

In summary, the presence of an auditory/verbal deficit in Down syndrome was confirmed in this study. However, this deficit was not dependent on the sequential nature of the tasks. Therefore sequential processing does not appear to be the cause of this deficit. As to possible explanations for the verbal deficit, Kay-Raining Bird and Chapman (1994) consider the possibility of a failure to use rehearsal. Although they found that the verbal measures were independent of speech rate and cognitive level, they point out that this may be due to the way they measured speech rate, thus leaving open the possibility of a deficit in rehearsal mechanisms. Another possibility they suggest is poor comprehension and more specifically a slow rate of comprehension processing in the verbal tasks. If this is the case, they suggest that it be taken into consideration in educational programmes and propose alternative teaching methods that are based on the visual advantage by providing visual aids to learning.
5.3.2.3. Summarising the findings from psychometric tests

In summary, there are a number of studies based on STM tasks, mostly span tasks with auditory and visual presentation that have explored modality and ordering effects in Down syndrome. Thus, there is adequate documentation on the auditory deficit in Down syndrome, as demonstrated by digit span (Bower & Hayes, 1994; Marcell, Harvey & Cohran, 1988; Marcell & Weeks, 1988; Snart, O'Grady, & Das, 1982), letter and word span (Varnhagen et al., 1987) and memory for sentences (Bower & Hayes, 1994; Marcell, Ridgeway, Powell, Sizemore, & West, 1991). The picture is less clear when evidence for modality effects is discussed. In particular, it is not clear whether the differences in performance between visual and auditory tasks observed in most studies reflect a genuine visual advantage or merely an auditory deficit. The failure of people with Down syndrome to show an auditory advantage as typically developing children do (Conrad, 1971; Hitch, Halliday, & Littler, 1993; also see Gathercole & Baddeley, 1993) suggests an auditory/verbal deficit. It is less evident, however, whether visual memory is as good as in typically developing individuals. Marcell and Armstrong (1982) for example, found equal performance in both modalities for the Down syndrome group, and so did Bower and Hayes (1994) and Marcell and Weeks (1988). Similar findings are reported for auditory and visual word spans by Varnhagen et al. (1987). On the other hand, Pueschel et al. (1987), Rohr and Buhr (1978), and Silverstein et al. (1982) do find generally worse performance in verbal tasks. Finally, Kay-Raining Bird and Chapman (1994) did find that the Down syndrome group were better at the visual task than the digit span task, but still they scored lower in the visual STM task compared to the control group. As mentioned above, all these studies used different tests and designs, making it difficult to conclude a clear pattern of memory performance for Down syndrome.
5.3.3. Contrasting verbal and nonverbal span tasks

Contrasting digit or word spans with auditory and visual presentation has the advantage that the stimuli are the same and what is manipulated is modality of presentation only. However, in these tasks visual presentation is not necessarily purely visual, since the stimuli can be encoded both verbally and visually (see Paivio, 1971; 1986). A number of studies have compared auditory digit span with Corsi block span (Milner, 1971) that reflect verbal and visuo-spatial STM respectively. Again, results are contradictory, since control groups and the ages of participants vary. Moreover, not all studies using this contrast have reported the significance of any differences in performance between the two tasks. Two studies with adults (Azari, Horwitz, Pettigrew, Grady, Haxby, Giacometti & Schapiro, 1994; Haxby, 1989) have shown superior Corsi span to digit span in young adults. However, Vicari, Carlessimo, & Caltagirone (1995) testing children with Down syndrome as well as a group of MA-matched children with learning difficulties, found similar spans within the Down syndrome group as well as compared to the control group. Fowler, Doherty, and Boynton (1995), on the other hand, report slightly better performance on the Corsi blocks by individuals with Down syndrome. Wang and Bellugi (1994) found evidence for a double dissociation between verbal and visuo-spatial STM when comparing a group of children with Down syndrome with children with Williams syndrome. Children with Down syndrome had lower digit spans but higher Corsi spans than children with Williams syndrome, and had overall slightly better Corsi scores than digit spans.

Jarrold and Baddeley (1997) carried out a more controlled study to explore verbal and visuo-spatial STM in children with Down syndrome within the working memory model. They tested a group of children with Down syndrome, a group of children with general learning difficulties, and a group of typically developing children matched for vocabulary level on the BPVS. In addition, the Down syndrome group was tested on general measures from the Differential Ability Scales (DAS) to establish verbal and performance mental ages, and on auditory sensitivity.
(McCormick Toy Discrimination Test). As expected on the basis of previous studies, the Down syndrome group had a lower mean digit span than the control groups. However, no differences were found for Corsi spans between the Down syndrome group and the controls. Moreover, analysis of scores within each group showed superior performance on the Corsi task for the children with Down syndrome, though only when ordering errors were not taken into account, and the reverse pattern was established for the control groups. Further, correlational analyses showed that verbal mental age in Down syndrome did not correlate with digit span, nor did nonverbal age correlate with Corsi span. Hearing sensitivity, on the other hand, correlated with BPVS scores and the picture similarities subtest of the DAS, but not with digit span.

Jarrold and Baddeley (1997) discussed these findings within the framework of the working memory model, suggesting that children with Down syndrome have a specific verbal memory deficit. They further rejected the possibility that this discrepancy between verbal and visuo-spatial STM scores is due to a superiority of nonverbal abilities. If this were the case, then correlations between MA measures and memory scores would be expected, but no such links were found. Furthermore, although a superiority of nonverbal versus verbal ability scores was found in the DAS measures, it was due to one subtest only. Finally, since the groups were matched on verbal ability, the performance of the Down syndrome group indicated a specific verbal deficit rather than a nonverbal advantage.

Another possibility considered by Jarrold and Baddeley was that performance of the Down syndrome group on verbal STM is due to reduced hearing sensitivity. However, although hearing problems in Down syndrome do correlate with sentence repetition, language comprehension, and word identification (Marcell, 1995), and possibly affect STM span (see Henry & Millar, 1993, for effects in typically developing children), no correlation between hearing sensitivity and digit span was found. Having considered these possibilities, Jarrold and Baddeley (1997) considered the hypothesis that the specific memory deficit manifested in Down
syndrome is due to an impaired phonological loop in working memory, possibly a failure to use rehearsal. This would explain the lack or reversal of the modality effect in Down syndrome, evidenced in many previous studies.

5.3.4. Exploring the phonological loop in Down syndrome

The impairment in the phonological loop mentioned above needs further exploration. For one thing, it is important to investigate whether the deficit lies in the storage component or the active rehearsal process of the phonological loop. To differentiate between these two components, many studies have been based on the phonological similarity and word length effects that are thought to reflect storage and rehearsal processes respectively (see Chapter One).

Varnhagen et al. (1987) included a phonological similarity condition in their letter span tasks. If people with Down syndrome have a deficit in the phonological loop, they would be expected not to show an phonological similarity effect. This was indeed the case. Conversely, the learning difficulties group did show an phonological similarity effect. This difference again indicates a deficit peculiar to Down syndrome. Varnhagen et al. suggest that their results reflect a deficiency in both retrieval and storage in STM, a conclusion consistent with earlier findings (Marcell & Armstrong, 1982; McDade & Adler, 1980). Having also recorded word identification times, they found that individuals with Down syndrome had particular difficulty in accessing words and that for this group only, this correlated with their memory span, especially visual span. Thus, although in typically developing children there is evidence that articulation rate is a better predictor of span than visual identification time (Hitch, Halliday, & Littler, 1989), it seems that in Down syndrome lexical access could partly account for their STM difficulties.

Broadley et al. (1995) tested a group of children and adolescents with Down syndrome on visual and auditory digit span and on visual and auditory word span, including word length and phonological similarity conditions. Effects of visual
similarity were also explored. The participants were also tested on a rhyme oddity test, a measure of phonological awareness.

Although no significant modality effect was found for the word spans, visual digit spans were longer than auditory digit spans. There was also an effect of age on memory span, with the older children having longer spans than a younger age group. Word length, phonological similarity, and visual similarity effects were also significant for all ages. Finally, there was a weak relationship between phonological awareness and memory spans, though the stronger, if not significant, correlation appeared for auditory spans.

The results, therefore, seemed to suggest that individuals with Down syndrome are using rehearsal when remembering both auditorily and visually presented material (hence the word length effect in both presentation modalities). This, as Broadley et al. (1995) suggest, is consistent with findings from studies with preschool typically developing children (Hitch, Halliday, Dodd, & Littler, 1989). Another, quite unexpected, finding was that the phonological similarity effect, again evident in both modalities, remained stable across all age groups. Studies with typically developing children have shown that the phonological similarity effect becomes more pronounced in older children for auditorily presented material only (Hulme, 1987), a phenomenon reasoned to reflect the development of rehearsal.

Given the suggestion of a deficient phonological loop in Down syndrome, it should not be expected that children with Down syndrome would use phonological coding and rehearsal to remember information; but Broadley et al. (1995) found a very similar pattern of performance between children with Down syndrome and that found by other researchers for typically developing children. To explain the phonological and visual similarity results, Broadley et al. proposed the possibility that the children use their presumably more developed visual skills to compensate for their auditory deficit, and that they actually recode verbal material to be remembered
into a visual code, possibly mental images. Thus, people with Down syndrome may use an alternative route to rehearsal.

However, a series of experiments reported by Hulme and Mackenzie (1992; also Mackenzie & Hulme, 1987) present a quite different picture. Their studies explored the nature of STM difficulties in learning difficulties, with particular reference to the phonological loop. Hulme and Mackenzie tested three groups: children with Down syndrome, children with learning difficulties of mixed aetiologies, and typically developing children. They first examined correlations between digit span, verbal mental age, and chronological age, to demonstrate the existence of a deficit in auditory memory in both the Down syndrome and learning difficulties groups. They showed that while the three measures were strongly correlated with each other in typically developing children, both the Down syndrome and learning difficulties groups were well behind for their chronological age, and quite behind for their mental age in digit span, correlations between digit span and MA being significant but weak. The lag between chronological and mental age and memory span was also shown in a cross-sectional study which showed that, in contrast to typically developing children, digit span did not increase in line with mental age in the Down syndrome and learning difficulties groups, being about 3 digits on average. Finally, these findings were supported by a longitudinal study where digit span was measured at two years and five years after initial testing. On the whole, a slow but steady increase in mental age, followed by a significant increase in memory scores at five years but not at two years, was observed in the two learning difficulties groups. This increase was still below the one expected for the mental age of the participants.

Having gathered evidence for a deficit in auditory memory in both the Down syndrome and learning difficulties groups, Hulme and Mackenzie (1992) explored possible explanations for it. If the deficit lies in the failure to effectively use the articulatory loop, then one must look at factors that affect retention of material in the loop. One possible factor is speech rate, since slow speech, usually characteristic of
children with learning difficulties, would lead to slow rehearsal, and thus loss of information due to decay.

Hulme and Mackenzie studied the effect of word length, speech rate, and phonological similarity on recall in the same three groups, with three mental age subgroups in each. They showed the expected word length and phonological similarity effects for the normal group, but the word length effect was absent in the other two groups. Interestingly, the relationship between articulation rate and recall was less dramatic in the learning difficulties groups than in the typically developing group. These results could indicate an absence of a rehearsal mechanism, possibly a failure to efficiently use rehearsal strategies. A small phonological similarity effect was present in the two groups, which was attributed to phonological misidentification of the words during retrieval, but not to rehearsal.

Jarrold, Baddeley, and Hewes (2000) considered different explanations for the verbal STM difficulties in Down syndrome, in a group with moderate learning difficulties, and in a group of typically developing children. They found no significant correlations between memory span and performance on a hearing test, suggesting that hearing loss cannot account for STM difficulties in Down syndrome. Neither did they detect a significant relationship between articulation rate and word span. This finding, along with the fact that a probed recall task abolished any word length effects observed when verbal recall was required, implies that none of the groups that took part in their study engaged in verbal rehearsal. The word length effect in Down syndrome could be, therefore, attributed solely to output effects.

As the STM performance of the Down syndrome group was lower compared to the control groups, but none of the groups appeared to rehearse, Jarrold et al. (2000) discussed alternative explanations for the STM deficit in Down syndrome. In the probed recall task the group with Down syndrome appeared to have selectively impaired memory for initial list items, but not for recency items (experiment 2). This suggested that the memory difficulties of the Down syndrome group could be
attributed to a deficit in storage of information. This general storage deficit could, in turn, be attributed either to rapid loss of information from the phonological store, or to reduced STM capacity. Although Jarrold et al. (2000) seem to favour the latter explanation, they also point out that more detailed theoretical models of STM are needed to guide future research that explores the ‘limited storage capacity’ hypothesis in Down syndrome.

5.3.5. Memory training studies

As seen above, explanations other than a rehearsal deficit, such as reduced storage capacity, possibly due to a structural deficit in Down syndrome, also seem plausible. More direct evidence about causal relationships is provided by training studies. If, for example, most evidence points at a deficient rehearsal mechanism as the prime cause of the memory deficits of people with learning difficulties, then it would be important to study the effects of rehearsal training on memory span. However, it should be pointed out that showing beneficial effects of strategy training on STM does not necessarily reveal the cause of the STM deficit; it is possible, for example, that individuals with Down syndrome have a structural deficit in the phonological store, but that they can benefit from learning a range of different strategies not directly linked to the nature of the deficit.

5.3.5.1. Rehearsal training

Hulme and Mackenzie (1992) carried out a rehearsal training study on adolescents with Down syndrome. Digit span and phonological similarity were assessed before and after training. The training took place over two weeks, for ten minutes everyday, and consisted of teaching an overt cumulative rehearsal strategy (Brown, Campione & Murphy, 1974) where the trainee repeats after the researcher a set of successively longer sequences. Retesting at the end of training showed that span increased for the training group, as well as for a control group that was tested repeatedly every week but without receiving training. However, this effect was small for the control group,
suggesting that rehearsal was more beneficial than repeated testing. Furthermore, phonological similarity was found for the trained group only, which indicated the use of rehearsal.

As Hulme and Mackenzie (1992) point out, it would be important to study whether children of younger ages benefit more from training, and whether longer duration of the training is even more effective. Comblain (1994) carried out a training study on three age groups of individuals with Down syndrome: children, adolescents, and young adults, using the same cumulative rehearsal procedure as Hulme and Mackenzie (1992), but with visual presentation of the material to be rehearsed. Training took place over eight weeks, for half an hour every week, and was carried out by the researcher.

The trained group and an untrained control group matched for mental age and memory span were tested at three times after training: immediately after training, six weeks later and six months later. Memory spans for all three age groups in the trained group had increased significantly (by one digit on average) immediately after training, while no significant differences were found for the untrained group. In addition, some individuals of the trained group showed signs of subvocal rehearsal (lip movements) and strategies (using fingers to facilitate recall, as was demonstrated by the researcher during training). However, the trained group failed to produce these behaviours at re-testing after six weeks, and their memory spans decreased. Six months later, spans had decreased even more, but were still slightly higher than pre-training scores.

5.3.5.2. Teaching different STM strategies

More elaborate studies on memory training examined the effects of teaching memory strategies on a range of cognitive abilities. Broadley and MacDonald (1993)—see also Broadley (1994)—conducted a large study on strategy training with a sample of 25 children and adolescents with Down syndrome. They initially assessed the
participants on measures that indicated rehearsal (picture and verbal memory from the McCarthy scales (McCarthy, 1972), visual recognition test from the British Ability Scales (Elliot et al., 1978)), memory tests (visual and auditory word spans with words varying in length, to be recalled verbally or by probe pointing) and measures that indicated organisation of material (semantic categorisation, McCarthy fluency test, and semantic oddity task). Following this, they divided their sample in two groups that were matched for cognitive ability on subtests from the British Ability Scales.

Training took place over six weeks with two 20-minute sessions each week. A cumulative rehearsal technique and a training programme of categorisation and organisation as memory aids were applied for the training group. Either a keyworker (parent, teacher or assistant) or a researcher was assigned to carry out the programme. Half of the training group did the rehearsal training first, and half did the organisation training first.

The results at the end of the training were very straightforward. The groups benefited equally from all measures of rehearsal and organisation. Memory measures improved, but the more significant gains were observed for the visual modality. This further confirms the modality findings reported in other studies (see above). Another important observation in Broadley and MacDonald's study (1993) was that the effectiveness of the training programme very much depended on the flexibility and systematic but relaxed nature of teaching, which proceeded by setting small attainable goals, thus taking into account motivational factors and the children's sense of achievement. It was also found that the subgroup trained by a keyworker benefited more than the group trained by an researcher, who was not in continuous contact with the child and therefore did not have the opportunity to apply the taught strategies in everyday contexts. The success of the programme was further established as the training was replicated twice with new groups of children.
As the greatest rehearsal improvements were observed for the group that had received the rehearsal training last, and a similar, though smaller, pattern was observed for the organisation training, the question arises of how long-lasting and transferable were the strategies and skills learned in that study. Broadley, MacDonald and Buckley (1994) explored this on a follow-up of the trained and a new control group after eight months. The children were tested on the same measures of rehearsal, organisation and word span.

The scores showed that the improvements on rehearsal measures made by the trained group persisted for the visual recognition and picture memory only. The trained and control groups did not differ on verbal memory measures. Training gains also persisted for the word spans, with larger effects for the visual and probe tasks than for the auditory condition. Organisation measures were also significantly higher for the trained group, with the exception of fluency. Overall, although the control group had themselves improved with age since initial testing eighteen months before, the trained group presented a clear advantage on tasks that involved visual processing. Subgroups that had benefited most from the programme were the ones trained by keyworkers and attending mainstream rather than special schools.

A final evaluation of the study attributed its success to the training method that was carried out systematically, the long duration of training, the enthusiasm of the keyworkers, and the general beneficial effect of mainstream school placement on the children's development. However, an eight-month follow-up does not seem adequate to consider the long-term effects of the training; nor is it possible to assess whether the acquired skills are transferable.

5.3.5.3. Long-term effects of memory training programmes and generalisation of acquired skills

Laws, MacDonald, Buckley and Broadley (1995) carried out a three-year follow-up study on a sample of 14 children from the initial trained group of 25. Again, they
assessed the children on the same measures as in the previous studies. At that stage, however, there was no difference in word spans between the trained and a new control untrained group, the whole performance suggesting normal developmental progress alone, and no continued effects of training. The visual memory advantage that had been gained over training also had disappeared, as auditory and visual memory scores did not differ significantly within the trained group. Still, the visual memory scores of the trained children were slightly but significantly higher than those of the control group, while no such difference was found for auditory memory scores.

Although the memory scores of the trained group were still above pre-training scores, the training advantage had not persisted. This was quite expected since the children, according to parents’ questionnaires, had not continued to practise the learnt skills. It also indicates that, however promising and well structured the training programme, the children had not reached the stage of spontaneously applying these strategies into new contexts or inventing their own strategies, an ability that would reflect metacognitive ability.

To directly assess whether the acquired skills could generalise to other tasks, two rehearsal generalisation measures had been taken immediately after training (Broadley, 1994): a memory task for complex instructions, a picture memory test and a face memory task, where the children were asked to learn the names of four faces seen on photographs. On reassessing the children on these skills, Laws, MacDonald, Buckley, & Broadley (1995) found a significant decline in performance for the picture memory test only; scores on the other two tests had not decreased significantly. However, those measures had been introduced after training, so it was not possible to compare with an untrained group. An interesting finding of that study was that reading ability, as assessed on the BAS reading test, proved to be a confounding factor in the comparison of memory scores between the trained and untrained group. As reported above, the groups slightly differ in visual memory scores, a result that could be interpreted as a long-term retained visual memory
advantage of the trained group. However, further analysis showed that the difference in memory scores could be attributed to the higher reading ability of the trained group, and not to the training programme. Beneficial effects of reading were also found for auditory memory. This leads to the assumption that reading instruction may have a causal effect on the development of memory skills, although the nature of this relationship is complex (see Gathercole & Baddeley, 1993).

Laws, Buckley, Bird, MacDonald, and Broadley (1995) further explored this hypothesis. Half of the children that were included in the three-year follow-up study had meanwhile acquired reading skills; therefore it was possible to study the possible changes in language and memory that might have occurred, as suggested by previous reports (Buckley, 1995). As expected, the children that had become readers had significantly improved their vocabulary and grammar knowledge over the non-readers, as assessed by the BPVS (Dunn & Dunn, 1982) and the Test for the Reception Of Grammar (TROG; Bishop, 1983). Nonverbal ability, on the other hand, had not been affected by reading instruction. More interestingly, auditory and especially visual memory performance had improved for the readers. Further analyses showed that these advantages were really gained because of reading instruction, and not because of the kind of school attended: the effects remained when readers and non-readers from similar educational environments were compared.

The mechanisms of learning to read and the interrelations between language, memory and reading skills are not the subject of this review. However, in view of the evidence that visual memory is an area of strength in Down syndrome that could be further enhanced, it is important to take such results into account when thinking about educational applications of memory remediation programmes.

Laws, MacDonald and Buckley (1996) carried out a study to develop a set of memory teaching materials that could be continuously used at school or at home. The training materials consisted of a plastic wallet containing sequences of
removable pictures of varying length that could be replaced by new ones, to teach rehearsal strategies. In this way, words from various categories could be learned, allowing generalisation to occur.

Using these materials, a six-week training programme was carried out, over three 15-minute sessions each week. The children were trained either in school by teachers or assistants, or at home by parents.

Pre- and post-training measures included vocabulary and grammar tests, measures of nonverbal ability and memory measures, including spans for words of varying length, with visual and auditory presentation conditions and verbal or manual response conditions. The children benefited from the training as their memory scores for both auditory and visual presentation conditions increased. However, this improvement was smaller than the one observed in the prolonged training study by Broadley (1994). There was also evidence that those improvements reflected acquired rehearsal skills that were used to learn longer words, and that could generalise on learning new material.

To summarise the findings from studies on strategy training, it seems that people with Down syndrome can benefit from both rehearsal and organisation instructions, the larger gains made for the visual modality. The longer and more systematic the training, the vaster the improvements. The effectiveness of rehearsal training in particular recalls the question of the role of the articulatory loop in the memory problems of people with Down syndrome.

5.3.5.4. Metamemory

Another problem that remains is whether the acquired strategies can be consolidated and used spontaneously in new contexts, and to what extent the new memory skills are applied into everyday tasks. The research presented above suggests that this is
possible if appropriate training materials are used regularly and if memory remediation projects are incorporated into educational programmes.

In their review and evaluation of memory training in learning disabilities, Swanson, Cooney and O'Shaughnessy (1998) make a distinction between programmes that teach "quick-fix" strategies, such as rehearsal and organisation, and "multiple-component" strategies that include a number of memory improvement techniques to meet the knowledge base and abilities of the student. These may include semantic processing, building associations, using mnemonics, imagery and so on (p. 150). As Swanson et al. note, research is still needed to assess which of these methods are most effective for each special population, also taking into account individual differences. In this approach, emphasis is given to the own control processes of the individuals and their awareness of their own memory resources and their effectiveness, known as "metamemory" or "know about knowing and knowing how to know" (Brown, 1975; see Pressley, 1995).

As language difficulties are in general one aspect of the cognitive characteristics of people with Down syndrome (Fowler, 1995) it seems difficult to teach them memory strategies that rely on complex instructions. However, as Broadley's (1994) study shows and as the design of memory teaching materials attempts, systematic training, application of skills on everyday contexts, and encouragement and praise of the children's performance can be promising. There is some evidence that adolescents and young adults with Down syndrome have some understanding, albeit primitive, of memory functions (Vianello, Moniga, Cornoldi and de Beni, 1998) and this understanding can be further exploited to explicitly teach monitoring of memory skills. Vianello et al. (1998) presented a longitudinal study from their larger research programme on metacognition that compared adolescents with Down syndrome to typically developing children matched on mental age, tested three times over eighteen months. They presented two illustrated stories in which the hero either had to remember something, or pay attention to something, to achieve a goal. The participants were asked questions about the cause of forgetting, the strategies that
could be used to avoid forgetting, and so on. As opposed to the control group, the Down syndrome group made little progress on the quality of their statements about memory, being comparable to 4-year-old children; however, they showed a tendency to associate forgetting with time decay, distractions and other external factors. It seems promising to incorporate metamemory training in the form of stories into memory teaching programmes.

5.3.5.5. Visual imagery as a mnemonic strategy

In view of the evidence that individuals with Down syndrome show a relative strength in processing visual information, it seems appropriate to consider the role of visual imagery as an STM strategy in this population. Mental imagery has been recognised as a useful strategy in a variety of contexts, including verbal learning (Bower and Winzenz, 1970; Paivio, 1971, 1986), spatial learning (Kosslyn, 1980; Pylyshyn, 1981), memory performance (Einstein, McDaniel and Lackey, 1989; Frost, 1972) and text comprehension and recall (Billingsley and Ferro-Almeida, 1993; Gambrell and Jawitz, 1993; Oakhill and Patel, 1991). However, it is rather underestimated as a formal instructional strategy (Iodes, 1992). More research is needed to further establish its role in learning, especially in relation to other instructional variables, such as illustrations.

Trudewind, Krebs, and Sievert (1990) studied the effectiveness of an imagery training programme on memory for short stories in a sample of children with general learning difficulties aged from 8 to 13 years. They found that the training was effective only if the instructions to use imagery were accompanied by both pictorial support and metamemory training. This suggests that individuals with learning difficulties are able to generate visual images, but are only able to apply this ability in memory tasks if explicitly instructed to do so. Courbois (1996) also showed that individuals with learning difficulties are able to generate, maintain, and manipulate mental images of relatively complex patterns, although their performance was significantly lower than that of typically developing children matched on mental age.
Courbois also showed that children with learning difficulties with a variety of organic aetiologies performed worse than children with nonspecific diagnosis, highlighting the importance of considering aetiology.

Indeed, although it seems that individuals with learning difficulties as a whole experience problems in the spontaneous production of strategies, it is possible that people with Down syndrome, demonstrating a relatively intact visual processing system in many studies, are more able to benefit from instructions to use this strategy. Simon, Rappaport, and Agriesti (1995) studied the effectiveness of encoding interactive images of objects in a group of adults with Down syndrome and a group of adults with general learning difficulties matched on chronological and mental age. Both groups appeared able to benefit from interactive imagery to an equal extent. However, Simon et al. (1995) point out that any additional visual advantage in the Down syndrome group could be masked by difficulties in lexical access, which was required during verbal recall of the pictures. Further research that contrasts verbal and nonverbal processing at the encoding and retrieval stage could provide more evidence about the usefulness of visual strategies in this population.

5.3.6. Conclusions

The evidence presented above raises several issues related to the nature of STM difficulties in Down syndrome. The studies discussed in this review are summarised below, and the relevant issues are outlined.

5.3.6.1. A specific STM deficit in Down syndrome?

Most studies presented above compared a group of individuals with Down syndrome to a group of individuals with nonspecific diagnosis of learning difficulties. This allowed to explore the possibility of a unique STM profile in Down syndrome. On the whole, the research reviewed above indicated a specific verbal STM deficit in this population. However, Hulme and Mackenzie (1992) did not find any differences
in memory performance between their participants with Down syndrome and their group with mixed learning difficulties. It is possible that such differences were not detected because the two groups were matched on receptive vocabulary level, which is strongly related to STM performance (Gathercole and Baddeley, 1993).

The nature of this STM deficit is not clear. Some studies suggest a structural basis of the deficit, which could be linked to a specific neurological profile (Jarrold & Baddeley, 1997). This structural deficit could be attributed to an impairment of the phonological loop (Jarrold & Baddeley, 1997) or a reduced capacity of the phonological store (Jarrold et al., 2000). Alternatively, the verbal STM deficit could be viewed as part of a more general difficulty in processing verbal information (Fowler, 1998). Most studies (e.g. Kay-Raining Bird & Chapman, 1994) did not support a difficulty in processing information sequentially in Down syndrome. However, it is possible that individuals with Down syndrome find free recall of items easier than retaining serial order, as the latter may require more attentional resources. Various other factors, including hearing difficulties, slow articulation rates, slow processing speed, difficulties in lexical access, or even a more general deficiency in applying memory strategies, could lead to a reluctance or inability to use verbal rehearsal (e.g. Hulme & Mackenzie, 1992). This suggests that the verbal STM deficit in Down syndrome may be due, at least partly, to a functional rather than a structural impairment.

5.3.6.2. A visual STM advantage in Down syndrome?

Many studies reviewed above suggest a superiority in recalling visually presented information compared to auditory information (see Sections 5.3.2 and 5.3.3). It was suggested that individuals with Down syndrome do show a relative strength in processing visual material, and this ability may be unique to this syndrome (e.g. Wang & Bellugi, 1994). However, as this advantage has been demonstrated as superior performance in a range of nonverbal tasks, it is important to further explore which aspects of visual information may facilitate STM performance. For example,
the relative contribution of visual and spatial factors in STM should be studied. Future research could address this issue.

5.3.6.3. Which STM strategies are most effective in Down syndrome?

The training studies reviewed above have showed short term beneficial effects of a variety of strategies, including verbal rehearsal (e.g. Hulme & Mackenzie, 1992), and organisation (Broadley, 1994). It was also shown that these gains are greater and more sustained in the visual modality (Laws et al., 1996). This indicates that, regardless of the causal factors in the STM deficit, STM can be improved via several pathways. Given the evidence for a visual advantage in Down syndrome, it would be interesting to focus on the efficiency of visual strategies in future research. Visual imagery seems a promising option; however, as it involves several complex processes and may rely heavily on verbal ability (see Kosslyn, 1994; Kosslyn, Malikovic, Hamilton, Horwitz & Thompson, 1995) it should first be established that individuals with Down syndrome are able to generate mental images.

Some of the above issues raised are reconsidered and explored in the experiments presented in the next chapter.
Chapter Six

Exploring visual strengths in the short-term memory of individuals with Down syndrome

6.1. Introduction

As discussed in Chapter Five, there is abundant evidence suggesting that individuals with Down syndrome may have a particular deficit in phonological STM. This is apparent as lower phonological STM performance of people with Down syndrome compared to typically developing children matched for mental age (e.g. Jarrold & Baddeley, 1997; Kay-Raining Bird & Chapman, 1994; Marcell & Armstrong, 1982; McDade & Adler, 1980). It is also evident as lower memory performance of people with Down syndrome compared to matched individuals with mixed learning difficulties (e.g. Bower & Hayes, 1994; Jarrold & Baddeley, 1997; Jarrold et al., 2000; Varnhagen et al., 1987), implying that this deficit may be specific to this syndrome.

It is, however, less clear whether visual STM represents an area of strength in this population. As stressed in the literature review, 'strength' does not necessarily mean exceptionally high performance in visual memory tasks, or better performance of individuals with Down syndrome compared to typically developing children of comparable mental age—even if some studies suggest that this may be the case (e.g. Jarrold & Baddeley, 1997). Rather, visual strength is considered here as the ability to use visual information in effective ways, possibly to overcome difficulties in remembering verbal material. This ability, in turn, may be evident as a dissociation between visuo-spatial and verbal tasks: better performance in tasks where processing of visual and spatial information is involved, and relatively worse performance in tasks of a purely verbal nature.
Indeed, several studies show better performance in visual tasks when visual STM measures are contrasted with auditory STM measures within the population of people with Down syndrome (Bilovsky & Share, 1965; Kay-Raining Bird & Chapman, 1994; Pueschel et al., 1987; Silverstein et al., 1982). However, other studies show equivalent scores for auditory and visual STM tasks (Broadley et al., 1995; Marcell & Armstrong, 1982; Vicari et al., 1995). It is therefore less well established whether there is an advantage in STM for visually presented material in this population.

In Chapter Five, different explanations for the nature of this deficit were discussed, ranging from an inability to use verbal rehearsal (e.g. Hulme & Mackenzie, 1992) to a more general, and still unclear, deficit related to the capacity of the phonological loop (Jarrold et al., 2000). Two important conclusions were drawn (see Broadley, 1994; Laws et al., 1995, 1996). First, whatever the underlying cause of the verbal memory difficulties encountered in this population, training to use memory strategies, particularly verbal rehearsal, has led to improvements in memory performance. Second, these improvements are more pronounced and sustained in the visual modality. These conclusions are, in turn, open to further speculation. For instance, the effectiveness of training programmes does not necessarily mean that a production deficiency of memory strategies is responsible for the memory difficulties of people with Down syndrome. It could be that, even if a structural deficit in the phonological store was established as the causal factor, learning to use memory strategies could still provide alternative ways to learning.

Therefore, if, as suggested in the literature review, the visuo-spatial component of working memory is relatively intact in this population, this could be exploited for designing more effective memory training programmes. In other words, even if a visual 'advantage' as such is not immediately apparent, it can develop as a result of training. Broadley (1994) reported greater gains for the visual modality after training, even though the initial memory scores were equivalent for the auditory and
the visual condition. It seems that this relative strength in visual skills should be further explored and applied to memory training programmes.

The present study had several aims. Firstly, the question of whether young individuals with Down syndrome make better use of visual than verbal information was re-addressed. Given the often controversial findings regarding the effects of modality on the STM performance of people with Down syndrome (see Chapter Five), Experiment Four was carried out as a starting point towards exploring visuo-spatial and verbal skills in this population. Thus, auditory digit span was contrasted to visual digit span and Corsi span in a sample of children and adolescents with Down syndrome and a control group of typically developing children matched for verbal mental age. A dissociation between a mostly verbal and a mostly visuo-spatial task would provide further evidence for spared visual memory skills in Down syndrome.

To further establish the use of verbal and visual information in Down syndrome, Experiment Five explored the effects of phonological and visual similarity on recall of spoken words and pictures, again in a group of young individuals with Down syndrome and a control group. Again, the inconsistent findings regarding the detection of these effects in Down syndrome, reported in Chapter Six, necessitated the replication of this experiment. Evidence that children with Down syndrome rely more on visual coding for recalling information would serve as a basis for further exploring the nature of these visual skills.

A third experiment (Experiment Six) was designed in order to explore the use of spatial information in picture recall in Down syndrome. Broadley (1994) hinted that the visual advantage confirmed in her study could be related to the use of spatial information. Thus, in Experiment Six, picture spans were measured with spatial location manipulated as a within-subjects condition. If children with Down syndrome had higher picture spans when spatial location was used as a cue, this
would indicate a possible source of information to be exploited in memory training programmes.

However, as stressed above, whether or not people with Down syndrome make spontaneous and effective use of visual and/or spatial information during STM tasks, they are still likely to learn to use visual memory strategies successfully. Broadley’s (1994) memory training programme explored the effectiveness of two memory strategies: organisation and rehearsal and found they both resulted in gains in memory span; there was also evidence for some transfer of these gained skills to related tasks. It was interesting to explore whether instructions to use a visual strategy would facilitate memory performance in Down syndrome.

Mental imagery was chosen as such a visual strategy, as the relationship between mental imagery and memory performance is quite well established (see literature review). In Experiment Seven, the ability of young individuals to use mental imagery was assessed, using computerised tasks that tested the generation and maintenance of a visual image. These tasks were those developed by Courbois (1996) for his study on mental imagery abilities of people with general learning difficulties. All these experiments are reported below.

6.2. Experiment Four: Contrasting digit span and Corsi span in young individuals with Down syndrome

6.2.1. Introduction

As mentioned above, some previous studies have used digit span and Corsi span as measures of verbal serial recall and visuo-spatial serial recall in Down syndrome. Some findings suggest longer Corsi spans relative to digit spans in this population (e.g. Wang & Bellugi, 1994). Other researchers report no significant differences between Corsi and digit span (e.g. Jarrold & Baddeley, 1997; Vicari et al., 1995). This difference in the findings may be due to differences in the ages and abilities of
the children tested, as well as differences in the procedures followed for the tasks themselves. For example, Jarrold and Baddeley (1997) used a computerised version of the Corsi task, where the items to be remembered were highlighted one by one on a screen, instead of being tapped on a wooden board by the researcher. It is possible that the traditional block-tapping procedure of the Corsi task facilitates performance, as it offers an additional option for encoding information: remembering the sequence of movements followed on the Corsi board as a whole trajectory.

The studies that have contrasted auditory and visual presentation of digits in Down syndrome suggest an advantage for the visual modality. Marcell and Armstrong (1982) reported comparable visual and auditory digit spans in the Down syndrome group, as opposed to a verbal advantage in their control group. Broadley and MacDonald (1993) reported higher visual than auditory digit spans, attributing this to use of visual coding to compensate for verbal memory difficulties. However, as their experiment was part of a training study (Broadley, 1994), it did not include a typically developing control group. Thus, the present experiment re-addressed the visual advantage issue by contrasting auditory digit span, visual digit span, and Corsi span in a group with Down syndrome as well as a control group matched for receptive vocabulary.

Finally, another issue relates to the sequential nature of the STM tasks. It has been suggested that the memory difficulties in Down syndrome may be due to difficulties with recalling information in serial order. Most studies, however, do not seem to support this possibility, as they report no significant difference between tasks that require recall in serial order and tasks that require simultaneous processing of information (e.g. Kay-Raining Bird & Chapman, 1994; Pueschel et al., 1987; Varnhagen et al., 1987). On the other hand, Snart et al. (1982) did find poorer performance on tasks that required serial processing of information. Jarrold and Baddeley (1997) also found that Corsi span was higher than digit span in the Down syndrome group, but only when correct order of the items was not taken into account in the analysis: in other words, this group seemed to have a strength in remembering
the blocks in the Corsi task, but not in the correct order. In the present study, therefore, this issue was addressed again.

The position adopted was that, given the general suggestion that people with Down syndrome are selectively impaired in verbal STM, but have an intact visuo-spatial memory system, a dissociation should be apparent in their performance. More specifically, the following hypotheses were formulated:

H1/ Children with Down syndrome should have significantly shorter auditory digit spans than children in the control group.

H2/ Children with Down syndrome should have lower visual digit spans compared to children in the control group. Lower digit spans in the visual modality would be due to possible slower item identification time in the group of children with Down syndrome; possibly more effort will be required to recode the digits; and slower speech rates during verbal recall.

H3/ Given the evidence from previous studies, children with Down syndrome should have comparable Corsi spans to children in the control group.

H4/ When the correct order of recall is not taken into account, children with Down syndrome might achieve higher scores on digit recall and recall of Corsi blocks. It is possible that the differences in the scores between the two groups would be abolished, but this is to be explored. If the Down syndrome group and the control group do not differ on recall of items regardless of order, this should suggest that remembering information sequentially may be central in the STM difficulties of people with Down syndrome.

H5/ A dissociation should be evident, with the Down syndrome group having longer Corsi spans than auditory digit spans. The pattern observed in the control group should depend on their age. According to previous research and the findings of the
cross language study (Chapter Three), from age 6 years onwards typically
developing children should have longer digit spans than Corsi spans.

H6/ Visual digit span should be at least equal to, or even superior to, auditory digit
span in the Down syndrome group. Visual presentation of digits should offer an
advantage to children. However, whether this additional visual code would be used
successfully should depend on children's familiarity with numbers, as this affects
identification rates.

H7/ If the correct order of item recall is not taken into account in the analysis, this
should not affect performance in the control group. However, in the Down
syndrome group, it is possible that memory for the items alone would be higher than
memory of items in correct order. Therefore, such an analysis would clarify
whether the memory difficulties of this group can be attributed to difficulties with
retaining information in serial order.

6.2.2. Method

6.2.2.1. Participants

Fourteen children and adolescents (7 males and 7 females) with Down syndrome
were recruited from special schools or day centres in Surrey. Their mean age was 13
years 8 months (range: 10 years to 21 years, SD = 42.56 months). Written consent
from the parents, or, in the case of young adults, from the participants themselves,
was obtained prior to the beginning of the study.

The control group consisted of 14 children (7 boys and 7 girls) attending primary
school or nursery in Surrey. Their mean age was 4 years 9 months (range: 2 years 8
months to 8 years, SD = 18.74 months).
The two groups were matched individually on the short form of the BPVS (Dunn & Dunn, 1982). As the nature of the tasks administered was verbal, it was decided to match the groups on a measure of receptive vocabulary. The mean BPVS score of each group was 8.93 (range: 4 to 17, SD = 3.87), with a mean age equivalent of 4 years (range: 2 years 2 months to 7 years 9 months).

6.2.2.2. Measures and procedure

Each participant was tested individually in a quiet room, at school or in the day centre. Auditory digit span, visual digit span, and Corsi blocks were administered. The order of auditory and visual digit span was counterbalanced. The tasks administered are described below:

*Auditory digit span*

Auditory digit span was measured using the sub-tests of the BAS (Elliott et al., 1978). The researcher spoke out digit lists of increasing length, at a rate of one digit per second. Participants were instructed to wait till the researcher finished reading the list, after which they were prompted to repeat the digits in the same order. Practice trials of two digits were used before the actual test, to make sure the participants understood the instructions.

Scoring was carried out as specified in the manual of the BAS: each sequence length contains a block of five lists. One point is scored for each list recalled correctly, therefore the maximum score for each block is five points. Testing begins with a series of two digits; if the child is successful in two trials, then credit is given for all the remaining lists of this block. For lists longer than two digits, all five trials are given. Testing is discontinued when the child fails all trials in one block. The sum of the points scored is the total raw score of the test.
In addition, a span measure was recorded, defined as the longest sequence that participants could recall in correct order in at least three trials out of five in a given block. Usually the raw score is about double the digit span calculated.

Finally, a more liberal measure was calculated from each digit span raw score, defined as the number of correct digits recalled regardless of order.

*Visual digit span*

The same lists of digits and scoring procedure were used for the visual digit span task. In this task, however, the digits were displayed on cards that were placed in a row, one at a time. Participants were free to name aloud the digits at presentation. Indeed, the group with Down syndrome was indirectly prompted to do so, while the researcher pointed at each number during presentation in order to keep the participant's attention on the task. After display of all cards on a list, the array of cards was covered and participants were prompted to repeat the digits.

Prior to testing, the participants were asked to read digits aloud, to ensure they could name them correctly. Two children with Down syndrome and 10 children from the control group confused the numbers when reading them and did not carry on with this task.

*Corsi blocks*

The lists and scoring procedure used for the Corsi task were the same used for the digit span tasks. The researcher tapped, at a rate of 1 block per second, a series of blocks randomly arranged on a board, starting from a sequence of two. The participants had to point, in the correct order, at the locations tapped by the researcher. Again, practice trials of two blocks were given prior to testing.
6.2.3. Results

In the analysis reported below, the raw scores of the digit recall and Corsi tests were used instead of the span measures. This procedure was used because the variability of raw scores was greater than spans, so a clearer pattern of differences emerged between the two groups, as well as differences between types of task within a group. Finally, examining raw scores permitted the contrast between serial recall and free recall of items to be investigated.

6.2.3.1. Comparing the two groups on short-term memory performance.

Descriptive statistics for the raw scores obtained for each task are displayed in Table 6.1.

Table 6.1. Mean raw scores for each STM task for the Down syndrome and control group (standard deviations in parentheses)

<table>
<thead>
<tr>
<th>Memory task</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Down syndrome</td>
</tr>
<tr>
<td>Spoken digits</td>
<td>7.17 (2.04)</td>
</tr>
<tr>
<td>Printed digits</td>
<td>9.75 (2.86)</td>
</tr>
<tr>
<td>Corsi blocks</td>
<td>8.57 (2.34)</td>
</tr>
<tr>
<td>Spoken digits (no serial order)</td>
<td>7.75 (2.01)</td>
</tr>
<tr>
<td>Corsi blocks (no serial order)</td>
<td>10.50 (2.07)</td>
</tr>
</tbody>
</table>

Hypothesis H1 suggested that the Down syndrome group would have shorter auditory digit spans compared to the control group. As shown in Figure 6.1, this was indeed the case.
Figure 6.1. Contrasting recall of digits and Corsi blocks (serial and nonserial recall) in the two groups.
This pattern was also supported by a mixed ANOVA with type of task (auditory digit span versus Corsi)\(^6\) as the within-subjects factor and group as the between-subjects factor, which showed a significant overall effect of group (F(1,24)=4.28, p=0.05). Inspection of the means shows that this effect was due to differences in recall of digits between the two groups, whereas the groups did not differ significantly on recall of Corsi blocks. This confirmed hypothesis H3, which predicted that the Down syndrome group would have comparable Corsi scores to controls.

6.2.3.2. Contrasting digit span and Corsi span

Figure 6.1 also shows the differences between auditory digit recall and blocks recall in the two groups. As can be seen, there was a trend for Corsi blocks to be better remembered than spoken digits in the Down syndrome group, while the reverse pattern was suggested for the control group. This was also suggested by a small but significant interaction between type of task and group (F(1,24)=5.03, p=0.034) when the above-mentioned ANOVA was carried out. However, when the two groups were studied separately, no significant differences between the two tasks were detected for either the Down syndrome group or the control group. Thus, both groups had comparable digit and Corsi scores. This contrasted hypothesis H5, according to which the Down syndrome group should perform better on the visuo-spatial task.

As the scores on the visual task were only obtained for the Down syndrome group, hypothesis H6 was explored for this group only. As seen in Table 6.1, recall of visually presented digits was higher than recall of spoken digits—also supported by a paired samples t-test: (t(11)=3.74, p=0.003).

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\(^6\) As most children in the control group were not able to recognise the printed digits accurately, the scores from the printed digits were excluded from this analysis. Thus, the two groups were not compared on recall of printed digits, and hypothesis H2 was not explored.
6.2.3.3. Contrasting sequential recall to free recall

To explore hypothesis H7, free recall of items in the memory tasks was contrasted to serial recall. As Figure 6.1 suggests, both recall of digits and recall of Corsi blocks showed a tendency to be higher in the Down syndrome group, when the order of the items was not taken into account. A similar, but less dramatic difference between sequential and free recall was apparent in the control group. To further explore this, a mixed ANOVA contrasting serial to free recall (2 levels) and type of task (spoken digits versus Corsi blocks) in the two groups was carried out. This revealed a small but significant interaction between group and effect of order (F(1,24)=5.04, p<0.034), but no significant interaction between effect of order and type of task. Indeed, separate analyses in each group showed that, in both the Corsi task and the digit recall task, nonserial recall was better than serial recall (F(1,11)=16.84, p=0.002 for the Down syndrome group; F(1,13)=15.17, p=0.002 for the control group). Therefore, in both groups nonserial recall was better than serial recall regardless of the type of task. The significant interaction between order of recall and group possibly reflected that the effect was more pronounced in the Down syndrome group.

Finally, Figure 6.1 also suggests that the effects of type of task on recall may change when order of recall is not taken into account, at least in the Down syndrome group. It seems that in the Down syndrome group, free recall of Corsi blocks was higher than free recall of digits, while the two tasks were equivalent in the control group. This was supported by a significant interaction between type of task and group (F(1,24)=12.10, p=0.002). When this was further explored within each group, it was confirmed that the Down syndrome group had higher Corsi scores than digit scores for free recall of items (F(1,11)=12.92, p=0.004), while no such difference was significant in the control group.
6.2.4. Discussion of Experiment Four

On the whole, the findings from Experiment Four appear to agree with the initial predictions. The group with Down syndrome had lower scores on the verbal STM task compared to children of similar mental age, but performed as well as the control group on the visuo-spatial task. This picture also agrees with previous research suggesting that individuals with Down syndrome have specific difficulties in retaining verbal information.

Similarly, a relative strength in visuo-spatial abilities was evident as equivalent performance of the two groups on the Corsi task. However, the expected higher performance of the Down syndrome group on Corsi blocks compared to recall of digits, was not supported: in the Down syndrome group the digit scores and Corsi scores did not differ significantly. This agreed with the findings of Jarrold and Baddeley (1997). However, there was a tendency for recall of Corsi blocks to be higher than recall of digits. It is possible that such a dissociation between the two tasks would become significant in a larger sample.

Another finding to support the suggestion of a visual advantage in Down syndrome was provided by contrasting recall of spoken digits to recall of visually presented digits. The better recall of visually presented digits in the Down syndrome group was in line with Broadley and MacDonald's (1993) findings. This could be interpreted as an advantage provided by the additional visual code offered in the visual task, which helps individuals with Down syndrome to use visual information. It can also be interpreted as a more general attentional advantage: the children with Down syndrome might have been more able to concentrate on the task, as they were prompted to name the stimuli during presentation, and thus encouraged to use dual coding in the task. Finally, there is the possibility that the array of cards provided an extra spatial cue for retaining information. However, this possibility could not be directly tested in this experiment.
On the whole, the group with Down syndrome did not appear to have a specific difficulty in remembering information in serial order. Although the performance of this group improved when correct recall of order was not considered in the analysis, so did the performance of the control group. This agreed with the findings of Kay-Raining Bird and Chapman (1994) who suggested that typically developing children and children with Down syndrome made the same amount of ordering errors in the serial recall task. Similarly, in the present experiment it appeared that the two groups found the serial recall task equally difficult.

An interesting finding was that the predicted higher performance on Corsi blocks compared to digits in the Down syndrome group became apparent when recall of order was not taken into account. This was not the case in the control group, who performed equally well on the two tasks, regardless of the sequential or nonsequential nature of the task. Thus, the group with Down syndrome recalled Corsi blocks significantly better than spoken digits, when order was not taken into account. Jarrold and Baddeley (1997) reported very similar findings, as in their study the same dissociation became evident only for free recall of items.

It appears, therefore, that remembering information in serial order is not a specific or causal factor in the short memory difficulties of people with Down syndrome. However, any visual advantage evident in this population may be enhanced when serial recall is not required. It can be concluded that this population performs better in STM tasks where information is visuo-spatial and where no serial processing of information is required.

The above findings do suggest some visual strength in the performance of people with Down syndrome. To further explore this, the next experiment was carried out to explore phonological and visual similarity effects on recall of spoken words and pictures in this population. This would further elucidate the nature of difficulties and possibly confirm previous research suggesting strengths in visual processing in this population.
6.3. Experiment Five: phonological and visual similarity effects in Down syndrome

6.3.1. Introduction

As mentioned in the general introduction to this chapter, the studies that have explored STM spans in Down syndrome often report disparate findings. In particular, the presence or absence of a phonological similarity effect or a word length effect on recall has been interpreted in different ways. For example, Varnhagen et al. (1987) did not detect a phonological similarity effect on recall of either spoken or written letters that sounded similar. They attributed this to a lack of use of the phonological loop for maintaining verbal material. In contrast, Hulme and Mackenzie (1992) did detect a small phonological similarity effect in their Down syndrome group, which, interpreted along with the absence of a significant effect of word length, was attributed solely to confusion of items during recall, and not to verbal rehearsal. This was also supported by the results of a subsequent experiment, where the phonological similarity effect became apparent after rehearsal training.

Conversely, Broadley et al. (1995) attributed the significant phonological similarity and word length effects reported in their study to the use of phonological coding and verbal rehearsal by children with Down syndrome. Moreover, they explained the absence of a difference between picture and spoken word recall, as well as the presence of a significant phonological similarity effect on picture recall, as successful use of visual information, which might be exploited to compensate for difficulties in using verbal rehearsal. This reliance of visual coding was also evident as a significant visual similarity effect in their study.

Finally, Jarrold et al. (2000) reported a significant phonological similarity effect on spoken word recall in their sample of children with Down syndrome. However, given the absence of a significant word length effect, they claimed that neither their Down syndrome group, nor their control groups, engaged in verbal rehearsal.
As the procedure they used involved prompted recall instead of repetition of a whole sequence of words, the phonological similarity effect could not be attributed to confusion of the items during recall. Rather, they argued that the group with Down syndrome did use phonological coding for retaining material, even if their further experiments suggested that the capacity of this store might be limited in this group (see literature review).

The aim of the present study was to re-address the role of visual coding during STM tasks in Down syndrome. Of particular interest was the question of whether individuals with Down syndrome would show a preference for visual information when it is available to them. To investigate this, spoken words and their pictorial equivalents were used as stimuli for measuring memory span. Examining the effects of presentation modality on recall, as well as the effects of phonological similarity and visual similarity, should help to reveal possible strengths in the visual modality that could be exploited in memory training programmes. Thus, the present experiment was essentially a replication of Broadley's (1994) study. However, in the present experiment a control group of typically developing children was included. This would indicate whether the verbal memory performance of the group with Down syndrome was in line with their mental age, or reflected a specific deficit that could not be explained solely in terms of developmental delay.

More particularly, the following hypotheses were formulated:

H1/ The group of individuals with Down syndrome should have significantly lower memory spans for spoken words compared to the control group. This would be in accord with most of the research on the memory performance of this population (see above).

H2/ If individuals with Down syndrome exhibit a strength in visual processing, then their visual memory spans should be at least equivalent to the visual memory spans of the control group.
H3/ The group with Down syndrome should have at least equivalent, or possibly longer, spans for pictures than spoken word spans. The modality effects observed in the control group should depend on their age.

H4/ If, as suggested by most studies, individuals with Down syndrome do make use of the phonological store, a phonological similarity effect on recall of spoken words should be evident. For picture recall, however, the presence of a phonological similarity effect—as was detected in the Broadley (1994) study—would indicate verbal recoding of visual information. This possibility was explored again here.

H5/ The presence of a visual similarity effect on recall of pictures would suggest that the group with Down syndrome use visual coding for retaining information. If this effect was not detected in the control group, this could indicate that the group with Down syndrome relied on visual information for a longer time than suggested by their mental age, possibly to compensate for difficulties with verbal coding and rehearsal.

6.3.2. Method

6.3.2.1. Participants

The same participants that took part in Experiment Four also took part in this study. Matching was based on the same measures as in Experiment Four.

6.3.2.2. Measures and procedure

Each participant was tested individually in a quiet room, either at school or at the day centre. Auditory and visual word span tasks were administered, as follows:

Three variables were manipulated: phonological similarity and visual similarity of words, and presentation modality (auditory versus visual). Words were selected
from three sample sets, with 6 sets in each sample: (1) phonologically similar set (cat, bag, tap, hat, bat, rat); from Conrad, 1971; (2) visually similar set – drawings of elongated objects that were pictorially similar and had the same orientation along their long axis (brush (or broom), key, spade, hammer, nail (or pin or screw), fork); from Hitch, Halliday, and Littler, 1989; and (3) a control set (clock, chair, pig, car, bell, leaf). As this set contained phonologically dissimilar words whose shapes/orientations also were dissimilar, it served as a control for both the phonological and the visual similarity conditions.

For the visual presentation condition, all the cards were first shown to the children to make sure that they could name all the objects correctly. To ensure the children understood the demands of the task, training trials were given for both presentation conditions, using two training words (bus, man). The experimental conditions started with a sequence of two. The order of presentation modality was counterbalanced. Within each presentation condition, the order of presentation of the three word sets (phonologically similar, visually similar, control) was randomised.

In the auditory presentation condition, a sequence of words randomly selected without replacement from each list was spoken by the researcher at a rate of one word per second. Three trials were offered in each list length. Participants had to repeat back the list, in the correct order. Testing was discontinued after a child failed two trials out of three at a given list length. A span measure was established as the list length in which the child was successful in at least two out of three trials.

The same procedure was applied for the visual condition, except that the words were presented as black and white drawings on 10 x 15 cm cards. The participants were shown the pictures one at a time, after which each card was turned over. When all the pictures were covered, the participants had to repeat back their names. Upon presentation, the names of the pictures were not named by the researcher, but all the participants in the Down syndrome group were encouraged to verbally label the presented pictures, in order to focus their attention on the task.
6.3.3. Results

6.3.3.1. Contrasting word spans in the two groups

To explore hypotheses H1 and H2, the Down syndrome group and the control group were compared on verbal and visual span for the control words. The means and standard deviations for each span measure are shown in Table 6.2. Figure 6.2 shows the mean word spans for all conditions in the Down syndrome group and the control group.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Down syndrome</td>
</tr>
<tr>
<td>Spoken words, phonological similarity</td>
<td>2.07 (0.47)</td>
</tr>
<tr>
<td>Spoken words, visual similarity</td>
<td>2.36 (0.63)</td>
</tr>
<tr>
<td>Spoken words, control</td>
<td>2.36 (0.50)</td>
</tr>
<tr>
<td>Pictures, phonological similarity</td>
<td>2.43 (0.65)</td>
</tr>
<tr>
<td>Pictures, visual similarity</td>
<td>2.43 (0.51)</td>
</tr>
<tr>
<td>Pictures, control</td>
<td>3.07 (0.73)</td>
</tr>
</tbody>
</table>
Figure 6.2. Contrasting mean spans for each condition in the two groups.
6.3.3.2. Examining modality effects in the two groups

As can be seen, the control group appeared to have longer spans for spoken words compared to the Down syndrome group, while there did not seem to be a large difference in picture spans between the two groups. A mixed ANOVA with presentation modality (spoken words versus pictures) and type of material (phonologically similar, visually similar, and control) as within-subjects factors and group as the between-subjects factor also supported this difference, showing a significant overall effect of group on recall ($F(1,26)=4.84$, $p=0.037$). Inspection of the means shows that this effect is due to difference between the spoken word spans of the two groups, while the two groups did not differ significantly on picture spans. Therefore, hypotheses H1 and H2 were supported.

The main ANOVA also showed a trend towards a significant effect of presentation modality ($F(1,26)=3.92$, $p=0.059$) and a significant interaction between modality and group ($F(1,26)=8.37$, $p=0.008$). To explore this interaction, spans for spoken words and pictures were contrasted within each group separately. As Figure 6.2 shows, in the Down syndrome group recall of pictures tended to be higher than recall of spoken words, while no such difference was apparent in the control group. Again, this pattern was confirmed by conducting the same ANOVA within each group separately, which showed significantly higher picture recall than spoken word recall in the Down syndrome group ($F(1, 13)=10.02$, $p=0.007$; c.f. Figure 6.2), but an absence of a significant modality effect in the control group. Thus, hypothesis H3 which predicted a picture advantage for the Down syndrome group was supported.

6.3.3.3. Exploring effects of phonological similarity on recall

Figure 6.2 also compares recall of phonologically similar items to recall of the control items, thus exploring hypothesis H4. As can be seen, both groups displayed similar patterns, with longer spans for the control items in both presentation
conditions. This pattern was supported by planned comparisons. An overall effect of phonological similarity ($F(1,26)=41.89$, $p<0.001$) along with the absence of a significant interaction between group and phonological similarity, presentation modality and phonological similarity, or a three-way interaction between modality, similarity, and group, confirmed that both groups were sensitive to phonological similarity both for spoken word and picture recall.

6.3.3.4. Exploring visual similarity effects on recall of pictures

Finally, to explore hypothesis H5, spans for visually similar items and visually presented control items were contrasted in the two groups. Figure 6.2 shows that, in the Down syndrome group, there was a tendency of visually similar drawings to be less well recalled than control pictures. In contrast, no such difference was evident in the control group. Planned comparisons showed that the overall effect of visual similarity was not significant ($p=0.081$); neither was the interaction between visual similarity and presentation modality ($p=0.061$) or the three-way interaction between group, visual similarity, and modality. Thus, although there was a trend towards a significant effect of visual similarity on picture recall in the Down syndrome group, it did not reach significance.

6.3.4. Discussion of Experiment Five

The findings of Experiment Five seem to support the presence of a visual advantage in the STM of individuals with Down syndrome. The most straightforward finding supporting this was that, while the group with Down syndrome had shorter spans for spoken words compared to the control group, they performed on the picture span task equally well as the control group. As the matching of the two groups was done on the basis of a verbal test, it was confirmed that this population perform well below their vocabulary age on verbal memory tests. This finding agreed with many studies that have shown a dissociation between verbal and visual memory tasks in Down syndrome (see review).
Within the Down syndrome group, a dissociation between verbal and visual STM was also apparent, while this modality effect was not significant in the control group. Although Broadley (1994) reported comparable auditory and visual word spans in her group, in the present study the Down syndrome group performed significantly better on the picture task. This could be attributed to a number of factors. As mentioned in the Method section, the participants of this group were encouraged to name the pictures upon presentation, in order to maintain their attention on the task. This may have favoured dual coding of the material to be remembered. Alternatively, this group may simply have been better at encoding visual information than verbal information, especially as their hearing difficulties and more general receptive language difficulties may not favour phonological coding. Finally, it is possible that, in the picture span task, the array of cards that remained turned over during recall, provided a spatial cue for recalling material. However, the present experiment did not allow a distinction between these possibilities.

Further evidence about STM coding in Down syndrome was provided by examining phonological and visual similarity effects on recall. It was also interesting to observe possible differences between the control group and the Down syndrome group. A phonological similarity effect on recall of both spoken words and pictures was apparent in the Down syndrome group, as was also reported by Broadley et al. (1995). Moreover, a similar pattern was observed here for the control group. This similarity between individuals with Down syndrome and typically developing children, as Broadley et al. also note, indicates that this group was able to use phonological encoding, possibly in the same way as typically developing children. Still, it is possible that confusion of the phonologically similar words took place during verbal recall.

Finally, the trend for a visual similarity effect in the Down syndrome group, but not in the control group, suggested a potential for using visual information, possibly to compensate for difficulties with verbal coding. Although the visual similarity effect
did not reach significance, as in the Broadley et al. (1995) study, it is possible that it would emerge in a larger sample of children.

On the whole, therefore, the evidence pointed towards a reliance of individuals with Down syndrome on visual information. This evidence of a relative strength in visual abilities could be further exploited by prompting, or training, these individuals to use more consistent visual strategies. One area pointed out by Broadley (1994) which remains unexplored in Down syndrome, refers to the role of spatial location as a cue for remembering information. As was noted here, the apparent visual advantage observed in digit span and word span tasks could be a spatial advantage. This possibility was explored in Experiment Six.

6.4. Experiment Six: investigating the role of spatial cues in the STM of young individuals with Down syndrome.

6.4.1. Introduction

As mentioned above, Experiments Four and Five replicated the findings of previous research, supporting the presence of a visual advantage in the STM of individuals with Down syndrome. In the present experiment, this visual advantage was explored further, by attempting to investigate a possible dissociation of visual and spatial elements. The possibility that the participants relied on spatial cues, rather than, or in addition to, visual cues, was suggested.

There were several reasons for suggesting this possibility. Broadley (1994) did stress that relying on spatial information could account for some of her findings on word spans. Moreover, there is some evidence that typically developing young children are able to use spatial cues in a serial memory task (Berch, 1978). There is also some evidence to suggest that individuals with learning difficulties are more able to use spatial information than temporal information in a recognition task (O’Connor & Hermelin, 1973). Although these studies did not involve verbal serial
recall, in the present experiment it was still interesting to see if the Down syndrome group would spontaneously benefit from the spatial cues offered, as typically developing children appear able to do.

Another argument favouring the use of spatial cues in Down syndrome is based on the nature of spatial information. Hasher and Zacks (1979) claimed that memory for spatial location is an automatic process, in the sense that it requires minimal processing resources; it should not, therefore, depend on intellectual ability. Although there is, in fact, much debate regarding the distinction between automatic and effortful processes in memory (e.g. see Walker, Hitch, Doyle, & Porter, 1994), it still seems important to investigate the possibility that individuals with Down syndrome could benefit more from cues that require less effort to be registered in memory. Indeed, Dulaney, Raz, and Devine (1996) explored memory for items and spatial location in Down syndrome as well as in a group of individuals with nonspecific learning difficulties and a control group of young volunteers. The three groups were only matched on chronological age. The control group performed better on memory for spatial location than the two groups with learning difficulties, which did not differ from each other.

Dulaney et al. (1996) suggested that what seems to be a relatively effortless process in typically developing individuals may require effort in people with learning difficulties, who may have lower mental capacity. However, Dulaney et al. referred to a long-term memory spatial task where the location of items was to be recognised 24 hours after presentation. In the present study, the specific question asked was whether, during a STM serial recall task, individuals with Down syndrome would be able to use the spatial location of the items as a cue for remembering the items themselves.

To explore this question, a picture serial recall task was used, with two conditions of stimuli presentation: one with spatial cues and one without spatial cues. In the first condition, the cards were placed in an array in front of the participant; after
presentation, they remained turned over during recall. In the control condition the cards that served as potential spatial cues were removed immediately after presentation. The aim was to examine whether performance changed when the location of the items did not serve as a cue. Recall of the items was verbal in both conditions.

In addition, a spoken word task was administered, again with two conditions. In the first condition, lists of words were spoken to the participant. In the second condition, the researcher pointed at blank cards while speaking aloud the words to be remembered. This condition was included to explore whether children could use some sort of visualisation strategy to associate the spoken words with the location of the blank cards.

The following hypotheses were formulated:

H1/ If the group with Down syndrome were able to benefit from spatial cues, then their performance should be better when the cards were present during recall, than when the cards were removed after presentation.

H2/ If the group with Down syndrome were able to benefit from spatial cues to compensate for difficulties in verbal recoding, then they should exhibit a different pattern of performance compared to typically developing children. Typically developing children might not need spatial cues as much, especially if they were able to rely on verbal recoding of the stimuli.

H3/ If the group with Down syndrome performed better at the spoken word span task when a spatial framework was provided, this would suggest that they are able to generate mental images of the spoken words, or, at least, associate the words heard with a particular spatial location. Again, it would be interesting to explore their performance in relation to the control group.
The above general hypotheses could be tested in two ways: by examining differences between the task conditions, and comparing the groups on the different conditions; and by examining the serial position curves of the two groups for each task condition, as the fixed length procedure allowed us to record how many items were recalled correctly at each position. Looking at primacy and recency effects in the two groups would reveal more information about the nature of strategies used for each task. Therefore, a final, more open-ended and less specific hypothesis was formulated:

H4/ Primacy effects, thought to reflect the use of verbal rehearsal (e.g. Atkinson, Hansen, & Bernbach, 1964), should be evident if either of the groups engaged in verbal rehearsal. In contrast, a recency effect in the absence of a primacy effect is thought to reflect short-term visual memory, especially if recency is confined to the final item (e.g. Broadbent & Broadbent, 1981; Hitch et al., 1988). If such a pattern were evident in either group and condition, it would support the use of a visual strategy for remembering the pictures. Moreover, if such a serial position curve with recency and no primacy were observed for the spatial cue position of the spoken word task, it would suggest the use of visual imagery for remembering spoken words. This possibility, which has been pointed out by Broadley et al. (1995), would be particularly interesting in the case of the Down syndrome group. If the group with Down syndrome demonstrated the ability to use some sort of visual strategy, possibly mental imagery, as a compensatory mechanism for difficulties in verbal processing, this would strongly support the suggestion of a visual strength that could be further exploited in this population.

6.4.2. Method

6.4.2.1. Participants

Seventeen children and adolescents with Down syndrome were recruited from schools in Surrey. Of these, 14 attended special schools while 3 attended
mainstream schools. Parents' written consent was obtained before the study began. Three children were excluded from the study as they found it very difficult to understand the word span tasks. The mean age of the remaining 14 children was 12 years 4 months (range: 7 years 11 months to 17 years 2 months; SD=3 years 5 months). There were 9 boys and 5 girls in the group.

Fourteen typically developing children attending nurseries and mainstream schools in Surrey formed the control group. Their mean age was 4 years (range: 2 years 11 months to 7 years 8 months; SD=1 year 3 months). There were 6 boys and 8 girls in the group.

The two groups were matched individually on the second edition of the British Picture Vocabulary Scales (BPVS-II: Dunn, Dunn, Whetton, & Burley, 1997). The mean BPVS score of the Down syndrome group was 38.14 (SD=14.75); the mean BPVS score of the control group was 37.93 (SD=15.02). An independent-samples t-test showed that there were no significant differences between the BPVS scores of the two groups. The age equivalent of both scores was 3 years 8 months.

6.4.2.2. Measures and procedure

Each participant was tested individually in a quiet room. A spoken word recall task and a picture recall task were administered to each participant, with 2 conditions in each task. Two sets of words were used, with 6 words in each set. In set 1, the words were: duck, chair, clock, shoe, hand, and bus. In set 2, the words were: fish, house, ball, hat, eye, and car.

Picture recall

The picture recall task was administered using 10 x 15 cm cards showing black and white line drawings of the words in sets 1 and 2. To avoid floor and ceiling effects, a fixed length procedure was used. Each participant was presented with 3 items to be remembered, selected at random without replacement from the set of stimuli used.
Three trials were given at this list length. If the participant was successful in at least 2 out of 3 trials, then a list of 4 items was also administered. The span measure was calculated as the total number of items that were remembered in the correct serial position. Therefore, as each participant was presented with 3 trials in each condition, the total score ranged from 0 to 9 at a given list length.

In Condition 1, the cards were presented one by one in a row in front of the participant. Upon presentation, each card was turned over. The researcher did not name the pictures and the participants were not encouraged to name them. When all cards were presented, they remained turned over in a row in front of the participant, who had to recall them verbally.

In Condition 2, each card was presented at a time, but was removed immediately after presentation. After all the cards were shown, the participant had to recall the words verbally.

The researcher did not name the pictures on presentation in either condition, and did not encourage the participants to name them.

Spoken word recall
The same procedure and scoring as with picture recall was used for recall of spoken words. In Condition 1, blank cards were placed in a row in front of the participant. As the researcher spoke the lists of words, she pointed at each blank card in succession. During verbal recall, the blank cards were still present, but the participants were not prompted to use them as cues for remembering the spoken words.

In Condition 2, the lists of words were spoken by the researcher and the children were asked to repeat back of words in the same order. No blank cards were present. This condition was therefore, the same as the auditory presentation condition in Experiment Five.
Practice lists were given to participants prior to both tasks. Before the picture recall task, all pictures were presented and named by the children, to ensure that they were named accurately.

The orders of word sets and conditions were counterbalanced. All participants were given the picture task before the spoken word task. Although this may have caused carry-over effects between tasks, of interest here was the effect of spatial cues on recall. If anything, practice with the pictures and cards should facilitate the use of mental imagery in Condition 1 of the spoken word task.

6.4.3. Results

Table 6.3 shows the mean number of items recalled by the two groups, with and without spatial cues, for spoken words and pictures respectively. As can be seen, the presence of spatial cues did not have an effect on recall of spoken words in either of the Down syndrome group or the control group. Inspection of the means also shows that a tendency for pictures to be better remembered when spatial cues were present in the Down syndrome group, and a reverse tendency in the control group, but these trends were not significant: a three-way ANOVA with spatial condition and presentation modality as the within-subjects factors and group as the between-subject factor did not reveal any significant main effects of presentation modality, spatial cues, nor any significant interactions. Thus, neither of the groups seemed to benefit from the presence of spatial cues, and hypotheses H1 to H3 were not supported. However, it is possible that a spatial advantage would emerge with a larger sample of participants. As can be seen, the Down syndrome group recalled pictures in the spatial cue condition as well as the control group. This finding also agrees with the results of Experiment Five, where equivalent picture spans were reported for the two groups. In contrast, the Down syndrome group performed worse than the control group on the picture STM task when spatial cues were removed. This suggests that the visual advantage in the Down syndrome group may, after all, be attributed to use of spatial information.
Table 6.3. Mean scores for each presentation modality/spatial cues condition in the Down syndrome and control group (standard deviations in parentheses).

<table>
<thead>
<tr>
<th>Condition</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Down syndrome</td>
</tr>
<tr>
<td>Spoken words, spatial cues</td>
<td>4.57 (2.03)</td>
</tr>
<tr>
<td>Spoken words, no spatial cues</td>
<td>4.57 (0.39)</td>
</tr>
<tr>
<td>Pictures, spatial cues</td>
<td>5.00 (1.84)</td>
</tr>
<tr>
<td>Pictures, no spatial cues</td>
<td>4.35 (1.74)</td>
</tr>
</tbody>
</table>

Examining the effects of serial position on recall allowed an exploration of the issues expressed in hypothesis H4. Figures 6.3 and 6.4 (graphs 6.3a to 6.3d and 6.4a to 6.4d) show the serial position curves for each presentation modality/presence of spatial cues condition, and for each group separately. The most noticeable difference between the Down syndrome and the control graphs was that, while the control group displayed a trend towards a typical V-shaped curve in all conditions, with primacy and recency effects, in the Down syndrome group recall increased almost linearly from position 1 to position 3. Thus, in the Down syndrome group, a recency effect was evident, but the first item was the least well recalled.
Figure 6.3. Serial position curves for each condition in the Down syndrome group.

6.3a. Spoken words, spatial cues

6.3b. Spoken words, no spatial cues

6.3c. Pictures, spatial cues

6.3d. Pictures, no spatial cues
Figure 6.4. Serial position curves for each condition in the control group.
Within each group, the shape of the curves did not seem to vary across conditions; in other words, serial position effects did not appear to be affected by presentation modality or spatial cues.

These patterns were further explored in a mixed ANOVA with three repeated-measures factors: presentation modality (spoken words versus pictures), presence or absence of spatial cues (two levels) and serial position (three levels), and group as a between-subject factor. This analysis supported the patterns observed in the graphs. There was a significant main effect of serial position ($F(2,52)=26.28$, $p<0.001$) as well as a significant interaction between serial position and group ($F(2,52)=27.18$, $p<0.001$). This interaction was further explored by examining the same effects within each group separately. No other main effects or interactions in the main ANOVA were significant.

In the Down syndrome group, planned comparisons showed that position 1 was the least often recalled correctly, followed by positions 2 and 3. Thus, the differences in recall between positions 1 and 2 was significant ($F(1,13)=77.66$, $p<0.001$); as was the difference between recall of positions 2 and 3 ($F(1,13)=25.91$, $p<0.001$). The difference in recall between positions 1 and 3 was also large ($F(1,13)=227.96$, $p<0.001$). These effects support the general trend observed in the graphs, which shows a linear increase of recall from the first to the last item.

In the control group, however, the difference in recall between the first and the last item was not significant. Position 1 was better recalled than position 2 ($F(1,13)=22.19$, $p<0.001$); position 3 also was better recalled than position 2 ($F(1,13)=6.78$, $p=0.022$). These effects supported the V-shaped graphs observed in the control group.

Finally, the Down syndrome group and the control group were compared on item recall at each serial position. The two groups only differed significantly on recall of the first item, with the control group recalling more items in position 1 than the
Down syndrome group. This difference was significant for all conditions (p<0.001 for all four conditions at serial position 1).

6.4.4. Discussion of Experiment Six

The aim of the present experiment was to explore the possibility that individuals with Down syndrome possess the ability to encode the spatial location of the items to be remembered in serial recall tasks and benefit from this spatial information. This assumption was founded on the evidence of a more general strength in visuo-spatial processing in this population, as well as on the claim that spatial information is automatically encoded and does not depend on intelligence or require particular mental effort.

However, the findings reported above did not support the suggestion that individuals with Down syndrome make use of spatial information during STM tasks. The presence or absence of spatial cues did not affect performance, as was also the case in the control group. It could be concluded that the visual advantage reported in many studies cannot be accounted for by beneficial use of spatial information.

However, such a conclusion may be premature. Although it agrees with the findings of Dulaney et al. (1996) who claimed that spatial encoding may be an effortful task, especially in groups with learning difficulties, there is a number of reasons why, in the present experiment, the group with Down syndrome appeared not to rely on the spatial positions of the items for retrieving information. One possibility is that verbal recall was required, which may have increased the attentional demands of the task, thus disrupting any weak, temporary associations that may have been formed between an item and its location. Indeed, Walker et al. (1994) suggest that younger children's associations between features of items to be remembered—referred to as object files (see Kahneman, Treisman, & Gibbs, 1992)—are particularly sensitive to decay.
It should also be noted that, in contrast to Experiment Five, the pictures were not named at presentation. Therefore, if the Down syndrome group did not verbally recode the pictures spontaneously, a shift from visuo-spatial coding to verbal recoding was required at the time of recall, increasing the difficulty of the task. This could also explain why, in contrast to Experiment Five where a picture advantage was reported, pictures and spoken words were equally well recalled.

It is, therefore, possible, that if a probed recall task was used, a strength in retaining spatial location would be evident. As mentioned above, Berch (1978) found that young children were able to use spatial cues in a serial recall probe task. The different picture presented by the control group in the present experiment could, again, be attributed to the nature of the task, which required verbal recall. Furthermore, the mean age of the control group was 4 years. As Ellis, Katz, & Williams (1987) note, the 3- and 4-year-olds they tested on an incidental task of memory for location seemed to need some extra effort for encoding spatial location, as they were also the only age group whose performance improved after explicit instructions. They concluded that even a process thought to be automatic depends to some extent on the maturation of attentional systems.

This leads to the general claim regarding individuals with learning difficulties: that they experience difficulties in the controlled acquisition of information and the spontaneous and flexible use of strategies for solving tasks. This difficulty may stem from limited processing resources in these populations (e.g. see Bebko & Luhaorg, 1998, pp. 384-385). This limitation in processing resources is not unique to Down syndrome, and thus may also explain the absence of any difference in performance between the Down syndrome and the control group: as the group with Down syndrome showed a pattern similar to children of comparable mental age, it can be concluded that their performance with regard to this task was due to general developmental delay.
Finally, it is possible that the left-to-right arrangement of the cards did not assist spatial encoding. Berch (1978) showed that typically developing children showed a pronounced primacy effect for the first item when the pictures were arranged in a row, and attributed this to the "contextual uniqueness" of the first (far left) item: namely, having another item only at one side of it. The primacy effect disappeared when this cue was removed. In the present experiment, however, it is unlikely that either of the groups would benefit from this cue, as even the participants in the control group were younger than the ones in Berch's experiment. Instead, it is possible that a more random layout of the pictures would increase the salience of the spatial locations and thus encourage spatial coding, as it would differentiate more between temporal and spatial organisation.

Examining the serial position curves of the two groups did not reveal any differential use of visual or spatial information across conditions: both groups displayed similar patterns for both conditions of presentation modality and regardless of the presence or absence of spatial cues. An interesting finding, however, was the absence of a primacy effect in the Down syndrome group, which agrees with the findings of Jarrold et al. (2000). Moreover, as in the Jarrold et al. study, the two groups only differed in recall of position 1, with the control group showing better recall than the Down syndrome group in this position. The replication of this finding reinforces Jarrold et al.'s suggestion of a limited capacity phonological store in Down syndrome. However, Jarrold et al. reported these findings only for recall of spoken words, as their aim was to examine the function of the phonological loop. The fact that, in the present experiment, this pattern was replicated even for picture presentation, suggests that either the participants with Down syndrome were relying on phonological coding even for remembering the pictures, or that this suggested storage limitation is not confined to the phonological store.

In conclusion, the possibility that individuals with Down syndrome may, after all, be able to use spatial information cannot be rejected. The present experiment failed to show any spontaneous or functional use of spatial cues; but it also showed that this
may be attributed to a general developmental delay that leads to a reluctance to benefit from all available information, unless explicit instructions are given. In other words, individuals with Down syndrome may be able to learn to use visuo-spatial information in the same way as they are able to learn any other explicit memory strategy (see Broadley, 1994). Given the evidence that the greatest benefits of training are reported for the visual modality (see Laws et al., 1996), it seems worthwhile to conduct further experiments on the visual memory abilities of people with Down syndrome. In the next experiment, the visuo-spatial memory as well as the ability of this group to generate mental images of visuo-spatial patterns was assessed as a first step towards exploring the possibility of using mental imagery in memory training studies.

6.5. Experiment Seven: visual imagery in Down syndrome

6.5.1. Introduction

As discussed in Chapter Five, mental imagery is considered as playing a major role in a variety of learning contexts. Its role in cognitive development has also been investigated (see Kosslyn, 1980, chapter 10), with particular emphasis on the development of mental representations and the relationships between image generation and picture reproduction (Piaget & Inhelder, 1971). The use of mental images has also been discussed in the work of Paivio (1971, 1986) who proposed a model of cognitive processing based on both imaginal and verbal codes.

However, as the work of Kosslyn (1980; 1994) suggests, visual imagery is not a unitary process, but rather a composite of distinct mechanisms that have begun to be associated with specific areas of the brain. This componental model of mental imagery has proved very useful in neuropsychological research (e.g. Farah, 1984; Kosslyn, 1987) and developmental research (e.g. Kosslyn, Margolis, Barrett, Goldknopf, & Daly, 1990; Marmor, 1975). Among the numerous subprocesses of mental imagery, the most widely studied are image generation, image inspection,
image maintenance, and image manipulation. Each of these processes, in turn, may
depend to a varying degree on different abilities, including linguistic, spatial, and
perceptual abilities (e.g. Kosslyn et al., 1995). According to Kosslyn et al. (1990),
the development of mental imagery is likely to depend on the maturation and
progressive refinement of these subsystems, which become more sophisticated with
age. Kail (1997) also proposed a model according to which mental imagery as a
whole depends on age and speed of processing.

Given the potential value of mental imagery as an instructional strategy for people
with learning difficulties, Kosslyn’s model seems useful for identifying further areas
of strength within the mental imagery system. With respect to learning difficulties,
however, less imagery research of this kind is known (e.g. Courbois, 1996; Uecker,
Obrzut, and Nadel, 1994). In the present experiment, therefore, the mental imagery
abilities of young individuals with Down syndrome were considered with respect to
Kosslyn’s model.

It should, however, be noted that this computational model was only used as a
framework for studying visuo-spatial memory abilities in Down syndrome. It also
seems appropriate here as its assumptions can be accommodated within the working
memory model. Indeed, links can be drawn between the visuo-spatial sketch pad and
the ‘visual buffer’ of mental imagery (see Logie, 1995). Although the tasks used in
the present experiment were designed to tap subsystems of mental imagery in
Kosslyn’s model, the emphasis of this study will be on the ability of individuals with
Down syndrome to use any form of visualisation strategy.

Courbois (1996) studied the mental imagery abilities of individuals with learning
difficulties, adapting tasks used with aphasic patients (Kosslyn, Berndt, & Doyle,
1985) and children (Kosslyn et al., 1990). He used computerised tasks to compare
individuals with learning difficulties to typically developing 5- and 8- year old
children on the ability to generate, maintain, inspect and rotate mental images of
abstract patterns and objects. He found that the groups with learning difficulties
were slower and made more errors on all tasks compared to the mental age-matched 8-year-old group, and that their performance was generally similar to the 5-year olds. He also noticed that performance within the learning difficulties groups depended on aetiology, with organic causes being more strongly associated with low performance than non-identified causes of learning difficulties.

In the present experiment, the image generation task from Courbois’ (1996) study was administered to a group of adolescents and young adults with Down syndrome, in order to assess their ability to encode and retrieve a mental image from long-term memory. However, although the computerised task and the general procedure followed were the same as in Courbois’ study, the aims of the experiment reported here were different: while Courbois was interested in comparing individuals with learning difficulties to typically developing children on accuracy as well as speed of mental imagery, in the present experiment the primary aim was to assess the ability of individuals with Down syndrome to form mental images. Therefore, response times were not recorded in this experiment. These and other differences are reported in detail in the Method section.

6.5.2. Method

6.5.2.1. Participants

Ten adolescents and young adults with Down syndrome took part in the study. The task was initially piloted on younger children as well, who found it too difficult. Of the 10 participants who were eventually included in the study, 7 attended special schools and 3 attended day centres. There were 6 females and 4 males in the group. Parents’ consent was obtained for the younger participants; the adult participants were informed about the study and gave their written consent themselves. The mean age of the participants was 16 years 3 months (range: 12 years 3 months to 21 years, SD=36.24 months).
6.5.2.2. Measures and procedure

Each participant was tested individually in a quiet room. The following tasks were administered, in the order they are reported below.

**McCarthy’s Puzzle from McCarthy’s Scales of Children’s Abilities**

(McCarthy, 1972). This is a subtest of the nonverbal ability scale of the battery, which requires assembly of a picture from its parts. The pictures to be composed depicted familiar objects (cat, cow, carrot, pear, bear, and parrot) and increased in complexity and number of parts to be assembled. As each task was timed, points were awarded for accuracy as well as speed of solving the puzzle, and a raw score was recorded. This test was administered as a measure of the ability to construct a picture not previously seen; as it involved a component of imagination, it was included in the study in order to examine its possible association with performance on the imagery task.

**Image generation task**

This was a computerised task designed by Courbois (1996) based on a probe detection task by Finke and Shepard (1986). The task consisted of learning the associations between four animals and four abstract patterns drawn on a grid, and memorising the patterns. Upon seeing one of the animals accompanied by an empty grid, the participants had to generate the image of the corresponding pattern from long-term memory, and decide whether two dots that appeared on the empty grid fell on or off the imagined pattern.

The task consisted of a practice phase and a testing phase, which occurred immediately after the last training session. The last stage of the practice phase and the whole testing phase were administered on a laptop. It was ensured that the participants got familiar with using the computer and the keyboard, and that they could easily identify the stimuli that appeared on the screen. During the task, the participants were required to answer yes or no by pressing two keys at opposite ends of the keyboard. The keys were labelled with different colours to help differentiating
them. There was a 2-second interval between consecutive stimuli on the screen. In contrast to the study by Courbois, the participants were not required to respond fast; emphasis was given on accuracy only.

I. Practice phase
The stimuli were four pictures of a hot air balloon and an animal sitting in the basket of the balloon. The four pictures differed in the pattern decorating each balloon and in the animal in the basket (bear, tortoise, chicken, and cow). The patterns were four abstract designs, which appeared on a 4 x 5 grid. These patterns are shown in Figure 6.5. Each pattern was associated with a particular animal. As can be seen, the patterns differed in complexity as defined by number of segments.

![Figure 6.5. Patterns used in the image generation task.](image)

In Courbois' (1996) study, the practice phase took place over three consecutive sessions. In the present experiment, these sessions required a number of visits to the school or the day center, which ranged from four to eight. Each visit lasted about 25 minutes. At the end of the practice phase, all participants were equally familiar with the stimuli.

The practice phase was carried out to ensure that the participants learned the associations between the animals and the patterns, and that they could reproduce the patterns from memory using the animals as cues. Cards depicting the animals with their respective patterns, as well as cards showing the animals and the patterns separately, were used for this purpose. In each practice session, the participants were
asked to memorise the associations between the animals and the patterns. Following this, they were asked: (a) to pair each animal card with the correct pattern card, while the model was present; (b) to pair each animal with its pattern without looking at the model, and check if they were correct; (c) using the animals as cues, to draw the pattern by filling in squares on an empty grid on a transparency, first with the model present and then from memory, and check if they were correct by placing their transparency over the initial pattern. To succeed in steps (a) and (b) and proceed to the next step, the participants had to be correct in three consecutive series. To accomplish step (c), they had to be successful in drawing a complete series of patterns accurately from memory.

Finally, at the end of the last practice session, a computerized test was administered where the participants had to decide whether the animal that appeared on the screen was in the balloon with the correct pattern. The task consisted of 24 trials, and a ‘yes’ or ‘no’ response was required.

The pilot study also showed that the participants could not understand the requirements of the image generation task itself, unless they received practice trials. For this reason, two further steps were added to the practice phase used by Courbois: first, a card showing one of the patterns in the grid was presented, and two stickers were placed either on or off the pattern. The researcher demonstrated that only if both stickers were on the pattern, the correct response was ‘yes’; a ‘no’ response was required if either of the stickers, or both, fell off the pattern. Three practice trials were given in this step.

Finally, it was judged necessary to encourage the participants to use visual imagery in order to carry out the probe detection task. Thus, a card showing an animal with an empty grid was shown to the participants, who were instructed to ‘close their eyes and see the shape which goes with the animal in their head’. Following this, two stickers were placed either on or off the grid, and the participants had to decide
whether the stickers fell on the imagined pattern or not. Again, three practice trials were offered.

It should be stressed that although Courbois did not instruct his participants to visualise the patterns, in the present experiment this intervention seemed inevitable, as the participants seemed to need some prompting in order to carry out the task. Courbois did include four trials with feedback just before administration of the imagery task; but this did not seem adequate in the present experiment. This additional practice was not considered to be a problem, as this intervention was kept minimal. All the participants seemed able to understand this instruction and did not require further training. In addition, as the main question addressed in this experiment was whether image generation is an intact process in Down syndrome, and whether it could be used in strategy training, prompting before the task was not expected to alter the results.

II. Testing phase
The testing phase consisted of three conditions, administered in the following order: (1) associative condition, where the learning of the four associations between the animals and the abstract shapes was tested; (2) imagery condition, where, on the appearance of one of the four animals, the image of the associated shape was generated from memory on an empty grid; a decision had to be made on whether two probe dots that appeared one second after the grid fell on the imagined shape or not; (3) perceptual condition, where dot detection took place with the shape present on the grid. The associative and perceptual conditions were included to control for errors not related to mental imagery itself, i.e. perceptual encoding, response production, and search from long-term memory. There were 24 trials in each condition, 6 for each pattern, half of which required a ‘no’ response and half of which required a ‘yes’ response.
6.5.2.3. Results

The means and standard deviations for performance in each condition and complexity are shown in Table 6.4. Two factors were manipulated: condition (associative, imagery, and perceptual), and complexity of patterns, defined as the number segments in a pattern (see Figure 6.5), with a maximum score of 6 in each condition.

As can be seen, performance in the imagery task was not significantly above chance, while the participants performed well above chance level in the associative and perceptual conditions (also confirmed by a one-sample t-test: p<0.001 for the perceptual and associative conditions, but at chance level for the imagery task).

A repeated measures ANOVA with condition (3 levels) and complexity (2 levels) as within subjects factors also showed a significant main effect of condition (F(2,18)=33.40, p<0.001), but no significant main effect of complexity, or a significant interaction between condition and complexity. Inspection of the means shows that the effect of condition is attributed to better performance in the associative and perceptual conditions, compared to the imagery condition.

Table 6.4. Mean scores for each condition of the imagery task (standard deviations in parentheses).

<table>
<thead>
<tr>
<th></th>
<th>Simple</th>
<th>Complex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Associative</td>
<td>4.95 (0.86)</td>
<td>4.95 (1.28)</td>
</tr>
<tr>
<td>Perceptual</td>
<td>5.00 (0.71)</td>
<td>5.05 (0.90)</td>
</tr>
<tr>
<td>Imagery</td>
<td>3.40 (1.10)</td>
<td>3.35 (0.94)</td>
</tr>
</tbody>
</table>

Of interest were the correlations between age, performance on the McCarthy task (mean raw score= 16.2, SD=4.21) and performance on the image generation task
(imagery condition). No significant correlations were found among any of the three measures.

6.5.3. Discussion of Experiment Seven

The findings of this experiment were straightforward: it appeared that, while the participants performed above chance level in the associative and perceptual tasks, they performed badly in the image generation task. Moreover, in contrast to Courbois’ findings, the complexity of the patterns did not have an effect on imagery performance, indicating that the participants found all the patterns equally difficult.

It also seemed that performance on the imagery task was not correlated with age, or with their ability to construct the picture of a familiar object from its parts (McCarthy test).

As Courbois notes, the image generation task in this experiment involved more than simple generation of the pattern. In particular, it required the following processes: (a) encoding of the animal; (b) search in long term memory for the matching pattern; (c) image generation of the pattern, and maintenance of this image during the probe task; (d) probe detection and (e) response. The relatively good performance in the two control conditions suggests that steps (a), (b), (c), and (d) were not a problem during the task. These results could, therefore, be interpreted as an inability of individuals with Down syndrome to generate any kind of visual image at all.

However, such as a conclusion may be premature. The practice sessions indicated that all the participants were able to understand the demands of the image generation task, and that they were able to generate a visual image if prompted. They also had demonstrated that they were able to draw the patterns from memory, which indicated an ability to accurately retrieve and reproduce long-term representations. However, as the non-significant correlation between the McCarthy puzzle and the imagery scores suggests, it seems likely that image generation and reproduction or construction of an image from memory involve quite different processes.
It is possible that individuals with Down syndrome have an intact ability to generate visual images, but may face difficulties with coordinating the different processes involved in the image generation task; such difficulties could reflect a more general deficit in executive processing (see Gibson, 1991). Their performance in the imagery task could also be associated with a difficulty with generating accurately the spatial relations between the segments of the patterns, and placing them correctly in the grid. Indeed, an inspection of the pattern reproductions drawn during the practice phase indicated that, on the whole, the participants could reproduce the overall shape of the patterns correctly, but made more mistakes in the spatial location of the shapes. Bihrle, Bellugi, Delis, and Marks (1989) asked children and adolescents with Down syndrome to copy patterns that were composed of smaller elements. They found that the participants were able to reproduce the whole patterns, but did not appear to notice how they were composed. Designing imagery tasks that allow the distinction between visual and spatial elements could help to identify areas of competence within the imagery system.

The experiment presented here was carried out starting from the more general assumption that visual strategies may be worth considering as tools of memory training in Down syndrome. It should be stressed that the results do not suggest that image generation, or the use of mental imagery, is impossible in this population; the findings simply showed that the participants found it difficult to carry out a probe detection task on an imagined pattern generated from long term memory after cued recall. As the issue of interest was the use of visualisation strategies in STM, simpler imagery tasks should be designed and their effectiveness on STM performance should be assessed. Suggestions for such research are presented in Chapter Seven.
Chapter Seven

Discussion of the Down syndrome study

7.1. Summary of the Down syndrome study

The literature review presented in Chapter Five addressed a number of issues, namely:
- whether there is a specific verbal STM deficit in Down syndrome, and if so, what is its nature;
- whether the visual STM abilities are intact in Down syndrome;
- whether speech and hearing difficulties are associated with difficulties in verbal STM in Down syndrome;
- to what extent teaching of STM strategies is effective in this population.

The research reviewed in Chapter Five led to several general conclusions, although most issues remain open-ended. There is evidence suggesting a specific verbal STM deficit in Down syndrome, although whether this deficit reflects a limited capacity STM store or a dysfunction of the phonological loop is debatable (Jarrold & Baddeley, 1997; Jarrold et al., 2000). The same studies suggest that speech and hearing difficulties may impose constraints to STM performance, but is unlikely that they play a direct causal role. A general difficulty with processing verbal information (Fowler, 1995) may lead to a difficulty, or reluctance, to use verbal rehearsal (Hulme & Mackenzie, 1992). Verbal rehearsal can, however, be successfully taught to children with Down syndrome (e.g. Broadley & MacDonald, 1993; Laws et al., 1996). Difficulties in using verbal rehearsal could also be explained by a production deficiency in strategy use, due to a general developmental delay (Gibson, 1991). Finally, a number of the reviewed studies suggested a strength in visuo-spatial processing; however, this strength and its potential use in memory training should be further explored.
The experiments presented in Chapter Six addressed some of the above issues. In Experiment Four it was reported that the Down syndrome group had shorter digit spans than the MA-matched group, supporting the idea of a verbal memory deficit. In contrast, the Corsi scores were similar in the two groups. No dissociation was found between Corsi and digit span in the Down syndrome group, but when order of information was not taken into account Corsi scores were longer than recall of digits. Finally, recall of printed digits was better than recall of spoken digits in the Down syndrome group. On the whole, these findings suggested that, although remembering information in serial order did not appear to impair performance in the Down syndrome group, recall was best for simultaneous, nonverbal information (free recall of Corsi blocks). These findings generally agreed with previous studies on Corsi (e.g. Jarrold & Baddeley, 1997) and studies contrasting auditory and visual digit span (Broadley et al., 1995).

The findings of Experiment Five further supported the presence of a specific verbal STM deficit in Down syndrome; a dissociation between auditory and pictorial processing was also evident. Thus, the group with Down syndrome was worse than the MA-matched control group in recall of spoken words, but the two groups remembered pictures equally well. An advantage of pictures over spoken words was also apparent in the memory spans of the group with Down syndrome. In line with the findings of Broadley et al. (1995), this group also displayed a phonological similarity effect on recall of both spoken words and pictures, and a trend towards a visual similarity effect on picture recall.

The picture advantage was further explored in Experiment Six, where an attempt was made to differentiate between spatial and visual elements in the picture recall task. The Down syndrome group, as well as the control group, did not seem to benefit from the presence of spatial cues, as no advantage for the ‘spatial cues condition’ over the ‘no spatial cues condition’ was found. Several explanations for this were discussed, from a difficulty of people with Down syndrome to encode and use the spatial information in a functional way—a difficulty that may be due to general developmental delay—to a masking of the spatial advantage because of the recoding required for the verbal response. In addition, the serial position curves of the Down
syndrome group differed from those of the control group, as the former showed better recall of the last item (recency) but not better recall of the first item (lack of primacy). The control group had better recall of the first items of the list than the Down syndrome group, and this difference was evident in all conditions. This pattern was discussed with respect to the findings of Jarrold et al. (2000).

Experiment Seven examined the visual imagery abilities of a group of adolescents and young adults with Down syndrome. The task used was based on a model that views mental imagery as a multi-component system, which involves various processes and requires different abilities. It was shown that this group could not perform above chance level on the imagery task. However, it was also noted that this difficulty was not due an inability to learn paired associates, draw a complex pattern from memory, or understand the probe detection task. Successful completion of the training phase also indicated that the participants could understand simple instructions to imagine the pattern, and were probably able to reproduce the overall shape of the pattern 'in their mind', if not accurately. Further research on the role of mental imagery as an STM strategy was suggested.

7.2. Synthesis of the findings

On the whole, the experiments reported in Chapter Six are related to the issues formulated with respect to the literature review. In particular, Experiments Four and Five supported the suggestion of a verbal STM deficit in Down syndrome. The significant phonological similarity effect reported in Chapter Two could be attributed to confusion of the items during output, and/or to the naming of the stimuli on presentation; however, it could also indicate use of phonological coding, even if this was less efficient compared to the control group. Indeed, the worse recall of the first item which was evident for both spoken words and pictures (Experiment Six) suggests verbal recoding of pictures even when naming was not encouraged by the researcher. It appears that, as in typically developing children (see Palmer, 2000) verbal and visual coding are available in individuals with Down syndrome, and are both used in different degrees of effectiveness.
This assumption implies that the STM difficulties of individuals with Down syndrome are a result of general developmental delay. However, this picture may not be as simple. Evidence from the literature review and from Experiments Four and Five suggests that there is a specific verbal deficit possibly related to the syndrome. This deficit may, in turn, impose constraints to all areas of verbal processing, including verbal STM and language. Hearing and speech problems, associated with Down syndrome but also with other populations with learning difficulties, may impose further constraints. If, therefore, for a variety of not yet clarified reasons, verbal processing is impaired in Down syndrome, this would be reflected as a reluctance, or difficulty, in using phonological recoding and rehearsal.

Developmental delay may add further difficulties to the strategic use of phonological recoding and rehearsal. In other words, the verbal deficit alone, without further learning difficulties, could probably be bypassed with the use of appropriate STM strategies. However, individuals with Down syndrome do have additional learning difficulties, including metacognitive difficulties and problems with executive processes (e.g. Gibson, 1991) that hinder the effective use of strategies.

This general difficulty in strategy use may also explain why the participants in Experiment Six did not appear to benefit from spatial cues. A visual strength has only been reported in tasks where requirement of spontaneous use of strategies is minimum, namely when the Corsi blocks were remembered in free order (Experiment Four) and when the pictures were named on presentation (Experiment Five). When the pictures were not named, and when no instructions to focus on the spatial position of the pictures were given (Experiment Six), the visual advantage was no longer detected. Similarly, in Experiment Seven, if the participants could generate a mental image from memory (as demonstrated during the learning phase) they could not do so without prompting during the test phase.

It could be argued, therefore, that general developmental delay as well as the specific verbal deficit may contribute to the pattern of STM performance observed in Down syndrome. If this is the case, both factors should be considered when exploring STM in Down syndrome and when designing STM training programmes for this
population. Suggestions for exploring this issue further are discussed in the next section.

7.3. Suggestions for further research

7.3.1. Exploring the STM difficulties of individuals with Down syndrome

A first step towards exploring the relative contribution of specific and general factors in the STM of individuals with Down syndrome could be to study the use of STM strategies in different groups with learning difficulties and groups with problems in verbal processing but without learning difficulties. As the aim of the experiments reported above was to explore visual STM in Down syndrome in particular, a ‘general learning difficulties’ or ‘mixed aetiologies’ group was not included. However, comparing the STM performance of people with Down syndrome to the STM performance of selected groups would be very informative about the nature of the memory limitations in Down syndrome.

Evidence for a verbal STM deficit specific to Down syndrome can be provided by comparing individuals with Down syndrome with individuals with learning difficulties that are believed to be caused by general developmental delay, and for which there is no known organic aetiology (e.g. Bower & Hayes, 1994; Hulme & Mackenzie, 1992; Jarrold & Baddeley, 1997). However, as both groups would have difficulties in strategy use as a result of developmental delay, and as the group with general learning difficulties could have language problems that affect verbal STM, the deficit in Down syndrome would be masked. More evidence about the deficit could be provided by comparing modality effects in groups that are believed to show a dissociation between verbal and visual STM. Individuals with Williams syndrome constitute such a group; comparing their STM performance to the STM of people with Down syndrome has helped to reveal double dissociations between verbal and visuo-spatial abilities (Jarrold, Baddeley, & Hewes, 1999; Wang & Bellugi, 1994). Furthermore, as individuals with Williams syndrome appear to have a facility in verbal recoding of visual information (Udwin & Yule, 1991), comparing phonological similarity and word length effects in these two populations could help
to explore to distinguish between automatic and effortful elements in the use of these strategies.

However, individuals with Williams syndrome may have relatively spared language abilities that help verbal STM, but are still characterised by developmental delay. This makes it difficult to distinguish between factors common in Williams and Down syndrome (production deficiencies) and syndrome-related factors (modality effects). To make such a distinction, it would be useful to compare individuals with Down syndrome with deaf individuals who have language difficulties, but no learning difficulties. This group would be expected to be able to use STM strategies and have some metacognitive understanding, but their hearing difficulties should impose a constraint on their verbal STM and to the spontaneous use of rehearsal (e.g. see Bebko & McKinnon, 1990). It would be interesting to contrast strategy use in two populations both of which have language difficulties, but one of which does not have a deficit in strategy production.

7.3.2. Further exploring the ‘visual strength’ in Down syndrome

As mentioned above, the visual advantage that is manifest in many studies on Down syndrome seems to emerge more clearly when not much mental effort is required. This relative ease with automatic, but not effortful, processes characterises individuals with learning difficulties as a whole (Belmont & Mitchell, 1987). This may also explain why the group with Down syndrome that participated in Experiment Six did not show a modality effect, and did not appear to benefit from spatial information for remembering pictures. Another version of the same experiment, with either serial recall with a pointing response or probed recall, would minimise recoding into a different modality and involvement of verbal strategies and would probably allow any visual advantages to emerge (see Simon et al., 1995). Manipulating the spatial locations of the stimuli by comparing left-to-right alignment with more distinctive locations could also help to explore spatial processing in this population.
As stressed several times in Chapters Five and Six, exploring the visuo-spatial abilities of individuals with Down syndrome is very important with respect to the use of any revealed strengths to improve STM performance. As individuals with Down syndrome have a general executive difficulty with strategy use, a taught strategy that takes into account this difficulty along with the relative facility in visual processing could be very beneficial.

The role of visual imagery as an STM strategy should be studied further. The not so encouraging findings of Experiment Seven could be explained as a difficulty with executive control rather than inability to generate visual images. A task that requires minimal language involvement and is related to a pragmatic context (see Broadley, 1994) would be more appropriate for demonstrating the use of mental imagery. For example, people with Down syndrome could be taught to use the method of loci (e.g. see Gruneberg, 1992) for remembering information in serial order. The method of loci involves the learning of spatial locations that are paired with the information to be remembered; during recall, the locations serve as retrieval cues. The rationale for suggesting the method of loci in particular is based on the fact that it involves the learning of spatial information and the pairing of the learned locations with visual images, which does not rely on linguistic processing.

Training the loci method for remembering lists of familiar objects was piloted on four adolescents with Down syndrome, but was proved time-consuming and was not carried out or reported in this thesis. In that version of the loci method, the locations to be associated with the stimuli to be remembered were different parts of the face and the body, which have the advantage that they can be easily learned and automatised and even referred to as cues during recall. Although the study was not completed, it seems worthwhile to explore further the use of imagery and the method of loci as an STM strategy. However, given the general executive difficulties discussed above, it also appears that greater benefits would be gained if the STM training was accompanied by metacognitive training (see Trudewind et al., 1990). As Borkowski, Carr, and Pressley (1987) discuss, offering metacognitive training along with the explicit teaching of a strategy is more likely to ensure transfer of the
learned strategy to new contexts. This training could be provided with the aid of pictures and examples (see Vianello et al., 1998).

Visual STM strategies could also be contrasted with verbal memory strategies, namely rehearsal. This comparison would indicate whether visual STM strategies really are more effective for people with Down syndrome, or whether the critical factor in STM training lies in the method of teaching and the degree of elaboration (see Broadley, 1994) rather than in modality.

Finally, given the great variation in the abilities of people with Down syndrome, it is important to consider case studies in order to explore visual memory abilities. From the participants in the mental imagery experiment, two were particularly good in image generation; one of them was the only one that carried out an image maintenance and a mental rotation task successfully (these tasks were excluded from the study). Studying the cognitive profiles of particular individuals who benefit from training studies will help to identify which abilities are critical for the effectiveness of an STM strategy.

7.4. Concluding remarks

The above discussion of the literature review and the experimental findings suggests that the visual STM strength suggested by research on Down syndrome is not adequate, on its own, to improve STM performance. It was suggested that individuals with Down syndrome might have a verbal STM deficit related to the syndrome, but also have more general learning difficulties, which affect the use of strategies and acquisition of new STM skills, regardless of modality. This implies that the visual advantage suggested for this population would only be useful if considered in STM training programmes along with metacognition training, and by keeping mental effort to a minimum. It is possible that acquired strategies based on visual skills would be more easily automatised than verbal strategies. The relevance of the above conclusions to the main issue addressed in this thesis, namely the language constraints to STM development, is discussed in Chapter Eight along with the conclusions of the cross-linguistic study.
8.1. Restating the starting point of this thesis

The aim of this thesis was to explore the development of STM and the use of memory strategies with respect to the working memory model (Baddeley, 1986, 1990; Baddeley & Hitch, 1974). As was shown in the literature review, a main assumption of the model is that the number of items held in the phonological loop is inversely related to the length of items, and thus to the time it takes to articulate them. STM span appears, therefore, to reflect a fixed and universal capacity, which is biologically determined and should depend strongly on individual differences in speech rate and on the length of the items to be remembered.

It was also discussed that this conception of STM capacity is not as rigid as the simple relationship between item length and memory span suggests. For example, numerous studies have stressed the contribution of long-term memory representations to memory span (e.g. Hulme et al., 1991, 1995), the role of STM search (see Cowan & Kail, 1996), and, an issue particularly relevant here, the importance of memory strategies. Among these, phonological recoding and verbal rehearsal, as explored by studying phonological similarity and word length effects on recall, have shown that there is a greater flexibility in what determines memory span than is, perhaps, implied by the ‘item length - memory capacity’ equation alone.

In particular, developmental research has shown that changes in memory performance with age involve the gradual elaboration of optional processes that become more efficient and flexible with age, rather than global changes that would require a structural reorganisation of memory systems. This flexibility is evident as
a specific developmental shift in coding strategies, which is well documented (see Chapter One). Effects of presentation and response modality on STM performance suggest that children’s choice of memory strategies depends on the sensory modality in which the material to be remembered is presented (e.g. Henry et al., 2000; Hitch, 1990).

In order to study the use of STM strategies further, two different approaches were used in this thesis. Both approaches were based on the general assumption that if memory strategies can be used in a flexible manner, then the choice of a particular strategy could also be dependent on contextual factors, such as task difficulty. The perceived difficulty of a memory task may, in turn, be dependent upon the resources that are available to the individual at a particular age. Therefore, it should be expected that specific constraints or strengths dictated by general intelligence, culture, age or education may affect the use of memory strategies.

The starting point for the first approach was the assumption that native language can be one of the factors that expand or limit the STM resources of an individual. Therefore, this approach was based on the comparison of populations that speak a different language. Greek and English were chosen on the basis of differences in average word length between the two languages. It was assumed that, if word length is inversely related to short term memory span, as the working memory model postulates, this should be reflected on STM differences between Greek and English speakers. Moreover, the question of whether, and how, this difference would affect the choice of memory strategies of the two populations at different ages was also explored.

The starting point for the second approach was the evidence that individuals with Down syndrome experience difficulties in verbal processing and language skills, while their visual processing abilities are relatively spared (see Chapter Five). In this case, therefore, the contextual factor predicted to affect STM performance was related to biologically based limitations in cognitive processing. The main question
addressed was the extent to which children with Down syndrome could rely from visual and spatial information in STM tasks, and their potential in learning to further benefit from visual strategies.

8.2. Bringing together the findings from the two studies

Conclusions related to the cross-linguistic study and the Down syndrome study were discussed in Chapters Four and Seven respectively, and will not be repeated here. In the present section, the findings related to the general predictions of the thesis are discussed.

What the populations studied here had in common was the presence of language-based factors (inherent or external) that were likely to affect STM performance. Examining the patterns observed in the Greek group and the Down syndrome group reveals an interesting finding: both groups showed a reliance on visual coding, as observed in Corsi performance, an advantage for recall of pictures versus spoken words and an advantage of recall of printed digits versus spoken digits. This reliance is not surprising, as the modality effects related to STM performance were prolonged in Greek children compared to English children of the same age, while the visual span scores of children with Down syndrome were comparable to the performance of children matched for mental age.

In other words, a group of typically developing children speaking a language that has long words and probably receiving a literacy education adapted to the demands of their language, showed some similarities in visual STM performance with a group of children with learning difficulties and limitations in verbal skills. However, the verbal processing skills of Greek children were intact. Why, then, did they show this pattern of performance? Clearly, there are different underlying reasons for these patterns of STM.
Greek children within the same age group demonstrated an ability to switch between strategies in order to apply the best strategy for remembering words of increasing length. It was clear that they were also able to use verbal information—as they did not differ from English children of the same age in STM spans of spoken words that had the same length—but they relied on visual coding when this was possible and when the words became longer. Their use of mixed strategies also showed a progression towards verbal processing with increasing age.

The group with Down syndrome also showed a reliance on visual coding, as well as evidence for some verbal processing (significant phonological similarity effects on both spoken word and picture recall), but their verbal STM was impaired compared to typically developing children of the same mental age. However, this reliance on visual information was only evident when the tasks were relatively simple (free recall of Corsi blocks) and when, given the verbal STM deficit, visual coding was the only option (picture span task). There was, however, no evidence for spontaneous use of visual information in more complex tasks (spatial cues); the imagery task also showed a difficulty in coordinating abilities that were intact (memory for shape, probe detection, associative memory).

These similarities and differences between the patterns of results observed in the two studies lead to several general conclusions related to the questions addressed in the Introduction. First, item length is clearly not the only factor determining STM span. The main difference between the two groups lied in the ability to use high-level control processes in order to adapt their STM performance to confining factors affecting the use of the phonological loop. This suggests the importance of the central executive for adaptive use of strategies (see Baddeley, 1996). The findings from both studies also indicate that STM development does depend on contextual factors. The results of the cross-linguistic study suggested that language can be such a contextual factor. As stressed, however, the role of educational strategies and literacy should also be considered.
This dependence of STM on contextual factors also suggests a flexibility of memory development across different populations. This indicates a plasticity of memory processes, which could be exploited in memory teaching programmes. The literature review and the results of the Down syndrome experiments indicate that, with appropriate training, children with Down syndrome could improve their ability to apply visual strategies.

As mentioned in the separate discussion chapters, future research should focus on further exploring the aspects related to language that seem to affect STM performance. Research on memory in Down syndrome should focus on the teaching of visual STM strategies and the inclusion of metamemory training, to observe improvements in strategic use.
References


Appendix A

The Greek version of the British Picture Vocabulary Scale
(Dunn & Dunn, 1982).

As mentioned in Chapter Two, the Greek and English groups that were studied in the cross-linguistic experiments were assessed on a measure of receptive vocabulary. The short form of the BPVS (Dunn & Dunn, 1982) was used for this purpose. However, it should be stressed that the principal measure for matching the two language groups was a nonverbal test, Raven's Coloured Matrices (Raven, 1963), performance in which does not depend on native language. The BPVS was rather used here as an index of the children's level of vocabulary knowledge. As a different version of the test was used for the Greek group (see changes below), matching could not be based on this measure alone.

Pilot work with Greek children aged 4 to 10 years indicated that some of the stimuli, or the names of the stimuli, had to be replaced in the Greek version. There were several reasons for this: in some cases, the name of a picture was an easier Greek word compared to its English equivalent; in other cases, the Greek translation of an English word was not a single word. Changes involved replacement of a stimulus by another on the same page, or replacement of the literal translation of a word by another. The English words, their Greek equivalents, the changes made and the reasons for these changes are shown in Table A1. No changes were made for the training plates.

Although the Greek version of the test was not standardised, an inspection of the means within each age group indicated that: (a) performance increased with age; (b) the values of the BPVS scores within each Greek age group were equivalent to the respective mean scores of the English age groups (see Table A2). Thus, this adaptation of the BPVS provided information about vocabulary knowledge comparable to the English sample.
Table A1. Changes made for the Greek translation of the BPVS.

<table>
<thead>
<tr>
<th>English word</th>
<th>Greek word</th>
<th>Change to:</th>
<th>English translation of Greek word</th>
<th>Description of change</th>
<th>Reason for change</th>
<th>Other comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>bucket</td>
<td>kouvas</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>ball</td>
<td>balla</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>car</td>
<td>autokinito</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td>wooden</td>
<td>ksyline</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
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<tr>
<td>camera</td>
<td>camera</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
</tr>
<tr>
<td>envelope</td>
<td>fakelos</td>
<td>-</td>
<td>-</td>
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<td>-</td>
</tr>
<tr>
<td>circle</td>
<td>kyklos</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>furniture</td>
<td>epiplo</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>nostril</td>
<td>routhouni</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>dangerous</td>
<td>epikindyno</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>furious</td>
<td>orgismenos</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>athlete</td>
<td>athlitis</td>
<td>empodistis</td>
<td>hurdles athlete</td>
<td>Replacement with a more specific word</td>
<td>To match for difficulty</td>
<td>‘Athlete’ is a Greek word, and thus easier for Greek children</td>
</tr>
<tr>
<td>artist</td>
<td>kallitechnis</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Choice among several synonyms, to match for difficulty</td>
</tr>
<tr>
<td>weary</td>
<td>katakopi</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Table A1. Changes made for the Greek translation of the BPVS (continued)

<table>
<thead>
<tr>
<th>English word</th>
<th>Greek word</th>
<th>Change to:</th>
<th>English translation of Greek word</th>
<th>Description of change</th>
<th>Reason for change</th>
<th>Other comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>socket</td>
<td>priza</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Sockets look different in Greece, but change was not considered necessary</td>
</tr>
<tr>
<td>antler</td>
<td>kerato</td>
<td>havliodontas</td>
<td>elephant tusk</td>
<td>Replacement with another picture on the same page</td>
<td>No equivalent for 'antler'; one general word for 'horn, antler', etc</td>
<td></td>
</tr>
<tr>
<td>pulley</td>
<td>varoulko</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>inflated</td>
<td>diogkomeno</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Word too formal to describe a balloon, but matched for difficulty</td>
</tr>
<tr>
<td>assisting</td>
<td>voitho</td>
<td>ypovastazo</td>
<td>support</td>
<td>Word replacement</td>
<td>To match for difficulty</td>
<td>-</td>
</tr>
<tr>
<td>utensil</td>
<td>skevos</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>talon</td>
<td>-</td>
<td>hooked</td>
<td>-</td>
<td>Word replacement</td>
<td>No equivalent to match for difficulty</td>
<td>-</td>
</tr>
<tr>
<td>confiding</td>
<td>ekmystirevomai</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>inoculation</td>
<td>emvoliasmos</td>
<td>anosopeesi</td>
<td>immunisation</td>
<td>Word replacement</td>
<td>To match for difficulty</td>
<td>Meaning of word inoculation easy to guess in Greek</td>
</tr>
<tr>
<td>consuming</td>
<td>katanalono</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
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<td>Greek word</td>
<td>Change to:</td>
<td>English translation of Greek word</td>
<td>Description of change</td>
<td>Reason for change</td>
<td>Other comments</td>
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Table A2. Means of age, BPVS scores and Raven’s scores for each age group.

<table>
<thead>
<tr>
<th>Age group</th>
<th>Mean age in years and months (standard deviations in parentheses, in months)</th>
<th>Mean raw BPVS scores (standard deviations in parentheses)</th>
<th>Mean raw Raven’s scores (standard deviations in parentheses)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greek age 4</td>
<td>4:3 (3.35)</td>
<td>10.71 (2.39)</td>
<td>14.96 (2.65)</td>
</tr>
<tr>
<td>English age 4</td>
<td>4:4 (5.59)</td>
<td>9.25 (2.38)</td>
<td>13.5 (3.13)</td>
</tr>
<tr>
<td>Greek age 6</td>
<td>6:4 (3.02)</td>
<td>14.67 (2.20)</td>
<td>21.21 (3.05)</td>
</tr>
<tr>
<td>English age 6</td>
<td>6:4 (2.84)</td>
<td>13.38 (2.60)</td>
<td>20.10 (4.16)</td>
</tr>
<tr>
<td>Greek age 8</td>
<td>8:3 (2.62)</td>
<td>18.25 (2.56)</td>
<td>25.54 (2.30)</td>
</tr>
<tr>
<td>English age 8</td>
<td>8:1 (3.10)</td>
<td>19.17 (2.20)</td>
<td>26.00 (2.17)</td>
</tr>
<tr>
<td>Greek age 10</td>
<td>10:8 (5.50)</td>
<td>21.82 (2.09)</td>
<td>30.74 (2.24)</td>
</tr>
<tr>
<td>English age 10</td>
<td>10.1 (3.41)</td>
<td>23.48 (2.47)</td>
<td>28.67 (3.67)</td>
</tr>
</tbody>
</table>
Appendix B

Comparing Greek and English on average word length

One of the assumptions on which the cross-linguistic study was based was that Greek words are, on average, longer than English words, both in terms of number of syllables and number of phonemes. It could, however, be claimed that the crucial factor on which the two languages should be compared is phoneme spoken duration, as this factor is associated with STM span (see Baddeley, 1990, p.75). Although measuring articulation times would explain even more directly the cross-linguistic differences in STM development, they were not measured here. Nevertheless, the differences in the number of syllables and phonemes reported below are convincing, if less direct, evidence for the difference in word length between the two languages.

To support the claim that the two languages differ in word length, 100 English words designating concrete nouns and colour terms, and their Greek equivalents, were compared on number of syllables and phonemes. Fifty words were selected at random from the norms of age acquisition of Morrison et al. (1997), the only selection criterion being that they should be familiar to children aged up to 5 years. Fifty words were also selected at random from Greek nursery school story books, and were translated into English.

Table B1 shows the percentage of words at each length (in terms of number of syllables) in the two languages. As can be seen, the range of Greek word length was 1 to 6 syllables, while the English words ranged from 1 to 4 syllables. Most Greek words had 2 or 3 syllables, while most English words were 1-syllable long. The difference between the two languages was also evident when the mean number of syllables and phonemes was contrasted in the two languages. The average word length in the Greek sample was 2.74 syllables (SD=0.89) and 5.86 phonemes.
(SD=1.78). In the English sample, the average word length was 1.51 syllables (SD=0.73) and 3.92 phonemes (SD=1.54). One-way ANOVAS comparing the two languages on number of syllables and number of phonemes also showed that the Greek words were longer (F(1,199)=113.27, p<0.001 for syllables; F(1,199)=68.32, p<0.001 for phonemes).

**Table B1. Frequencies of word length in Greek and English**

<table>
<thead>
<tr>
<th>Greek</th>
<th>Number of words %</th>
<th>Cumulative percent</th>
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</thead>
<tbody>
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<td><strong>Number of syllables</strong></td>
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<tr>
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<tr>
<td>2</td>
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<td>44</td>
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<tr>
<td>3</td>
<td>40</td>
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<td>4</td>
<td>12</td>
<td>96</td>
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<tr>
<td>5</td>
<td>3</td>
<td>99</td>
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<tr>
<td>6</td>
<td>1</td>
<td>100</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>English</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of syllables</strong></td>
<td>Number of words %</td>
<td>Cumulative percent</td>
</tr>
<tr>
<td>1</td>
<td>61</td>
<td>61</td>
</tr>
<tr>
<td>2</td>
<td>29</td>
<td>90</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>98</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>100</td>
</tr>
</tbody>
</table>
Appendix C
Line drawings used as visual stimuli in Experiments Two and Three

Experiment Two
Stimuli used in the Greek group

Phonologically similar

Visually similar

Control
Experiment Two
Stimuli used in the English group

Phonologically similar

Visually similar

Control
Experiment Three
Stimuli used in the Greek group

2 syllables
- Eye
- Fish
- Door
- Apple
- T-shirt
- Cheese
- Duck

3 syllables
- Balloon
- Boot
- Pig
- Table
- Rat

4 syllables
- Shirt
- Ring
- Bicycle
- Clock
- Telephone
- Elephant

5 syllables
- Rose
- TV
- Plane
- Car
Experiment Three
Stimuli used in the English group

1 syllable

2 syllables

3 syllables