Executive Functioning and the Emergence of Conversational Understanding.

Clair Pond

VOL 2

A thesis submitted for the degree of Doctor of Philosophy

Department of Psychology

September 2009

Chapter 7: Experiment 5 – Effects of bilingualism on executive functioning and conversational understanding

7.1 Introduction

Experiment 4 investigated whether training the shifting EF of 3- and 4-year-olds would enhance their CVT performance. However, it did not provide strong support for the proposal that EF promotes CU. Although EF training appeared to lead to marked improvements in EF ability, it did not appear to significantly enhance performance on the CVT. Post-training CVT scores were not significantly better than pre-training CVT scores. Nevertheless, performance on the CVT rose from chance levels prior to the EF training, to significantly above chance levels following the training. This reflected the progression made from chance to above chance levels of performance for items representing the Maxims of Quality and Politeness following EF training. This improvement in CVT performance, although not significant in relation to pre-training levels, is nonetheless consistent with the suggestion that EF enhances CU. Although a control training condition would be required to establish that CU promotion was not a consequence of more general training effects. Establishing that children with enhanced EF also possess advanced CU would be an alternative method of providing support for the proposal that EF promotes CU. Bialystok (1999, 2001) suggests that bilinguals display advanced EF compared to monolinguals. Thus Experiment 5 sought to establish that bilinguals possess superior CU relative to their monolingual counterparts.

Definitions of bilingualism vary considerably. At a very basic level, bilingualism can be characterized as proficiency in two languages. However Bialystok (2001) points out that judgements of proficiency alter in accordance with contrasting epistemological stances taken towards language development. She notes that, at a formalist extreme, Bloomfield (1933) argues that bilinguals should demonstrate complete fluency in both of their languages whilst at a functionalist extreme Grosjean (1989) proposes the less demanding requirement that bilinguals need only demonstrate the capability to use each language to satisfy their communicative needs. It is not only the definition of language "proficiency" that causes problems. Bialystok (2001) notes that the conceptualisation of "language" is also awkward. That language would not seem constrained to the domain of vocal communication, so that the classification "bilingual" should encompass individuals proficient in both a signed and a vocal language, or even two signed languages, is not difficult to appreciate. However Bialystok also remarks on the often apparent arbitrariness of language delineation so that structural and operative differences between dialects of the same language can often seem at a greater contrast than those observed between two distinct languages. This issue can be problematic in determining what it is about the management of two languages that leads to processing differences between bilingual and monolingual populations.

Aside from formal and functional perspectives on issues of language proficiency, Bialystok (2001) points out the importance of considering competency levels in each of the bilingual's individual languages, and also the competency-balance between their two languages. Both factors would appear to influence bilingual performance (Bialystok, 1988). Thus it has been suggested that comparison of the cognitive development of monolingual and bilingual children ought to control for the effects of language competency and language balance by employing bilinguals with competency levels in their individual languages close to those of the monolinguals, and with approximately equal proficiency in their two languages (Bialystok, 2001). Although alternatively, language competency levels and balance could be controlled by covarying the vocabulary scores of both language groups in monolingual-bilingual analyses.

However, the proposal that monolingual-bilingual comparisons should avoid differences in language levels is simply put forward as a recommendation to enable investigators to uncover optimum performance from bilinguals. Discovery that unbalanced bilinguals who are weaker in their second language or even their first language compared to monolinguals, could demonstrate equal or even superior task performance comparative to their monolingual counterparts would confer an even greater advantage to the effect of bilingualism.

7.2 Comparison of the language skills of monolingual and bilingual children

It has been suggested that bilingual children might be expected to demonstrate advanced CU compared to their monolingual counterparts. However this expectation of linguistic superiority is in stark contrast to earlier findings reviewed by Diaz (1983) which indicated that, compared to monolinguals, bilingual children possessed an impoverished vocabulary (Barke & Perry-Williams, 1938), demonstrated inadequate articulation (Carrow, 1957) and weaker writing skills (Harris, 1948). Indeed Bialystok (2001) observes that Macnamara (1966) attempted a very basic form of "meta-analysis" on studies of bilingual language development, from which he concluded that language development suffered as a result of bilingualism.

However, Bialystok points out that earlier research and Macnamara's analysis can be criticised on both methodological grounds (which Macnamara himself concedes) and conceptual grounds. With regards to the latter point, Bialystok suggests that bilinguals often encounter a fractionation of social contexts in accord with language exposure, as when a child is exposed to one language at home and in the community but is exposed to a different language in school. She argues that this contextual differentiation leads to discrepancies in the way a bilingual's language is used, supported and so develops, both in relation to their other language and in relation to the language of a monolingual. Thus, skills in the bilingual's different languages are not comparable and neither should they be directly contrasted with the skills of a monolingual. A monolingual in one of the bilingual's languages is likely to have used that language in multiple additional contexts to the bilingual, e.g., not just at home, but also in school and at church. He or she might have also received support for this language from additional sources not available to the bilingual, e.g., not just from parents but also from their teachers, friends and from watching television. The monolingual is thus likely to have developed the language in an alternative manner to the bilingual.

In contrast to earlier studies, more recent evidence has indicated the absence of a bilingual-monolingual difference and even a slight bilingual advantage in basic language abilities. For example, Pearson, Fernández, and Oller (1993) reported no significant difference between the total production vocabulary expressed by 8-30 month old Spanish-English bilinguals and age-matched Spanish and English monolinguals. Furthermore, these bilingual toddlers were found to demonstrate enhanced receptive vocabulary. Moreover, a wealth of studies have actually revealed a bilingual metalinguistic superiority.

Metalinguistic awareness denotes the ability to "objectify" language (Cromdal, 1999). It requires speakers and listeners to "look *at* language rather than through it to the intended meaning" (Cummins, 1978, p. 127, italics added) in order to focus on the structure rather than the communication. Bialystok (2001) categorises tasks assessing metalinguistic awareness into those that investigate "word awareness" involving the appreciation of words as basic units of meaning and an understanding of how meaning is assigned to these words, "syntactic awareness" involving grammatical knowledge and "phonological awareness" involving the appreciation of component speech sounds and their function. Bialystok observes that bilinguals show a degree of superiority on tasks from all of these categories. For example, Ben-Zeev (1977) reported that Hebrew-English bilinguals between 5 and 9 years outperformed monolingual English and Hebrew children of the same age on a symbol/word substitution task, whilst Ricciardelli (1992) found that Italian-English bilingual 5- and 6- year olds had superior grammatical awareness to monolingual English children of the same age. Feldman and Shen (1971) showed that Spanish-English bilingual 4-, 5- and 6-year-olds were significantly better at symbol/word substitution than same-age Spanish monolinguals, and the results of Galambos and Hakuta (1988) indicated that the degree of bilingualism demonstrated by Spanish-English bilinguals aged between 5- and 13-years-of-age was related to their ability to detect ambiguity and grammatical errors. Furthermore, Galambos and Goldin-Meadow (1990) discovered that Spanish-English bilinguals aged between 4 and 8 years were better at noting grammatical errors than same-age Spanish monolinguals and were more proficient at correcting grammatical errors than same-age Spanish and English monolinguals and Campbell and Sais (1995) demonstrated that bilingual Italian-English 4-year-olds had an advantage over same-age English monolinguals on a phoneme deletion task and on a phoneme categorisation task. In addition, Yelland, Pollard, and Mercuri (1993) produced evidence that English Italian bilinguals aged between 4 and 8 years had a significantly greater ability to analyse the physical structure of words than same-age monolingual English children. However, Bialystok notes that the bilingual advantage evidenced in all of these tasks is not all encompassing. Bialystok claims that the specific nature of the metalinguistic tasks used determines the outcome of bilingual-monolingual performance comparisons.

7.3 Executive functioning and bilingualism

Bialystok (2001) uses an "analysis-control" processing framework to describe the demands of metalinguistic tasks and to differentiate those tasks on which bilinguals reveal an advantage. She defines "analysis" as the ability to form mental representations of a subject, whether in the form of a concrete situation or event or presented as a set of abstract rules or hypotheses. "Control" is conceptualised as the EF ability to direct consideration of, or selectively attend to, such representations enabling focused processing of particular aspects of these mental knowledge structures. Bialystok notes that all tasks will involve both analysis and control processes to a degree but observes that tasks which primarily assess knowledge, such as basic grammatical judgement tasks which examine appreciation of grammatical rules, emphasise the analysis component. She considers that tasks which primarily assess the ability to ignore familiar but irrelevant cues, such as conventional word meanings in arbitrary word substitution tasks, emphasise the control (EF) component.

Consideration of bilingual-monolingual performance comparisons reported in the literature, across tasks conceptualised in terms of their relative analysis-control demands, led Bialystok to conclude that the bilingual advantage is restricted to tasks emphasising processing control/EF. As support, she further considers the effect on the monolingual-bilingual performance comparison, of manipulating a single task so that the demands for analysis and control are varied. She notes that in a typical grammaticality judgement task, in which meaningful though often grammatically incorrect sentences such as THE GIRL CHOCOLATE BAR ATE THE are presented, bilingual and monolinguals improve at the same rate, in accordance with their level of literacy (Bialystok, 1986). Since such a task primarily assesses knowledge of grammar, it can be considered high in demand for analysis, its low involvement of distracting cues, limiting its demands for processing control.

However, Bialystok (2001) notes that when the sentences used in the task become non-sensical, as in THE GIRL RED SHOE ATE THE, bilinguals demonstrate clear superiority (Bialystok, 1986). Although the analysis requirements of these task sentences are still high, the incorporation of contextually inappropriate and therefore distracting words raises the control (EF) demands to a similar elevated level. Bialystok (2001) uses this finding to support her suggestion that is the ability of bilinguals to control their processing, that differentiates their metalinguistic performance from that of monolinguals, not their ability to represent knowledge, which she claims is similar across groups.

Further evidence supports the proposal that the bilingual processing advantage promotes control of attention (EF), but leaves their ability to represent information at a monolingual level. Bialystok and Senman (2004) gave an appearance reality task to monolingual English 4- and 5-year-olds and same age bilinguals from a variety of native language backgrounds (e.g. Armenian, Filipino, Hebrew, Russian, Tagalog, Spanish, Arabic, African, Chinese, Somali, Hungarian, Polish, Persian, Mandarin and French) who spoke English as a second language. They found that there was no difference between the ability of monolinguals and bilinguals to appreciate the appearance of task items, indicating a similar ability to represent knowledge. However, bilinguals appeared to be better able to inhibit the deceptive appearance information to enable identification of the true character of the stimuli, once differences between the language proficiency of the two groups was taken into account.

Similarly, Bialystok and Martin (2004) gave four DCCS tasks to Chinese-English bilingual 3- and 4-year-olds and same-age English monolinguals. Consistent with a bilingual advantage in shifting EF, bilinguals outperformed the monolinguals on two standard tasks which assessed the ability to shift between basic perceptual representations of the images on the target and sorting cards, such as shape, colour and object. However, there was no difference between the performance of the bilingual and monolingual groups on two modified versions of the task which required children to shift between more complex semantic representations of card images, such as function, location, kind and place. If bilinguals have superior representational abilities, their performance advantage should have carried over to the complex representation tasks. However, the greater representational demands of these tasks appeared to have reduced bilingual performance levels to those produced by monolinguals. This indicates that the facilitatory effects of bilingualism apply to shifting EF abilities but may not extend to representational power.

Bialystok, Martin, and Viswanathan (2005) note evidence indicating that both of a bilingual's language systems remain active during processing in either language (Chen & Ho, 1986; Dijkstra, Grainger, & Van Heuven, 1999; Gollan, Forster, & Frost, 1997). For example, Chen and Ho (1986) demonstrated that bilinguals take longer than monolinguals to identify in one language the colours of the ink used to write conflicting colour words in a colour stroop task, despite the fact that the conflicting words they need to ignore are written in their other language. The "naming cost" indicates active interference from, and hence processing of, the other language despite its irrelevance to the task set.

Bialystok et al. (2005) suggest that the constant threat to processing in one of a bilinguals' languages from intrusion of processing in their other language requires bilinguals to actively inhibit the irrelevant language. This process serves to enhance their inhibitory ability. Consistent with this proposal, Bialystok (2009) notes that neuroimaging studies (Hernandez, Dapretto, Mazziotta, and Bookheimer 2001; Rodriguez-Fornells et al., 2005) reveal the activation of frontal brain regions which are commonly associated with EF activity in bilinguals when they switch or select between their languages.

Bialystok (2009) considers that Abutalebi and Green's (2007) model of brain network connections engaged in bilingual language production is a plausible account of the way in which the bilingual EF advantage might arise. In this model, there is a network involving various parts of the brain, such as the prefrontal cortex, anterior cingulate cortex, inferior parietal region and basal ganglia, which are involved in bilingual language processing. However, Bialystok notes that these networks are not solely devoted to language processing and also play a role in non-linguistic processing. She suggests that, when bilinguals are required to select between their languages, it is not just brain regions specialized in language production, such as Broca's area, which are involved. Areas dedicated to conflict resolution, such as the dorsolateral prefrontal cortex and anterior cingulated gyrus, are also activated. She proposes that the linguistically motivated activation of conflict resolution areas in bilingual language selection, in addition to the standard applications observed in monolinguals, effectively "trains" bilinguals' EF resources, enhancing their application.

Emmorey, Luk, Pyers, and Bialystok (2008) demonstrated that enhanced EF in bilingualism arises from selecting between competing language systems rather than the act of selection itself. Emmorey et al. used flanker tasks to compare the EF performance of monolinguals, bilinguals whose two languages were spoken, and bilinguals who used one spoken and one signed language. The premise was that signed and spoken languages were not mutually exclusive, using two different forms of production and so enabling simultaneous usage, reducing the conflict involved in language selection. It was expected that the reduced conflict experienced by bilinguals using both signed and spoken languages would prevent EF training effects, removing the EF superiority for this bilingual group. However, it was anticipated that this EF advantage would remain for bilinguals whose two languages were spoken, preventing simultaneous production. The mutual exclusivity experienced by this latter group of bilinguals was expected to promote conflict resolution, resulting in EF training effects. Indeed, as expected, the EF performance of the spoken and sign bilingual group did not differ from that of the monolingual group, whilst the bilingual group whose two languages were spoken demonstrated the standard bilingual EF advantage.

However, Bialystok points out that the bilingual EF superiority is not just attributable to the enhancement of standard mechanisms of control. She notes the observation of Bialystok et. al. (2005) that the enhanced performance of bilinguals in a Simon EF task was attributable to their additional activation in the language specialised region: Broca's area. Thus, the bilingual EF advantage is attributable to "both more resources (Broca's area) and more efficient resources (other frontal regions)" (Bialystok, 2009, p.8).

The bilingual enhancement of non-linguistic specific frontal region sources of EF and supplementary application of the typically linguistic-specific Broca region to non-linguistic EF tasks, provides accommodation for findings indicating that the bilingual advantage in control extends beyond the linguistic domain. For example, Bialystok and Codd (1997) reported that bilingualism promoted the application of control to quantification tasks. Bilingual children aged 4 and 5 years who spoke fluent English as well as one of a variety of additional languages performed better than same age English monolinguals, in a control-rich element of the Towers task. The bilingual children were better able to ignore deceptive perceptual cues to quantity, and instead counted individual component blocks of each tower, enabling more accurate identification of the towers with the greatest number of blocks.

A bilingual control advantage can also be linked to benefits in spatial awareness. Bialystok and Majumder (1998) found that 7- to 9-year-old French-English bilinguals outperformed same-age English monolinguals on the Block Design task (Weschler, 1974), which requires control of attention to individual marked blocks rather than the whole pattern they create when placed together. Bilingual children have also been found to demonstrate enhanced performance relative to the monolinguals, on the Water Levels Task (Piaget & Inhelder, 1956) which assesses appreciation that the water level axis observed when the liquid is enclosed in a container is determined by the horizontal base on which the container is placed, rather than the base of the container itself.

The enhanced bilingual performance on the appearance-reality task reported by Bialystok and Senman (2004), which requires control of attention away from the form of items, and revealed by Bialystok and Martin (2004) on the DCCS, which requires control of attention directed towards sorting dimensions (see p258-259) provide additional evidence that bilingualism promotes the application of control to the non-linguistic domains of object identification and categorisation respectively.

Bilingual superiority in executive control also may have a facilitating effect on visual perception. Bialystok and Shapero (2005) found that bilingual 6-year-olds who spoke English at school but used another language such as French, Korean, Chinese, Russian or Spanish, at home, were better able to make out the alternative image in a reversible figure, than same-age English monolinguals. Viewing the alternative figure requires exertion of control to direct attention away from the obvious image in search of another figure.

Feng, Diamond, and Bialystok (2007) demonstrated an additional bilingual benefit for non-linguistic control manifest in memory updating. Children were presented with 9 squares set out in a 3 x 3 matrix and were then shown a series of sequences in which individual squares were marked one at a time. The children were told that the markings reflected the jumps of a frog moving from one pond (square) to another, and were asked to remember these jumps. They were then asked to recall these jumps either in the order in which they were made (assessing basic short-term memory) or according to some ordering rule (assessing the ability to manipulate information held in memory/updating), such as one requiring identification of the squares jumped on whilst moving from left to right in each row, and from the top row to the bottom row. Feng et al. reported that there was no difference between the ability of bilingual and monolingual children to recall jumps made in the order they were made. However, they found a bilingual advantage for memory updating based on children's recall manipulated according to ordering rules.

Martin-Rhee and Bialystok (2008) refined current understanding of the bilingual EF advantage by demonstrating that bilingual superiority was not generalised across inhibitory control tasks. They looked at the inhibitory performance of 4- and 8-year-old English speaking bilinguals who also spoke either French, Chinese, Spanish, Russian or Hebrew. Martin-Rhee and Bialystok found that these bilinguals outperformed same-age English monolingual children on Simon tasks requiring suppression of attention to irrelevant cues such as location in space, to enable focus on relevant cues such as colour. However, this bilingual advantage was not found to extend to performance on "opposite" tasks which required suppression of pre-potent responses such as standard labelling of a cat, to enable novel conflicting responses such as labelling the cat as a "dog". Martin-Rhee and Bialystok used these findings to argue that the bilingual advantage applied to inhibition of interference but not inhibition of responses.

Whether, the superior control ability of bilinguals can be interpreted in terms of socioeconomic status (SES) or cultural differences in communication sensitivity is controversial. Morton and Harper (2007) suggested that differences in SES associated with bilingualism and monolingualism might account for variation in control proficiency, rather than the number of languages children have been exposed to. Children from backgrounds of high SES had previously been found to demonstrate enhanced EF relative to children from backgrounds of low SES (Mezzacappa, 2004). Furthermore, Morton and Harper pointed out that previous studies appearing to reveal a bilingual advantage in control ability, neglected to consider the influence of SES on their data. Therefore, Morton and Harper recruited English monolingual and English-French bilingual 6- and 7-year-olds from very similar ethnic and SES backgrounds, and investigated language group differences in performance on the Simon EF task. Morton and Harper found no difference in the control ability of the two groups. Furthermore, Morton and Harper found that SES was significantly related to control competence within their sample.

However, Carlson and Meltzoff (2008) have since reported evidence of a bilingual superiority in control ability when SES has been taken into account. They compared the control abilities of 4-, 5- and 6-year-olds who had been classified as either monolingual English with only minimal exposure to a second language, English dominant but belonging to an immersion group with 6-months experience of either Spanish or Japanese instruction, or bilingual since birth: Spanish-English. Like Martin-Rhee and Bialystok (2008), Carlson and Meltzoff sought to provide elucidation of the bilingual superiority in control. They wanted to investigate whether this bilingual advantage extended beyond control in the cognitive domain, to include motor control. Carlson and Meltzoff were interested in whether the bilingual advantage in command over cognitive focus, as required in the DCCS task for example, was mirrored by superior management of motor behaviours, as would be required if a child was rewarded for not opening a present immediately.

Carlson and Meltzoff (2008) initially found no significant difference between the control ability of any of the language groups. However, when the significantly lower SES and verbal ability of the bilingual group was taken into account, the cognitive control ability of the bilingual group was significantly enhanced relative to the monolingual and immersion groups. When SES and verbal ability was covaried, there was no significant difference between the control ability of the immersion and monolingual groups. The bilingual superiority remained however, even when the significantly higher value attributed to obedience by the parents of the bilingual children, was taken into account. Furthermore, in concordance with the findings of Martin-Rhee and Bialystok (2008), Carlson and Meltzoff reported that the bilingual advantage in control was restricted to tasks requiring cognitive control. Bilinguals did not demonstrate enhanced performance relative to the monolingual or immersion groups on tasks requiring motor control.

Evidence thus appears to indicate that bilinguals do demonstrate enhanced EF and that this ability is not restricted to linguistic specific tasks but can be applied to other quite disparate domains such as those of visual perception and quantification. However, this enhanced control does not appear to be manifest in the physical realm, seeming to confine itself to cognitive control.

7.4 Aim of Experiment 5

Studies suggest that bilinguals indeed demonstrate sensitivity to the communicative context from an early age. Genesee, Nicoladis and Paradis (1995) reported that 2-year-old French-English bilinguals used more of their mother's native language with their mothers and more of their father's native language with their fathers, even when both parents were present and were using both distinct languages with their children. Further, Genesee, Boivin, and Nicoladis (1996) found that this accommodation effect extended to monolingual French or English strangers.

Moreover, a few studies have indicated that bilinguals demonstrate superiority in CU tasks. Genesee, Tucker, and Lambert (1975) reported that when asked to explain a game to blindfolded participants, bilingual English-French 5- to 7-year-olds made more reference to (unseen) materials involved (e.g. "there is a die") indicating their appreciation of the use of visual context when interpreting instructions, than same age monolinguals. Also, Doyle, Champagne and Segalowitz (1977) reported that French-English bilinguals demonstrated greater story-telling fluency than monolinguals, indicating an enhanced ability to consider linguistic context effects. However, the two studies cited above are around 30-years-old, with the bilingual status of children in the Genesee et al. (1975) study not even clear, presumed on the basis of inclusion in an immersion program, but lacking verification from consideration of language proficiency levels.

More recently, Siegal, Iozzi, and Surian (2009) found that bilingual Italian-Slovenian 4-, 5- and 6-year-olds attained significantly higher CVT scores than Italian and Slovenian monolinguals of the same age. Moreover, this bilingual superiority effect was found despite the fact that both monolingual groups demonstrated greater language proficiency on picture vocabulary tasks. However, although Siegal et al. also looked at the effect of bilingualism on EF, they found no evidence that access to two languages conferred an advantage on inhibitory EF ability, as assessed using the Day-Night task (Gerstadt, Hong, & Diamond, 1994), and found that both bilinguals and monolingual Slovenians demonstrated greater shifting EF, measured using the DCCS (Zelazo, 2006), than monolingual Italians. There was no significant difference in the shifting EF ability of the bilinguals and monolingual Slovenians. Furthermore, the bilingual advantage in CVT performance remained when DCCS performance taken into account, indicating that the bilingual superiority in CU was not attributable due to their enhanced EF abilities on this measure.

A bilingual advantage on the CVT could reflect an enhanced representational skill, arising from the ability to conceive/represent the same concepts in two different language forms. This might promote perception of language as a mere representation of meaning, and so enable earlier ability to represent context as additional evidence relevant to the meaning of communication. However, findings which indicate that the bilingual advantage does not extend to representational abilities (Bialystok & Senman, 2004; Bialystok & Martin, 2004) suggest this explanation is unlikely. There is thus the need for further investigation into the relationships between bilingualism, EF and CU.

Alternatively, a bilingual advantage on the CVT might result from their possession of enhanced ToM rather than enhanced EF per se. As argued in Section

1.6, CU requires appreciation of communicative intentions, and intentions are a type of mental state, so CU would seem to require ToM competence. Furthermore, Goetz (2003) and Kovács (2008) reported that 3- and 4-year-old Mandarin-English bilinguals and 2- and 3-year-old Romanian-Hungarian bilinguals demonstrated superior ToM skills to same age monolingual children in these languages, consistent with a ToM account of bilingual CU advantage. However one could question, as Goetz does, the mechanism promoting precocious ToM development in bilinguals. Goetz's consideration of enhanced representational ability (enabling conception of the representational nature of mental states) would appear undermined by studies mentioned above, which indicate that the bilingual advantage does not extend to representational abilities. Her suggestion that early pragmatic sensitivity to the linguistic knowledge of others stimulates more general appreciation of the potential for conflicting mental representations, attributes enhanced ToM skills to early CU competence in the first place, failing to provide a ToM account of initial pragmatic advantage. However, Goetz also considers whether enhanced EF promotes ToM appreciation, by enabling inhibition of automatic behaviour processing biases. Such an account would in fact seem to be consistent with an EF model of CU development, where these processing biases would appear to be directed at the interpretation of linguistic behaviour.

The purpose of Experiment 5 was to examine whether the EF superiority of bilingual children confers an advantage to their CU. More specifically, Experiment 5 was conducted to investigate the effect of bilingualism upon performance on the CVT and EF ability, and to examine the relationship between EF and CVT proficiency. EF ability was assessed in terms of performance on the Frog-Simon inhibitory task and the Dibbets updating task which had both been previously used in Experiments 2 and

3, and the DCCS shifting task which had previously been employed in Experiments 3 and 4. The bilingual population consisted of 4- and 5-year-olds who were bilingual in Italian and English, having been exposed to English mainly in their school context. Their performance was compared to that of age-matched monolingual English children.

In line with previous evidence of a bilingual advantage in EF and CU, it was hypothesised that the bilingual children would demonstrate enhanced performance on the one or more of the EF tasks and on the CVT compared to the group of monolingual English children. Furthermore, in accordance with the masked competence model of CU development, it was predicted that performance on one or more of the EF tasks would predict performance on the CVT.

7.5 Method

Participants. Bilinguals: These were 19 children aged between 48 and 66 months (M: 58.42 months, SD: 5.24.months). The children attended an English Instruction International school in Trieste, Italy. These children were predominantly white and middle class and spoke Italian as their first language. None were known to have any specific language impairment. All had Italian-speaking parents and had been exposed to English as a second language through the school environment. Two other children were excluded, both of whom were aged 60 months. These were an Australian boy who had English-speaking parents and had been exposed to Italian outside the home and a native Italian who was unable to follow English instructions.

English Monolinguals: These consisted of 19 native-born English participants with English-speaking parents and living in England, reflecting the same proportion of 4- and 5-year-olds found in the bilingual/second language exposed group (M: 62.68

months, SD: 6.31 months). These children were predominantly Caucasian and middle class and spoke only English. None were known to have any specific language impairment.

Procedure. All children were tested individually in a quiet area of their school. The bilingual participants completed seven tasks: two CVTs - one in English and the other in Italian, two picture vocabulary tasks - one in English (BPVS) and the other in Italian (IPVS: Dunn & Dunn 2000), and three EF tasks – the Frog Simon Inhibition task, the DCCS shifting task and the Dibbets updating task. The experimenter providing instruction for the Italian CVT and the IPVS was an Italian native-speaker who introduced these tasks to the bilinguals in Italian. All other tasks were presented in English by an English native-speaking experimenter. English monolinguals completed all of the tasks presented to the bilinguals with the exception of the Italian CVT and IPVS. All tasks were presented to the English monolinguals in English by the same native-speaking English experimenter who had worked with the bilingual group.

Testing was conducted over the course of three sessions for the bilingual group and two sessions for the English monolingual group. Each session lasted between approximately 10 and 20 minutes. The first session commenced with a CVT followed by a picture vocabulary task in the corresponding language. For the bilingual group the language of the CVT and picture vocabulary task used in this session was counterbalanced. The second session, was used to present the Frog Simon Inhibitory task, the DCCS shifting task and the Dibbets Updating task, in that order. The third session, given only to the bilinguals, was used to present the CVT and picture vocabulary task in the language not received in the first session.

CVTs. The English version was identical to the CVT presented in Experiment 3 (see Section 5.2). The Italian CVT used the same puppet scenario as the English CVT, and was almost an exact Italian translation, with the exception that three items had been modified slightly to accommodate the different cultural background of the Italian children. For example, in response to the question: "What do you usually have for lunch?" the response given to the English monolinguals of "A sandwich" was replaced with "Pasta" (see Appendix XII).

Picture Vocabulary Tasks. The BPVS was used to assess picture vocabulary scores (PVS) in English. The Italian Picture Vocabulary Scale (IPVS) was used to assess Italian PVS.

Frog Simon Inhibitory EF Task. This was identical to the task used in Experiment 2 (see Section 4.2). No child failed to respond correctly to the first two slides.

DCCS Shifting EF Task. This was identical to the task used in Experiment 1 (see Section 3.2). No child failed to sort 5 cards correctly in the pre-switch phase.

Dibbets Updating EF Task. This was based on the training task used in Experiment 2 (see Section 4.2). However, two modifications were introduced. First, training scores in Experiment 5 were based on the classification of children with regards to the three performance categories used to identify those who were suitable to move onto the switch test trials in Experiment 2. Thus, in Experiment 5 children were awarded points on the basis of having achieved a poor, intermediate or good level of updating training. This contrasts with the less finely differentiated training score scheme used in Experiment 2 in which children were awarded points on the basis of having achieved either weak or strong updating training. Second, the criterion used to distinguish children in the "Good Level of Updating Training" category from children in the "Intermediate Level of Updating Training" category, was deemed as the ability to correctly identify the location of the kitten on 8 rather than the original 7 consecutive trials. This was for ease of scoring. Children who were classified as belonging to the "Good Level of Updating Training" category, were assigned a score of 3. Children belonging to the "Intermediate Level of Updating Training" category were assigned a score of 2 and children in the "Poor Level of Updating Training" category were assigned a score of 1.

7.6 Results

Score means and standard deviations are presented in Table 7.1. As has often been observed, the bilingual children's vocabulary scores in both of their languages lagged behind those of the monolingual group.

Table 7.1: *Mean scores and standard deviations achieved for all of the tasks given to the monolingual English children and Italian-English bilingual children in Experiment 5.*

	Italian-English bilinguals	English monolinguals
No. of children	19	19
Age in months	58.42 (5.24)	62.68 (6.31)
British PVS standard scores	76.95 (11.02)	108.95 (12.04)
Italian PVS standard scores	86.26 (12.08)	-
English CVT/25	14.58 (3.86)	18.53 (4.13)
Italian CVT/25	17.42 (2.99)	-
DCCS shifting EF/6	4.37 (2.61)	5.42 (1.47)
Frog-Simon Inhibitory EF/20	18.05 (1.31)	17.32 (2.14)
Dibbets updating training EF/3	1.89 (0.99)	2.26 (0.99)

Note: PVS=Picture Vocabulary Scores; CVT=Conversational Violations Task; DCCS=Dimensional Change Card Sort Task; EF=Executive Functioning.

Relationship between language group and CVT competence: Native language CVT

The effect of language group on native language CVT performance was investigated by comparing the native language CVT scores of the Italian-English bilingual children with those of the monolingual English children. Preliminary t-tests revealed significant differences between the language groups in both age, $t(36) = 2.266$, $p<0.05$ and standardised native language PVS, $t(36) = 5.797$, $p<0.001$. The English monolingual children were significantly older and had significantly greater native language PVS than the Italian-English bilingual children. Thus, both age and native language PVS were covaried out of analyses focusing upon language group differences in native language CVT performance. A 2 (language group: Italian-English bilingual children vs. English monolingual children) X 5 maxim (First Quantity vs. Second Quantity vs. Quality vs. Relation vs. Politeness) ANCOVA, covarying out age in months and native language PVS, was conducted to assess native language CVT performance (see Table 7.2 for mean CVT scores and standard deviations for the language groups across maxims). Although the main effect of language group was not significant, $F(1, 178) = 1.573$, $p>0.20$, there was a significant main effect of maxim, $F(4, 178) = 3.785$, $p<0.01$. Performance on CVT items reflecting the maxims of Quality, Relation and Politeness appeared to be greater than performance on items reflecting the maxims of First and Second Quantity, although performance for all maxims was above chance (t's>4.275, p's<0.001). There was no significant interaction between language group and maxim, $F(4, 178) = 0.073$, $p>0.90$. Table 7.3 reports the summary data for this analysis and Table 7.4 reports the estimated marginal means and standard errors of CVT scores for the language groups across maxims when the effects of age and native language PVS were taken into account.

Table 7.2: *Mean maxim scores and standard deviations for the Italian-English bilingual and English monolingual children.*

	Italian-English bilingual children: English CVT	Italian-English bilingual children: Italian/Native CVT	English monolinguals: English/Native CVT
First Quantity	2.47 (1.07)	3.26 (1.28)	3.42 (1.17)
Second Quantity	2.74 (1.37)	3.05 (0.78)	3.32 (0.89)
Quality	3.05 (0.91)	3.68 (1.11)	3.79 (1.36)
Relation	3.11 (1.24)	3.68 (1.11)	4.00 (0.88)
Politeness	3.21 (1.27)	3.74 (0.81)	4.00 (1.16)

Table 7.3: *Summary table for the 2 (Language group: Italian-English bilingual children vs. English monolingual children) x 5(Maxim) analysis of covariance of native language CVT scores partialling out the effects of age and standardised native language PVS.*

Source	SS	df	MS	F	p	Partial Eta²
Within	173.650	178	0.976			
Age covariate	31.031	1	31.031	31.809	0.001	0.152
Native PVS covariate	1.543	1	1.543	1.582	0.210	0.009
Language group	1.535	1	1.535	1.573	0.211	0.009
Maxim	14.768	4	3.692	3.785	**0.006**	0.078
Language group X maxim	0.284	4	0.071	0.073	0.990	0.002
(corrected model)	50.145	11	4.559	4.673	0.001	0.224
(corrected total)	223.795	189				

Table 7.4: *Estimated marginal mean native language CVT maxim scores and standard errors for the Italian-English bilingual and English monolingual children, when the effects of age and native language PVS had been taken into account.*

	Italian-English bilingual children: Italian/Native CVT	English monolinguals: English/Native CVT
First Quantity	3.50(0.24)	3.18(0.24)
Second Quantity	3.29(0.24)	3.08(0.24)
Quality	3.92(0.24)	3.55(0.24)
Relation	3.92(0.24)	3.76(0.24)
Politeness	3.98(0.24)	3.76(0.24)

Relationship between language group and CVT competence: English language CVT

The effect of language group on English CVT performance was investigated by comparing the English CVT scores of the Italian-English bilingual children with those of the monolingual English children. Preliminary t-tests revealed significant differences between the language groups in standardised English PVS scores, $t(36) = 8.545$, $p<0.001$. English monolingual children had significantly greater English PVS than Italian-English bilingual children. Thus, both age and English PVS were covaried out of analyses focusing upon group differences in performance on the

English CVT. A 2 language group X 5 maxim ANCOVA, covarying out age and English PVS was conducted to assess performance on the English CVT (see Table 7.2 for mean CVT scores and standard deviations for language groups across maxims). Although there was no significant main effect of language group, $F(1, 178) = 0.363$, $p>0.50$, the main effect of maxim was significant, $F(4, 178) = 3.270$, $p<0.05$. Consistent with the analysis of performance across maxims for the native language CVT, performance on English CVT items reflecting the maxims of Quality, Relation and Politeness was greater than performance on items reflecting the maxims of First and Second Quantity. As with the results on native-language CVT scores, performance was above chance for all maxims ($\underline{t}$'s>2.285, $\underline{p}$'s<0.05), and there was no interaction between language group and maxim, $\underline{F}(4, 178) = 0.183$, $\underline{p}>0.90$. Table 7.5 reports the summary data for this analysis and Table 7.6 reports the estimated marginal means and standard errors of CVT scores for the language groups across maxims when the effects of age and English language PVS were taken into account.

Table 7.5: *Summary table for the 2 (Language group: Italian-English bilingual children vs. English monolingual children) x 5(Maxim) analysis of covariance on English language CVT scores partialling out the effects of age and standardised English language PVS.*

Source	SS	df	MS	$\underline{F}$	$\underline{p}$	Partial Eta^2
Within	191.534	178	1.076			
Age covariate	23.529	1	23.529	21.867	0.001	0.109
English PVS covariate	9.794	1	9.794	9.102	0.003	0.049
Language group	0.390	1	0.390	0.363	0.548	0.002
Maxim	14.074	4	3.518	3.270	**0.013**	0.068
Language group X maxim	0.789	4	0.197	0.183	0.947	0.004
(corrected model)	89.145	11	8.104	7.531	0.001	0.318
(corrected total)	280.679	189				

Table 7.6: *Estimated marginal mean English language CVT maxim scores and standard errors for the Italian-English bilingual and English monolingual children, when the effects of age and English language PVS had been taken into account.*

	Italian-English bilingual children: English CVT	English monolinguals: English CVT
First Quantity	2.95(0.26)	2.95(0.26)
Second Quantity	3.21(0.26)	2.84(0.26)
Quality	3.53(0.26)	3.32(0.26)
Relation	3.58(0.26)	3.53(0.26)
Politeness	3.68(0.26)	3.53(0.26)

Relationship between language group and EF ability

The effect of language group on EF ability was examined by comparing the EF scores of the Italian-English bilingual children with those of the monolingual English children. Previous t-tests had established significant differences between the language groups in both age and standardised English PVS scores. Language group differences in English, but not native language, PVS scores were considered in regards to EF analyses because the EF tasks were all presented in English. ANCOVAs were therefore performed on scores in the EF tasks, partialling out age and English PVS. The ANCOVA on scores in the DCCS shifting EF task revealed that although the bilinguals tended to perform better than the monolinguals on the DCCS shifting task when the effects of age and English PVS were controlled, the effect of language group was just below significance, $\underline{F}(1,34) = 3.408$, $\underline{p}<0.08$. Table 7.7 reports the summary data for this analysis and Table 7.8 reports the estimated marginal means and standard errors of DCCS scores for the language groups when the effects of age and English language PVS were taken into account.

Table 7.7: *Summary table for the 2 (Language group) analysis of covariance on DCCS scores partialling out the effects of age and standardised English language PVS.*

Source	SS	df	MS	$\underline{F}$	$\underline{p}$	Partial Eta^2
Within	118.846	34	3.495			
Age covariate	0.022	1	0.022	0.006	0.937	0.000
English PVS covariate	39.655	1	39.655	11.345	0.002	0.250
Language group	11.913	1	11.913	3.408	0.074	0.091
(corrected model)	52.733	3	17.578	5.029	0.005	0.307
(corrected total)	171.579	37				

Table 7.8: *Estimated marginal mean DCCS shifting EF, Frog Simon Inhibition EF and Dibbets updating EF scores and standard errors for the Italian-English bilingual and English monolingual children, when the effects of age and English language PVS had been taken into account.*

	Italian-English bilingual children: English CVT	English monolinguals: English CVT
DCCS shifting EF	5.87(0.61)	3.92(0.61)
FrogSimon inhibition EF	18.46(0.58)	16.91(0.58)
Dibbets updating EF	1.78(0.32)	2.38(0.32)

The ANCOVAs performed on scores attained in the Frog-Simon inhibition and Dibbets updating EF tasks did not reveal a language group effect either, $F(1,34) = 2.331$, $p>0.10$, and $F(1,34) = 1.128$, $p>0.20$ for the inhibition and updating EF tasks respectively. Table 7.8 reports the estimated marginal means and standard errors of inhibition and updating scores for the language groups when the effects of age and English language PVS were taken into account.

Relationship between EF ability and CVT competence

Table 7.9 presents correlations found between task scores for all 38 children when both tasks had been given to the bilingual and monolingual children, and for 19 children when only one of the language groups had received both tasks. Performance on the FrogSimon inhibition EF task was not found to be related to performance on either the English CVT ($r=-0.118$, $p>0.20$) or the Italian CVT ($r=-0.037$, $p>0.40$). Similarly, performance on the Dibbets updating EF task was not found to be related to either English CVT scores ($r=0.241$, $p>0.07$) or performance on the Italian CVT ($r=0.034$, $p>0.40$). However, although there was only a very weak correlation between DCCS shifting EF scores and performance on the Italian language CVT, ($r=0.050$, $p>0.40$), there was a strong positive correlation between DCCS scores and performance on the English CVT ($r=0.441$, $p<0.01$). Further analyses revealed that DCCS scores were also significantly positively correlated with performance on the English PVS ($r=0.488$, $p<0.01$), and that there was a significant association between English PVS performance and scores on the English CVT ($r=0.590$, $p<0.01$). When English PVS scores were partialled out, the relationship between DCCS scores and performance on the English CVT became nonsignificant ($r=0.217$, $p>0.09$).

Table 7.9: *Intercorrelations for the the CVT and EF measures*

	Age (months)	EnglishCVT	ItalianCVT	EnglishPVS	ItalianPVS	DCCS-EF	FrogSimon-EF	Dibtrain-EF
Age (months)	-							
EnglishCVT	**0.619****	-						
ItalianCVT	**0.478***	0.319	-					
EnglishPVS	**0.433****	**0.590****	0.134	-				
ItalianPVS	-0.188	-0.096	-0.193	-0.387	-			
DCCS-EF	0.202	**0.441****	0.050	**0.488****	-0.250	-		
FrogSimon-EF	0.036	-0.118	0.037	-0.078	0.308	-0.163	-	
Dibtrain-EF	0.237	0.241	0.034	0.107	-0.192	0.218	-0.168	-

N.B. English CVT: Scores on the English CVT produced by English monolinguals and Italian-English bilinguals, Italian CVT: Scores on the Italian CVT produced by Italian-English bilinguals, EnglishPVS: Standardised scores on the British Picture Vocabulary Scale produced by English monolinguals and Italian-English bilinguals, Italian PVS: Standardised scores on the Italian Picture Vocabulary Scale produced by Italian-English bilinguals, DCCS-EF: Scores for the 2 box dimensional change card sort shift EF task produced by English monolinguals and Italian-English bilinguals, FrogSimon-EF: Scores for the Inhibition EF task produced by English monolinguals and Italian-English bilinguals, Dibtrain-EF: Scores for the Updating EF task produced by English monolinguals and Italian-English bilinguals. For underlined task score correlations, n=19. For all other task scores n=38. *:Correlation is significant at the 0.05 level (1-tailed). **:Correlation is significant at the 0.01 level (1-tailed).

Analysis of CVT data collected from the Italian-English bilingual children

To investigate whether the CVT scores of the Italian-English bilingual children were affected by the first language in which they were tested, the task language or individual maxims, a 2 (First test language: English vs. Italian) X 2 (CVT language: English vs. Italian) X 5 (Maxim) ANOVA was conducted on the performance of the bilingual children. The numbers of children were comparable across first test language groups. Table 7.10 presents the mean maxim scores and standard deviations associated with first test language and task language. The analysis revealed a main effect of the first language in which a child was tested, $\underline{F}(1, 170) = 15.507$, $\underline{p}<0.001$. Children tested in Italian first attained significantly higher scores than children tested in English first. A main effect of task language was also uncovered, $\underline{F}(1, 170) = 9.943$, $\underline{p}<0.01$. As would be expected on the basis of their PVS scores, children performed significantly better on the Italian CVT than on the English CVT. In addition, there was a main effect of individual maxims, $\underline{F}(4, 170) = 3.365$, $\underline{p}<0.05$. Although, a conservative Scheffe test performed to analyse the variations between scores for the various maxims represented in the CVT, did not reveal any significant differences between maxim pairs, all $\underline{p}$'s >0.05.

However, the ANOVA further revealed that the main effects of first test language and CVT language were subsumed by a significant first test language-CVT language interaction effect, $\underline{F}(1, 170) = 12.103$, $\underline{p}<0.01$ (see Figure 7.1). Children who were tested in Italian first, performed significantly better on the English CVT than children tested in English first, $\underline{F}(1,17) = 21.534$, $\underline{p}<0.001$. By contrast, the English CVT scores of children tested in Italian first, did not differ significantly from the scores of children tested on the Italian CVT, whether they were tested in Italian first, $\underline{F}(1,14) = 0.016$, $\underline{p}>0.90$ or English first, $\underline{F}(1,17) = 0.236$, $\underline{p}>0.60$. First test language did not appear to affect performance on the Italian CVT, $F(1,17) = 0.061$, $p>0.80$. No other interactions were significant. Table 7.11 reports the summary data for this analysis.

Analysis of the Italian-English bilingual children's PVS scores across languages

A paired-samples t-test revealed a significant difference in the standardised PVS scores awarded to the Italian-English bilingual children in their different languages $t(18) = 2.109$, $p<0.05$. Scores were greater on the Italian PVS.

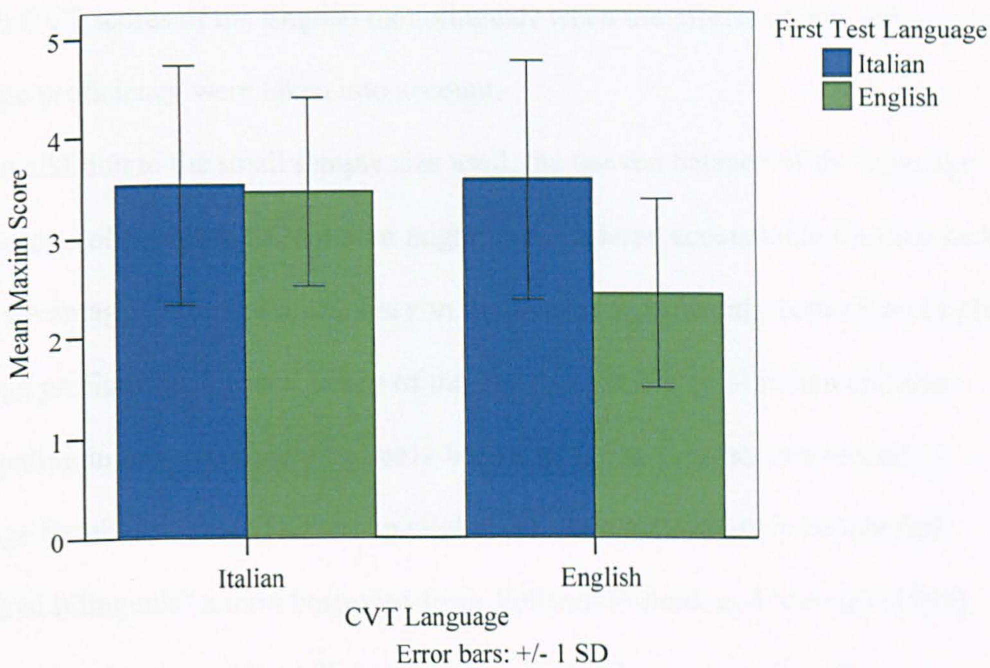
Table 7.10: *Mean maxim scores and standard deviations associated with first test language and task language for the Italian-English bilingual participants*

First test language	CVT language	Maxim	Mean score and standard deviation	Number of participants
Italian	Italian	First Quantity	3.13 (1.73)	8
		Second Quantity	3.00 (0.76)	8
		Quality	4.00 (1.07)	8
		Relation	3.88 (1.36)	8
		Politeness	3.63 (0.74)	8
	English	First Quantity	3.00 (1.07)	8
		Second Quantity	3.13 (1.36)	8
		Quality	3.63 (0.74)	8
		Relation	3.75 (1.58)	8
		Politeness	4.38 (0.74)	8
English	Italian	First Quantity	3.36 (0.92)	11
		Second Quantity	3.09 (0.83)	11
		Quality	3.45 (1.13)	11
		Relation	3.55 (0.93)	11
		Politeness	3.82 (0.87)	11
	English	First Quantity	2.09 (0.94)	11
		Second Quantity	2.45 (1.37)	11
		Quality	2.64 (0.81)	11
		Relation	2.64 (0.67)	11
		Politeness	2.36 (0.81)	11

Table 7.11: *Summary table for the 2 (First test language: Italian or English) x 2(CVT language) x 5 (Maxim) analysis of variance on the CVT scores of the Italian-English bilingual children.*

Source	SS	df	MS	F	p	Partial Eta²
Within	185.568	170	1.092			
First test language	16.927	1	16.927	15.507	**0.001**	0.084
CVT language	10.854	1	10.854	9.943	**0.002**	0.055
Maxim	14.694	4	3.674	3.365	**0.011**	0.073
First test language x CVT language	13.212	1	13.212	12.103	**0.001**	0.066
First test language x Maxim	2.820	4	0.705	0.646	0.630	0.015
CVT language x Maxim	1.199	4	0.300	0.275	0.894	0.006
First test language x CVT language x Maxim	4.315	4	1.079	0.988	0.416	0.023
(corrected model)	66.832	19	3.517	3.222	0.001	0.265
(corrected total)	252.400	189				

Figure 7.1: Mean Maxim Scores for Italian-English Bilingual Children across Alternative First Test Languages and CVT Languages



7.7 Discussion

This study was concerned with investigating the effects of bilingualism on CU to determine whether a bilingual EF advantage would confer a corresponding CU benefit. However, in contrast to expectations, and the findings of Feng, Diamond and Bialystok (2007), Martin-Rhee and Bialystok (2008) and Carlson and Meltzoff (2008), Italian-English bilingual 4- and 5-year-olds did not demonstrate significantly greater updating, inhibitory or shifting EF ability compared to English monolinguals. Furthermore, and also contrasting with expectations, and the findings of Siegal, Iozzi and Surian (2009), the bilingual children in Experiment 5 did not reveal a CU advantage. The bilinguals achieved CVT scores in both their native Italian language and their second language of English, which did not differ significantly from the English CVT scores of the English monolinguals when the effects of age and language proficiency were taken into account.

In addition to the small sample size used, the uneven balance of the language proficiencies of the bilingual children might be considered accountable for their lack of CU advantage. Bilingual proficiency in Italian was significantly better than English language proficiency, a consequence of the fact that the bilingual Italian children participating in this experiment had only been exposed to English as a second language for about a year. This group might thus more appropriately be labelled "marginal bilinguals" a term borrowed from Yelland, Pollard, and Mercuri (1993).

It is notable that whilst bilingualism appeared to have a positive effect on shifting EF in this study which was only just below significance, once the influences of age and vocabulary were taken into account, it did not appear to confer even such a slight benefit to either inhibitory or updating abilities. This result contrasts with reports that bilingual children display enhanced performance on inhibitory tasks (Martin-Rhee and Bialystok, 2008) and updating tasks (Feng et al. 2007). However, as Morton and Harper (2007) argue, it is not actually clear that target language production in bilingualism does place demands on and so consequently train, inhibitory abilities, as Bialystok would suggest. Non-target language translation equivalents promote target language picture naming relative to semantically unrelated words (Costa, Miozzo, & Caramazza, 1999). Moreover, target language "tip of the tongue" phenomena and speed of picture naming are reduced for words with non-target language translation equivalents relative to words lacking translation equivalents in the non-target language (Gollan & Acenas, 2004; Gollan, Montoya, Fennema-Notestine, & Morris, 2005). These findings indicate that far from introducing a competition for attentional resources, the presence of a non-target language might facilitate allocation of attentional resources to the target language. Indeed, Morton and Harper propose that the necessity of frequent shifting between languages and the consequential training this could entail might be more responsible for the enhancement of control typically demonstrated by bilinguals, a suggestion which sits well with the enhancement, albeit non-significantly, of shifting ability demonstrated by the bilinguals in the current study. This proposal is lent further support by Kovács and Mehler (2009) who report a bilingual shifting advantage for children as young as 7-months-old. Both monolingual and bilingual Italian infants learned to use auditory and visual cues to predict rewards on one side of a computer, indexed by their eye-gaze fixation. However, only the bilingual infants were able to shift their predictive focus when the cues switched to signal rewards on the other side of the screen. A shifting benefit demonstrated at such a young age, provides an indication that shifting plays a central role in the EF superiority of bilinguals.

However, the limited extent of bilingualism displayed by the bilinguals in this study could be used to explain the absence of gains in inhibitory and updating abilities for this group. Furthermore, it might be argued that either inhibitory or updating EF abilities, or both, play a central role in CU, so that the CU of the bilinguals would have been enhanced had the degree of bilingualism afforded gains in one or both of these EF abilities. However, the results of Experiment 3 indicate that it is shifting EF and not inhibitory or updating EF that is related to CVT performance. Therefore, the absence of a bilingual CU superiority would appear to be attributable to fact that the bilinguals in this study did not demonstrate a significant shifting EF benefit.

Although a relationship was demonstrated between the shifting EF and CVT performance of 4- and 5-year-old English monolinguals in Experiment 3, a training study which significantly improved the shifting abilities of 3- and 4-year-old English monolinguals in Experiment 4 did not induce improvements in CVT performance. Furthermore, Siegal et al. (2009) reported that covarying out the shifting EF ability of the 4- to 7-year-old Italian-Slovenian bilinguals they tested, could not account for a bilingual CVT advantage found, suggesting that the shifting ability of the bilingual children was not responsible for their superior CU. However, a positive relationship was demonstrated between shifting EF ability and CVT performance in Experiment 5. It might thus be that had the bilingual's shifting advantage in Experiment 5 been significant, it would have conferred a corresponding CU advantage.

However, because the bilingual children in Experiment 5 were found to demonstrate lower proficiency in English (the language in which the EF tasks were presented) than the English monolinguals, English proficiency was covaried, along with age, out of analyses examining the relationship between language groups and EF scores. Indeed, prior to the partialling out of English proficiency, the bilinguals did not even demonstrate a non-significant shifting benefit indicating the dependence of this non-significant benefit on the partialling out of English proficiency. Furthermore, English proficiency was also covaried out of an analysis examining the relationship between language groups and English CVT performance. This analysis did not reveal a bilingual CU superiority. However, whilst this could be attributable to the fact that the bilingual advantage was not significant, it could also be due to the relationships found between English language proficiency and both shifting EF and English CVT performance.

Since CVT performance reflects CU, which is an aspect of linguistic proficiency, the relationship between English PVS and English CVT scores is unsurprising. Furthermore, linguistic ability has been implicated in EF (Singer & Bashir, 1999; Vygotsky, 1962). Thus the relationship found between English PVS scores and shifting EF ability was also anticipated. Partialling out the effect of English language proficiency from the correlation between shifting EF and English CVT performance reduced the relationship from significance to non-significance. Thus it would seem that English language proficiency was mediating the relationship between shifting EF and English CVT performance in Experiment 5. Partialling out the effect of English proficiency on English CVT performance, appeared to remove the bilingual disadvantage of the non-native language format. However, it also appeared to dissolve the relationship between shifting and English CVT performance, removing the chance that even a significant shifting advantage revealed following the partialling out of vocabulary ability would have been found to promote the English CVT performance of the bilinguals.

However, having established that the bilingual CVT advantage they found could not be attributed to enhanced shifting EF abilities assessed using the DCCS, Siegal et al. (2009) suggested that bilingualism might lead to the promotion of EF in language-specific contexts, and that superior CVT performance might follow from these language-exclusive EF gains. Siegal et. al. proposed that the early vocabulary delay experienced in bilingualism, might lead to reliance on and consequential promotion of a compensatory mechanism placing more focus on the communicative context of language than typically demonstrated by monolinguals at this stage of language development. Siegal et al. suggested that this mechanism would require and so drive improvements in EF exerted in communicative situations, to enable attention to be shifted from the inherent language-stage-appropriate focus on the message to the communicative environment. It was argued that the promotion of such language-specific manifestations of EF would lead to improvements in CU resulting in gains in CVT performance. Suggestions were made for future research to look at the relationship between bilingual performance on language-focused EF measures such as The Hayling Sentence Completion Task which requires participants to complement sentence fragments using words unrelated to the given content, and CU tasks such as the CVT.

There was a significant maxim effect in CVT performance across languages, with children demonstrating superior performance on trials assessing appreciation of the maxims of Quality, Relation and Politeness comparative to performance on trials assessing appreciation of the maxims of First or Second Quantity on both English and native CVTs. This pattern of performance is in concordance with the findings of Siegal et al.'s Experiment 2, Surian, Baron-Cohen and van der Lely (1996) and Experiment 3 of this thesis, although the appropriateness of the CVT items designed to assess appreciation of the Maxim of First Quantity has been called into question (see Section 5.4). Nevertheless, performance was at greater than chance-levels for all maxims.

The native language CVT performance of the bilingual children in this study was compared to that of the Italian bilinguals in Siegal et al.'s Experiment 1. The 4- and 5-year-olds tested in this study (M= 58 months) achieved mean scores of 3.26, 3.05, 3.68, 3.68 and 3.74 for groups of CVT items assessing the appreciation of the maxims of First Quantity, Second Quantity, Quality, Relation and Politeness respectively. This can be contrasted with Siegal et al.'s sample of 4- to 6-year-olds (M= 66 months), who achieved mean scores of 3.41, 3.86, 4.50, 4.41 and 4.82 respectively in these trials. The Siegal et al. sample scored more highly in all of the maxim-based item groups but was older by 8 months. Furthermore, as highlighted in

Section 5.4, there was a difference in the CVT task demands made in the current study and the Siegal et. al. study. In the Siegal et al. study, children were directed to identify the silly or rude responses in each statement pair. However, in contrast, children in the current study were asked to identify the appropriate statement in each pair. The silly or rude responses might actually be more salient to the children precisely because of their inappropriateness. This could mean that children in the current study had to exert inhibitory ability in order to overcome their attention to the inappropriate responses and respond correctly. This inhibitory demand might not have been placed on the Siegal et al. sample who in contrast were asked to identify the inappropriate responses.

The CVT performance of the monolingual children in this study was also compared to that of the Italian monolinguals in Siegal et al.'s Experiment 1. The 4- and 5-year-olds tested in this study (M = 63 months) achieved mean scores of 3.42, 3.32, 3.79, 4.00 and 4.00 for groups of CVT items assessing the appreciation of the maxims of First Quantity, Second Quantity, Quality, Relation and Politeness respectively. Siegal et al.'s sample of 4- to 6-year-olds (M= 64 months) achieved mean scores of 3.37, 3.26, 3.84, 3.84 and 4.26 respectively in these trials. The maxim scores of the monolinguals in the current study seem roughly equal to those of the monolinguals in the Siegal et al. sample. This corresponds with their almost identical mean age, and suggests that age rather than differences in task demands might be accounting for the differences in CVT performance between the monolinguals in Experiments 3 and 5 of this thesis and the monolinguals in Siegal et al. Experiment 1 and between the bilinguals in Experiment 5 and the bilinguals in Siegal et al. Experiment 1.

The Italian dominance of the bilinguals in this study led them to attain greater scores on the Italian CVT than on the English CVT. However, a detailed analysis of the CVT performance of the bilinguals revealed an interaction between CVT language and order of presentation. The English CVT scores of bilinguals tested on the Italian CVT first were significantly better than the English CVT scores of bilinguals tested on the English CVT first. However, the first CVT language did not appear to affect performance on the Italian CVT: Italian CVT scores for children presented with the Italian CVT first were not significantly different from Italian CVT scores for children presented with the English CVT first. Thus, the enhanced English CVT performance of the bilinguals presented with the Italian CVT first is unlikely to be attributable to simple practice effects. Interestingly, the English CVT scores of bilinguals tested on the Italian CVT first, did not differ significantly from the Italian CVT scores of the bilinguals, whether these Italian CVT scores were from children tested in English first or Italian first. This result suggests that the greater CVT performance in Italian, and on the English CVT when it was presented after the Italian CVT, was reflecting more accurate interpretation of the instructions for the CVT task when these had been presented in Italian as they were for the Italian CVT, than when they were presented in English as they were for the English CVT. Thus it seems likely that the bilinguals would have improved their scores on the English CVT presented before the Italian CVT if the instructions for this task had been presented in Italian.

Experiment 5 was conducted to investigate the effect of bilingualism on CU, and to examine the impact of bilingualism on the nature of the relationship between EF and CU. A couple of previous studies have indicated that bilinguals demonstrate superiority in CU tasks (Doyle, Champagne and Segalowitz, 1977; Genesee, Tucker and Lambert, 1975) and Siegal et al. have recently reported a bilingual superiority on the CVT (Siegal, Iozzi, & Surian, 2009). However, this is the first study examining the connection between bilingualism and CU to systematically examine the role of EF in this relationship by employing measures to comprehensively reflect a current model of EF. Although Siegal et al. used measures of shifting and inhibitory EF to investigate the role of EF in the relationship between bilingualism and CVT performance in bilingual Italian-Slovenian 4-, 5- and 6-year-olds and same-age monolingual Italians and Slovenians, they did not include, for example, a measure of updating to reflect fully the various EF components such as have been described by Miyake et al. (2000).

7.8 Conclusions

Experiment 5 provided further evidence that shifting EF was related to CVT scores. However, the bilingual group did not demonstrate evidence of a significant EF superiority or an advantage in performance on the CVT. Thus the current study was not able to provide strong support for the masked competence account of CU. Experiment 6 was conducted to more comprehensively assess the nature of the relationship between EF and CU in monolingual children by presenting two tasks to measure CU and two tasks to assess each aspect of the 3-factor model of EF proposed by Miyake et al. (2000).

Chapter 8: Experiment 6 – A further examination of the relationship between executive functioning and conversational understanding

8.1 Introduction

Experiment 5 investigated whether childhood bilingualism, which has often been reported to promote EF, also has a positive effect on CU. However, despite controlling for language group differences in age and vocabulary scores, neither bilingual EF, not bilingual CVT performance was not found to be significantly better than monolingual performance. Thus, Experiment 5 did not provide strong support for the proposal that EF promotes CU.

Nevertheless, replicating the findings from Experiment 3, Experiment 5 demonstrated that shifting EF ability was positively related to a general measure of CU: the CVT, in line with the masked competence account. This compliments the findings of Experiment 2 which revealed that updating EF ability was significantly related to a specific aspect of CU: the computation of SIs.

The aim of Experiment 6, the final study in this thesis, was to provide a more detailed analysis of the relationship between the different EF abilities and CU. Children were presented with both the SI and CVT tasks together with the inhibitory, shifting and updating EF tasks used in Experiments 2-5 and three additional measures each of which was chosen to reflect a different one of Miyake et. al's 3 EF components. This design enabled a more extensive investigation of the EF-CU relationship, allowing the association to be examined using alternative EF measures and permitting assessment of the robustness of the EF-CU relationships found in earlier studies in the thesis.

As discussed in Section 1.5.2, Nilsen and Graham (2008) found that children's scores on the Red dog-blue dog inhibition EF task were positively related to successful performance on a referential communication CU task. The Red dog-blue dog task is similar to the day-night inhibitory EF task used in Experiment 1 in that both tasks require children to inhibit a label commonly associated with a picture they are shown (e.g. "night" if they are shown a picture of a black sky with a moon and stars or "red" if they are shown a picture of a dog depicted in red ink) in order to provide an alternative semantically conflicting label (e.g. "day" for the night sky picture and "blue" for the red coloured dog). However, the association between the picture and the label to be inhibited in the Red dog-blue dog task is more direct than in the day-night task. The colour description of the dog in the Red dog-blue dog task is a perceptual attribute which is automatically processed upon visual presentation of the picture stimulus. However the temporal description of the sky scene in the day-night task is a conceptual attribute which requires conscious processing. One might therefore anticipate that children would find the rules of the Red dog-blue dog task easier to grasp than those of the day-night task and so would not need the lengthy training required by many in Experiment 1. Since the Red dog-blue dog task has already been shown to linked to a measure of CU, it would seem suitable for inclusion in Experiment 6. The inhibitory EF tasks used in the final study of this thesis thus comprised the Frog Simon task used in Experiments 2, 3 and 5 and the Red dog-blue dog task employed by Nilsen and Graham in an article published after the previous experiments had been completed.

The shifting EF tasks used comprised the DCCS measure which had been presented in Experiments 3-5 and the Flexible Item Selection Task (FIST) created by Jacques and Zelazo (2001) and also employed by Nilsen and Graham (2008). As with the DCCS, the FIST requires children to shift their focus between alternative perceptual attributes of figures displayed on cards to enable reclassification. Each

FIST trial comprises presentation of three cards, such that one pair of cards is similar on a dimension not shared by the remaining card, and a different combinatory pair is similar on another dimension not shared by the excluded card. For example, on one trial, children may be shown a card (A) depicting two large blue cars, another card (B) depicting two large blue fish and a further card (C) depicting two large red fish. Cards (A) and (B) would thus be similar in terms of colour: blue, and so would form one pair and cards (B) and (C) would be similar in terms of subject: fish and so form the other pair. However, whilst the shared attributes are identified for the children in the DCCS i.e. children are told they must sort according to the shape rule so their focus is directed towards matching cards according to the shape dimension, the FIST requires independent recognition of common perceptual dimension values. In the FIST children are not given a sorting rule but are asked to identify two cards which are the same in some way, requiring an unguided search for similarities across a range of four presented dimensions. Furthermore, having established similarities, children must also identify differences on the same dimension. Each trial presents children with three cards displaying four dimensions of subject, colour, size and number. However, all three cards are identical on two dimensions only demonstrating differences on the other two dimensions. Cards (A), (B) and (C) in the earlier example demonstrated differences on the dimensions of subject and colour but were all identical with regards to the dimensions of number and size. It would not be appropriate to match two cards on a dimension when all three cards were identical in that respect, so the task requires children to identify differences in dimensions in addition to similarities. One might thus anticipate that children would find the FIST more difficult than the DCCS and so produce more variability in their scores on the former task. Greater score variability might increase the likelihood that a relationship between CU and EF would be uncovered. Although Experiments 3 and 5 revealed a relation between DCCS scores and performance on the CVT measure of CU, Experiment 1 did not find an association between DCCS performance and success on the SI task measure of CU. However, only the 6-year-olds were performing above chance on the SI task and their DCCS performance was almost at ceiling. If additional score variability occurs on the FIST shifting EF task compared to the DCCS shifting EF task, a significant relationship might emerge between SI appreciation and the FIST measure of shifting EF.

The updating EF tasks comprised the Dibbets training measure which had been presented in Experiments 2, 3 and 5 and The Farmyard Animal Task (FAT) which was a new measure created for this experiment. Like the Dibbets updating task, the FAT demands that children update their mental representation of a scene by deleting past details of a scene that have been superseded by recent changes and replacing these with more current information. The FAT presents children with a series of sequences of animals leaving a barn, and following each sequence children are asked to identify the animals who are currently the last to have left the barn. However, whilst the attributes to be updated in the Dibbets updating EF task remain visually present in the scene when the children are questioned, the information to be updated in the FAT does not. One might thus anticipate that children would find the FAT more difficult than the Dibbets updating EF task. No relationship was found between performance on the SI task and test scores on the Dibbets updating EF task in Experiment 2. However, there was a significant relationship between training scores for the Dibbets updating EF task and SI scores. Nevertheless, the training scores only differentiated 2 levels of performance, preventing a comprehensive assessment of the impact of EF variation on CU. The incorporation of a more difficult updating EF task with greater scope for assessing variation in performance was thus anticipated to provide stronger evidence for the effect of updating EF on CU.

8.2 Method

Participants. These consisted of 89 children were divided among three age groups; 28 4-year-olds (M= 56.39 months, range = 51-59 months), 30 5-year-olds (M = 67.20 months, range = 61-71 months) and 31 6-year-olds (M = 75.77 months, range =72-81 months). The children were predominantly white and middle class, and were recruited from primary schools in Sheffield. All children spoke English as their first language, and none were known to have any specific language impairment. Eight other children (aged 51, 51, 53, 58, 63, 66, 72 and 77 months) were excluded as three were unable to complete the FAT updating task and five were unable to complete the testing sessions due to school absence.

Procedure. All children were tested individually in a quiet area of their school. Each child completed eight tasks: two CU tasks – the SI task and the CVT, two inhibitory EF tasks – the Frog Simon task and the Red dog-blue-dog task, two shifting EF tasks – the DCCS task and the FIST task and two updating EF tasks - the Dibbets task and the FAT. Testing was conducted over the course of three sessions. Each session lasted between approximately 10 and 20 minutes, and the order of task presentation was fixed. The first session commenced with the SI task followed by the CVT. The second session was used to present the Frog Simon Inhibitory task, the DCCS shifting task and the Dibbets Updating task, in that order. The third session, was used to present the Red dog-Blue dog inhibitory task, the FIST shifting task and the FAT updating task, also in that order. The interval between testing sessions was usually between 1 and 2 days.

Session 1 Tasks:

SI task This was identical to the task used in Experiment 2 (see Section 4.2).

CVT This was identical to the CVT presented in Experiments 3 and 5 (see Section 5.2).

Session 2 Tasks:

Frog Simon (FS) Inhibitory EF Task. This was identical to the task used in Experiments 2, 3 and 5 (see Section 4.2). No child failed to respond correctly to the first two slides.

DCCS Shifting EF Task. This was identical to the task used in Experiments 1, 3 and 5 (see Section 3.2). No child failed to sort 5 cards correctly in the pre-switch phase.

Dibbets Updating EF Task. This was identical to the task used in Experiment ~~3~~ 5 (see Section 7.5), with children's updating ability differentiated into three levels and the criterion used to distinguish children in the "Good Level of Updating Training" category from children in the "Intermediate Level of Updating Training" category, set as the correct identification of the location of the kitten on 8 consecutive trials.

Session 3 Tasks:

Red dog-blue dog (RDBD) Inhibitory EF Task. This followed the procedure used by Nilsen and Graham (2008). Two different cards were shown, each depicting a cartoon dog outlined in black ink. The pictures of the dogs were identical except with respect to colour: One dog was filled in with blue ink, the other dog was filled in with red ink (see Appendix XIII). Children were informed that the name of the dog filled in with blue ink was "Red", and that the name of the dog filled in with red ink was "Blue". They were then asked to name each dog as it was presented. Two practice trials were provided, each presenting a different coloured dog. Children were required to correctly label the dogs in both practice trials in order to move on to the test trials.

Corrective feedback was provided if a dog was incorrectly labelled, although this rarely occurred. Following correct identification in the practice trials, 28 test-trials were given. Each test trial involved presentation of a card depicting either a red- or a blue-coloured dog. The red dog was shown in half of the test trials and the blue dog was shown in the other half of the trials. The trials were quasi-randomly interspersed in the following order: BMBMMBMBBMMBMBBMBMMBMBBMBM (B= picture of dog filled in with blue ink, M= picture of dog filled in with red ink). Scores ranged between a minimum of 0 points if the children responded on the basis of ink colour in all test-trials and a maximum of 28 points if the children correctly named the dog stimulus in each test-trial.

FIST Shifting EF Task This followed the procedure used by Jacques and Zelazo (2001). Children were initially given 1 demonstration trial followed by two criterion trials. All three of these trials involved the presentation of four cards, which depicted figures with four varying dimensions: subject, size, colour and number. For example, one card might depict 2 large yellow balls, another card might depict one medium red fish. Each of these pre-experimental trials presented two pairs of identical cards, i.e. two cards each depicting two large yellow balls (Cards A and B) and two cards each depicting one medium red fish (Cards C and D). The spacing of the card pair members varied across the trials. In the demonstration trial, each member of one pair was placed at either end of the sequence and members of the other pair were presented together in the middle: ACDB. However, in the first criterion trial, the members of both pairs were presented next to their identical pair member: ABCD, and in the second criterion trial, pair members were separated by one member from the other pair: ACBD.

The experimenter introduced the demonstration trial by saying: "Look! Here's a card, another card, here's another card and another card. I'm going to pick two cards that are the same in 1 way. So I'll pick these two cards (pointing simultaneously to Cards 1 and 4: A and B). These two cards are the same because they both have one medium red fish on each card. So they're the same. Now I'm going to pick two cards that are the same but in a different way. So I'll pick these two cards (pointing simultaneously to Cards 2 and 3: C and D). These two cards are the same because they both have two large yellow balls on each card. That's why they're the same. So these two cards are the same (pointing simultaneously to Cards 1 and 4) and these two cards are the same (pointing simultaneously to Cards 2 and 3). But see, these two cards here are different from these two cards. You know what? Now it's your turn to show me some cards."

In the criterion trials, children were instructed to "Show me two cards that are the same in one way" and having done this, to "Show me two cards the same in a different way." They were then asked to explain why each pair was the same. Children needed to pass both criterion trials to go on to the 12 test trials. The test trials were the same as the criterion trials except that children were only presented with three cards and were required to match the same card twice, with different pair members each time to reflect matching on two different dimensions (see Appendix XIV for examples of cards used in the demonstration, criterion and test trials). A score was awarded for pair-matching, ranging from a minimum of 0 if children were unable to match any second pair appropriately in any trials to a maximum of 12 if children matched all second pairs appropriately in all trials. A more conservative measure of matching-explanations was scored and recorded separately, ranging from a minimum of 0 if children were unable to explain why any appropriate second pair was matched in any trials to a maximum of 12 if children were able to explain why all appropriate second pairs were matched in all trials.

FAT Updating EF Task This was presented on a laptop using a Power-Point program. The first slide (A) presented all the animals used in the task: a mouse, a sheep, a rabbit, a cow, a chicken, a dog, a goose, a horse, a pig, a cat, a turkey and a duck, to ensure children were familiar with the animals involved and to provide names for any creatures which a child was unable to label (see Appendix XVa). Each animal appeared consecutively following appropriate naming of the previous animal presented. If a child was unable to name any of the animals, the experimenter labelled them instead and went back to those animals once all the creatures had appeared on screen to re-establish the names of those animals. This occurred frequently with the goose and the turkey, and sometimes with the duck which a lot of children initially labelled as a chick. However, the remaining animals were usually labelled successfully, and following experimenter labelling of any animals a child failed to name in the manner intended, children demonstrated appropriate labelling behaviour.

The next slide (B) was then presented and revealed a barn scene in which several animals: a pig, a chicken and a cow, were shown to be on their way to the barn (see Appendix IXb). This slide was used to establish that participants understood the concept of "last" and the animal furthest away from the barn (the cow) was highlighted with a purple border. Children were told that it was dinner-time on the farm and that although some of the animals were already in the barn eating their supper, some were still on their way. Several animals then appeared on the screen, one after the other, all moving towards the barn, and stopping just outside the barn, forming an orderly queue. Children were encouraged to label the animals as they appeared "There is the pig....and the chicken...and the cow" and were asked which animal would get to the barn last. Whether or not a child correctly identified the cow (a few did not), they were told that the cow would get to the barn last and that they could tell which animal would get there last because of the a purple shape around it. At this point, the experimenter pointed to the purple border encompassing the cow. Children were then shown some more animals appearing and joining the queue: a duck and a rabbit (Slide C, see Appendix XVc,). The moment the cow was superseded by the duck, the purple border around the cow disappeared, and the last animal to emerge: the rabbit, was instead highlighted with the purple border. Again, children were encouraged to label the animals as they appeared, and asked to identify the animal who would get to the barn last now. Correct identification of the rabbit resulted in presentation of the first practice trial. All children correctly identified the rabbit.

Having generated a labelling behaviour evoked by the appearance of each animal and established that children understood that purple borders identified the last animals in each sequence, children were then presented with a practice trial in which they were asked to tell the experimenter which animal was the last animal to come out of the barn. The practice trial was introduced by telling participants that all of the animals were in the barn eating their dinner, and that when they were finished they would come out to play in the field. An animal: a rabbit, then appeared at the barn door and moved horizontally across the screen until it reached the far side. The first animal out of the barn then disappeared and the second animal: a cat, appeared at the barn door. This creature also proceeded to move across the screen and then disappear, at which point the third and "last" animal: a horse, appeared at the barn door, highlighted by a purple frame. The third creature then proceeded to move across the screen, surrounded by its purple frame, before it disappeared.

Children were encouraged to label each animal, with the experimenter doing so if the child failed to label. Whilst this sometimes happened initially, once children got used to the experimenter labelling the animals, they started labelling the animals themselves without the experimenter's input. Once the "last" purple-bordered animal had disappeared, the experimenter asked, "Who was the last animal out of the barn." If children failed to correctly identify the horse, as sometimes happened, they were corrected and reminded that the horse had had a purple shape around it. All children were then told, "But now some more animals are coming out of the barn" and they viewed three different animals appear and move across the screen in the same manner as the three previous animals. As before, the third animal was "last" and purple-bordered, and following its disappearance children were asked, "Who was the last animal out of the barn". The few incorrect answers were corrected and children reminded about the significance of the purple border. Children then saw a final series of three animals leaving the barn, the third of which was "last" and purple-bordered and were asked, "Who was the last animal out of the barn." Correct identification of the third and trial-final "last" animal led to commencement of the test-trials. However, a couple of children incorrect identified the last animal on this trial. They received further practice trials, identical to the first practice trial except with respect to the order in which particular animals were shown to leave the barn. For example the rat was the final "last" animal in the first practice trial, but the dog was the final "last" animal in the second practice trial. Correct identification of the final "last" animal in any practice trial resulted in presentation of the test-trials and a score of 1 point. All children presented with the FAT managed to identify the final "last" animal in a practice trial, eventually.

The first and second test-trials were identical to the practice trials, except that children were now asked to identify the last two animals out of the barn each time, both of which were surrounded by purple frames. However inaccurate identifications were not corrected. A point was awarded for each of the final "last" two animals correctly identified in each trial. The third and fourth test-trials were similar to the first two test-trials, except that children were now asked to identify the last three animals out of the barn each time and each trial consisted of three groups of four animals leaving the barn. A point was awarded for each of the final "last" three animals correctly identified in each trial.

Scores were based on identification of the final "last" animals in each trial, and ranged between a minimum score of 1 awarded for the necessary correct identification of the last animal in a practice trial, and a maximum score of 11 achieved by correctly identifying the final "last" two animals in the first and second test trials and correctly identifying the final "last" three animals in the third and fourth test trials.

A subset of 32 children comprising 8 4-year-olds, 23 5-year-olds and 1 6-year old, were given the BPVS as an additional measure. The majority of these children had been included in Experiment 5 as the English monolingual sample. Standardised BPVS scores were used as a measure of verbal intelligence to scrutinise results from the main sample.

8.3 Results

The children's performance on the measures is shown in Table 8.1

Table 8.1 *Mean scores and standard deviations achieved for the SI, CVT and inhibition, shifting, and updating EF tasks given to the 4-, 5- and 6-year-olds in Experiment 6.*

	4-year-olds	5-year-olds	6-year-olds
N	28	30	31
Age in months	56.39 (2.49)	67.20 (2.66)	75.77 (2.63)
SI score/4	0.46 (1.11)	2.13 (1.68)	2.13 (1.78)
SI justification/4	0.25 (0.93)	1.33 (1.56)	1.52 (1.71)
CVT score/25	16.36 (3.28)	20.93 (2.70)	20.55 (3.22)
FS Inhib EF/20	17.54 (2.52)	17.67 (2.07)	18.35 (1.62)
RDBD Inhib EF/28	19.07 (6.56)	24.83 (3.76)	22.19 (6.83)
DCCS Shift EF/6	4.86 (2.34)	5.80 (0.55)	5.58 (1.26)
FIST Shift EF match/12	7.96 (3.77)	8.07 (4.04)	8.90 (4.09)
FIST Shift EF explan/12	4.14 (3.26)	6.50 (3.92)	6.71 (3.70)
Dibbets Update EF/3	2.04 (1.11)	2.30 (0.95)	2.29 (0.97)
FAT Update EF/11	8.21 (1.55)	8.97 (1.71)	9.29 (1.44)

Note: SI=Scalar Implicature task, CVT = Conversational Violations Task, FS Inhib EF = Frog Simon task measure of inhibitory executive functioning component, RDBD Inhib EF = Red Dog-Blue Dog task measure of inhibitory executive functioning component, DCCS Shift EF = Dimensional Change Card Sort task measure of shifting executive functioning component, FIST Shift EF match = Number of correct matches in Flexible Item Selection Task measure of shifting executive functioning component, FIST Shift EF explan = Number of appropriate justifications for correct matches in Flexible Item Selection Task measure of shifting EF component, Dibbets Update EF = Level of updating training achieved in Dibbets task measure of updating EF component, FAT Update EF = Number of correct responses in Farmyard Animals Task measure of Updating EF component.

Relationship between EF ability and CVT performance

Tables 8.2-8.4 display the results of ANOVAs investigating the effects of EF, age and maxims on CVT performance. Tables 8.5-8.11 report the means and standard deviations of CVT scores for children demonstrating weak and strong EF ability across the maxims and age groups. Children's inhibitory EF assessed using the Frog Simon task was classed as strong if scores for the task were 19 or greater and weak if these were less than 19. Inhibitory EF assessed using the Red Dog Blue Dog task was classed as strong if scores for the task were 25 or greater and weak if these were less than 25. Children's shifting EF assessed using the DCCS task was classed as strong if scores for the task were 6 and weak if these were less than 6. Shifting EF assessed using FIST matching scores was classed as strong if scores for the task were 10 or greater and weak if these were less than 10. Shifting EF assessed using FIST explanation scores was classed as strong if scores for the task were 7 or greater and weak if these were less than 7. Children's updating EF assessed using the Dibbets task was classed as strong if training scores were 3 and weak if these were less than 3. Children's updating EF assessed using the FAT was classed as strong if scores were 10 or greater and weak if these were less than 10. The weak and strong division criteria were selected on the basis that they enabled as equal a split as possible in the number of children assigned to the two EF ability groups for each task. Age group had three levels: 4-year-olds vs. 5-year-olds vs. 6-year-olds. Type of maxim had five levels: First Quantity vs. Second Quantity vs. Quality vs. Relation vs. Politeness.

For weak versus strong ability groups respectively for the Frog Simon inhibitory task, N was 18:10 for the 4-year-olds, 18:12 for the 5-year-olds, and 14:17 for the 6-year-olds. For weak versus strong ability groups respectively for the Red Dog Blue Dog inhibitory task, N was 21:7 for the 4-year-olds, 8:22 for the 5-year-olds, and 16:15 for the 6-year-olds. For weak versus strong ability groups respectively for the DCCS shifting task, N was 6:22 for the 4-year-olds. The 5- and 6-year-olds, were performing at ceiling on this task and so were excluded from analyses. For weak versus strong ability groups respectively for the FIST scores shifting measure, N was 17:11 for the 4-year-olds, 16:14 for the 5-year-olds, and 7:24 for the 6-year-olds. For weak versus strong ability groups respectively for the FIST explanation shifting measure, N was 21:7 for the 4-year-olds, 12:18 for the 5-year-olds, and 13:18 for the 6-year-olds. For weak versus strong ability groups respectively for the Dibbets updating task, N was 13:15 for the 4-year-olds, 11:19 for the 5-year-olds, and 11:20 for the 6-year-olds. For weak versus strong ability groups respectively for the FAT updating task, N was 22:6 for the 4-year-olds, 17:13 for the 5-year-olds, and 13:18 for the 6-year-olds.

The criterion for significance was set at the conservative level of 0.01 to offset the increased likelihood of Type I error incurred by inclusion of multiple analyses. Main effects of performance on the Red dog-blue dog inhibitory EF task and the Dibbets updating EF task were revealed. There were also main effects of age group and type of maxim. However, there were no interaction effects. Strong performers on the Red dog-blue dog inhibitory EF task and the Dibbets updating EF task attained significantly greater CVT scores than low performers on these tasks. One-tailed t-tests revealed that the CVT performance of the 5- and 6-year-olds was significantly greater than the performance of the 4-year olds, $t(56) = 5.815$, $p<0.001$, and $t(57) = 4.946$, $p< 0.001$, respectively. However the CVT performance of the 5- and 6-year-olds did not differ significantly, $t(59) = 0.505$, $p>0.60$. Scheffe tests indicated that performance on the Maxims of First and Second Quantity was significantly worse than performance on the Maxims of Quality, Relation and Politeness p's<0.001.

Table 8.2 *Results of 3 (age group: 4-year-olds vs. 5-year-olds vs. 6-year-olds) x 2 (inhibitory EF level: FS scores <19 =weak vs. FS scores ≥19 =strong; RDBD scores <25 =weak vs. RDBD scores ≥ 25 =strong) x 5 (type of maxim: First Quantity vs. Second Quantity vs. Quality vs. Relation vs. Politeness) ANOVAs on the CVT measure.*

	df	F	p	partial Eta^2
Age group				
FS	2,415	37.526	**0.001**	0.153
RDBD	2,415	20.156	**0.001**	0.089
EF level				
FS	1,415	0.119	0.731	0.000
RDBD	1,415	6.735	**0.010**	0.016
Type of maxim				
FS	4,415	22.466	**0.001**	0.178
RDBD	4,415	23.584	**0.001**	0.185
Age group x EF level				
FS	2,415	2.760	0.064	0.013
RDBD	2,415	2.330	0.099	0.011
Age group x type of maxim				
FS	8,415	0.831	0.575	0.016
RDBD	8,415	1.008	0.429	0.019
EF level x type of maxim				
FS	4,415	1.066	0.373	0.010
RDBD	4,415	0.888	0.471	0.008
Age group x EF level x type of maxim				
FS	8,415	0.815	0.590	0.015
RDBD	8,415	2.085	0.036	0.039

Note: EF level=Level of executive functioning; FS=Frog-Simon task; RDBD= Red dog-blue dog task.

Table 8.3: *Results of 3 (age group) x 2 (shifting EF level: DCCS scores <6 =weak vs. DCCS scores =6=strong; FIST match scores <10 =weak vs. FIST match scores ≥ 10 =strong; FIST explan scores <7 =weak vs. FIST match scores ≥ 7 =strong) x 5 (type of maxim) ANOVAs on the CVT. N.B. DCCS shifting analyses did not include the age group variable.*

	df	F	p	partial Eta²
Age group				
FIST match	2,415	34.557	**0.001**	0.143
FIST explan	2,415	34.722	**0.001**	0.143
EF level				
DCCS	1,130	0.147	0.702	0.001
FIST match	1,415	1.161	0.282	0.003
FIST explan	1,415	0.001	0.976	0.000
Type of maxim				
DCCS	4,130	3.805	**0.006**	0.105
FIST match	4,415	19.486	**0.001**	0.158
FIST explan	4,415	18.567	**0.001**	0.152
Age group x EF level				
FIST match	2,415	1.543	0.215	0.007
FIST explan	2,415	3.108	0.046	0.015
Age group x type of maxim				
FIST match	8,415	0.503	0.854	0.010
FIST explan	8,415	0.678	0.711	0.013
EF level x type of maxim				
DCCS	4,415	0.343	0.848	0.010
FIST match	4,415	1.125	0.344	0.011
FIST explan	4,415	0.332	0.857	0.003
Age group x EF level x type of maxim				
FIST match	8,415	0.473	0.875	0.009
FIST explan	8,415	0.491	0.863	0.009

Note: DCCS=Dimensional Change Card Sort task; FIST match=Flexible Item Selection Task matching scores; FIST explan=Flexible Item Selection Task explanatory scores.

Table 8.4: *Results of 3 (age group) x 2 (updating EF level: Dibbets scores <3 =weak vs. Dibbets scores =3=strong; FAT scores <10 =weak vs. FAT scores ≥ 10 =strong) x 5 (type of maxim) ANOVAs on the CVT measure*

	df	F	p	partial Eta²
Age group				
Dibbets	2,415	35.922	**0.001**	0.148
FAT	2,415	23.997	**0.001**	0.104
EF level				
Dibbets	1,415	9.930	**0.002**	0.023
FAT	1,415	2.606	0.107	0.006
Type of maxim				
Dibbets	4,415	21.242	**0.001**	0.170
FAT	4,415	16.688	**0.001**	0.139
Age group x EF level				
Dibbets	2,415	2.386	0.093	0.011
FAT	2,415	0.374	0.688	0.002
Age group x type of maxim				
Dibbets	8,415	0.850	0.559	0.016
FAT	8,415	0.695	0.696	0.013
EF level x type of maxim				
Dibbets	4,415	0.061	0.993	0.001
FAT	4,415	0.710	0.586	0.007
Age group x EF level x type of maxim				
Dibbets	8,415	0.683	0.706	0.013
FAT	8,415	0.617	0.764	0.012

Note: FAT =Farmyard Animal Task.

Table 8.5: *CVT score means and standard deviations across the maxims for children demonstrating weak and strong inhibitory EF on the Frog Simon (FS) task across the 4-year-old, 5-year-old and. 6-year-old age groups.*

Age group	FS Inhibitory EF	Maxim	Mean CVT score	Standard deviation
4	Weak	1	2.83	1.15
		2	3.11	1.02
		3	3.39	1.20
		4	3.50	0.99
		5	3.61	1.24
	Strong	1	2.20	1.55
		2	2.90	0.57
		3	3.30	1.16
		4	3.50	1.27
		5	4.30	1.06
5	Weak	1	3.61	1.42
		2	3.39	0.70
		3	4.33	0.97
		4	4.50	0.71
		5	4.61	0.78
	Strong	1	3.42	1.44
		2	4.17	0.72
		3	4.67	0.65
		4	4.58	0.67
		5	4.83	0.58
6	Weak	1	3.86	1.03
		2	3.50	0.94
		3	4.64	0.63
		4	4.57	0.76
		5	4.79	0.43
	Strong	1	3.65	1.00
		2	3.35	0.79
		3	4.12	1.36
		4	4.24	0.83
		5	4.53	0.84

Table 8.6: *CVT score means and standard deviations across the maxims for children demonstrating weak and strong inhibitory EF on the Red dog blue dog (RDBD) task across the 4-year-old, 5-year-old and. 6-year-old age groups.*

Age group	RDBD Inhibitory EF	Maxim	Mean CVT score	Standard deviation
4	Weak	1	2.76	1.22
		2	3.00	0.84
		3	3.19	1.21
		4	3.19	1.03
		5	3.52	1.21
	Strong	1	2.14	1.57
		2	3.14	1.07
		3	3.86	0.90
		4	4.43	0.54
		5	4.86	0.38
5	Weak	1	3.50	1.31
		2	3.38	0.74
		3	4.25	1.04
		4	4.50	0.76
		5	4.50	0.54
	Strong	1	3.55	1.47
		2	3.82	0.80
		3	4.55	0.80
		4	4.55	0.67
		5	4.77	0.75
6	Weak	1	3.50	0.97
		2	3.56	0.73
		3	4.25	1.13
		4	4.44	0.81
		5	4.75	0.58
	Strong	1	4.00	1.00
		2	3.27	0.96
		3	4.47	1.13
		4	4.33	0.82
		5	4.53	0.83

Table 8.7: *CVT score means and standard deviations across the maxims for children demonstrating weak and strong shifting EF on the DCCS task in the 4-year-old age group (5- and 6-year-olds were performing at ceiling so were excluded from analyses).*

DCCS Shifting EF	Maxim	Mean CVT score	Standard deviation
Weak	1	2.33	1.21
	2	2.83	0.98
	3	3.33	1.37
	4	3.83	1.17
	5	3.67	1.21
Strong	1	2.68	1.36
	2	3.09	0.87
	3	3.36	1.14
	4	3.41	1.05
	5	3.91	1.23

Table 8.8: *CVT score means and standard deviations across the maxims for children demonstrating weak and strong shifting EF on the FIST matching measure across the 4-year-old, 5-year-old and. 6-year-old age groups.*

Age group	FIST match shifting EF	Maxim	Mean CVT score	Standard deviation
4	Weak	1	2.41	1.28
		2	3.00	0.87
		3	3.18	1.19
		4	3.59	1.00
		5	3.71	1.21
	Strong	1	2.91	1.38
		2	3.09	0.94
		3	3.64	1.12
		4	3.36	1.21
		5	4.09	1.22
5	Weak	1	3.25	1.48
		2	3.88	0.81
		3	4.19	0.98
		4	4.44	0.73
		5	4.63	0.81
	Strong	1	3.86	1.29
		2	3.50	0.76
		3	4.79	0.58
		4	4.64	0.63
		5	4.79	0.58
6	Weak	1	3.57	1.27
		2	3.57	1.13
		3	4.71	0.76
		4	4.57	0.79
		5	4.71	0.49
	Strong	1	3.79	0.93
		2	3.38	0.77
		3	4.25	1.19
		4	4.33	0.82
		5	4.63	0.77

Table 8.9: *CVT score means and standard deviations across the maxims for children demonstrating weak and strong shifting EF on the FIST explanatory measure across the 4-year-old, 5-year-old and. 6-year-old age groups.*

Age group	FIST explan shifting EF	Maxim	Mean CVT score	Standard deviation
4	Weak	1	2.67	1.28
		2	3.10	0.89
		3	3.42	1.21
		4	3.67	0.97
		5	3.90	1.18
	Strong	1	2.43	1.51
		2	2.86	0.90
		3	3.14	1.07
		4	3.00	1.29
		5	3.71	1.38
5	Weak	1	3.33	1.44
		2	3.75	0.75
		3	4.08	1.08
		4	4.33	0.78
		5	4.50	0.91
	Strong	1	3.67	1.41
		2	3.67	0.84
		3	4.72	0.58
		4	4.67	0.59
		5	4.83	0.51
6	Weak	1	3.54	1.05
		2	3.31	0.95
		3	4.54	0.97
		4	4.54	0.78
		5	4.62	0.87
	Strong	1	3.89	0.96
		2	3.50	0.79
		3	4.22	1.22
		4	4.28	0.83
		5	4.67	0.59

Table 8.10: *CVT score means and standard deviations across the maxims for children demonstrating weak and strong updating EF on the Dibbets task across the 4-year-old, 5-year-old and. 6-year-old age groups.*

Age group	Dibbets Updating EF	Maxim	Mean CVT score	Standard deviation
4	Weak	1	2.31	1.44
		2	3.00	0.71
		3	3.15	1.21
		4	3.08	1.19
		5	3.69	1.32
	Strong	1	2.87	1.19
		2	3.07	1.03
		3	3.53	1.13
		4	3.87	0.83
		5	4.00	1.13
5	Weak	1	3.36	1.43
		2	3.55	0.93
		3	4.64	0.92
		4	4.73	0.65
		5	4.64	0.92
	Strong	1	3.63	1.42
		2	3.79	0.71
		3	4.37	0.83
		4	4.42	0.69
		5	4.74	0.56
6	Weak	1	3.55	1.13
		2	3.09	0.94
		3	3.82	1.40
		4	4.09	0.94
		5	4.45	0.69
	Strong	1	3.85	0.93
		2	3.60	0.75
		3	4.65	0.81
		4	4.55	0.69
		5	4.75	0.72

Table 8.11: *CVT score means and standard deviations across the maxims for children demonstrating weak and strong updating EF on the FAT across the 4-year-old, 5-year-old and. 6-year-old age groups.*

Age group	FAT Updating EF	Maxim	Mean CVT score	Standard deviation
4	Weak	1	2.41	1.33
		2	3.00	0.87
		3	3.36	1.29
		4	3.59	0.96
		5	3.77	1.31
	Strong	1	3.33	1.03
		2	3.17	0.98
		3	3.33	0.52
		4	3.17	1.47
		5	4.17	0.75
5	Weak	1	3.53	1.38
		2	3.82	0.73
		3	4.41	0.94
		4	4.41	0.71
		5	4.65	0.79
	Strong	1	3.54	1.51
		2	3.54	0.88
		3	4.54	0.78
		4	4.69	0.63
		5	4.77	0.60
6	Weak	1	3.46	1.13
		2	3.38	0.87
		3	4.31	1.18
		4	4.15	0.90
		5	4.54	0.88
	Strong	1	3.94	0.87
		2	3.44	0.86
		3	4.39	1.09
		4	4.56	0.71
		5	4.72	0.58

Relationship between EF ability and SI scores

Tables 8.12-8.14 display the results of ANOVAs investigating the effects of EF and age on SI scores. Tables 8.15-8.17 report the means and standard deviations of SI scores for children demonstrating weak and strong EF ability across the age groups. As before, the criterion for significance was set at 0.01. Children were divided into the same strong vs. weak EF groups used in the CVT analyses. Thus again, the DCCS shifting ability of the 5- and 6-year-olds was not included in these analyses. There was a main effect of age. However, there were no main effects of EF and no interaction effects. 1-tailed t-tests revealed that the SI scores of the 5- and 6-year-olds were significantly greater than the scores of the 4-year olds, $t(50.528) = 4.505$, $p<0.001$, and , $t(50.727) = 4.353$, $p< 0.001$, respectively. However the SI scores of the 5- and 6-year-olds did not differ significantly, $t(59) = 0.010$, $p>0.90$.

Table 8.12: *Results of 3 (age group) x 2 (inhibitory EF level) ANOVAs on the SI scores measure*

	df	F	p	partial Eta²
Age group				
FS	2,83	9.343	**0.001**	0.184
RDBD	2,83	6.660	**0.002**	0.138
EF level				
FS	1,83	0.885	0.350	0.011
RDBD	1, 83	0.078	0.781	0.001
Age group x EF level				
FS	2,83	1.008	0.369	0.024
RDBD	2,83	2.770	0.068	0.063

Table 8.13: *Results of 3 (age group) x 2 (shifting EF level) ANOVAs on the SI scores. N.B. Shifting analyses did not include the age group variable.*

	df	F	p	partial Eta²
Age group				
FIST match	2,83	9.574	**0.001**	0.187
FIST explan	2,83	7.772	**0.001**	0.158
EF level				
DCCS	1,26	0.008	0.931	0.000
FIST match	1,83	0.161	0.689	0.002
FIST explan	1,83	0.498	0.482	0.006
Age group x EF level				
FIST match	2,83	0.064	0.938	0.002
FIST explan	2,83	0.892	0.414	0.021

Table 8.14: *Results of 3 (age group) x 2 (updating EF level) ANOVAs on the SI scores measure*

	df	F	p	partial Eta²
Age group				
Dibbets	2,83	9.461	**0.001**	0.186
FAT	2,83	8.119	**0.001**	0.164
EF level				
Dibbets	1,83	0.455	0.502	0.005
FAT	1,83	0.005	0.942	0.000
Age group x EF level				
Dibbets	2,83	1.276	0.285	0.030
FAT	2,83	1.269	0.287	0.030

Table 8.15: *SI score means and standard deviations for 4-year-old children demonstrating weak and strong EF across the battery of EF measures used.*

EF skill	EF ability	Mean SI score	Standard deviation
FS inhibition	Weak	0.33	0.97
	Strong	0.70	1.34
RDBD inhibition	Weak	0.19	0.51
	Strong	1.29	1.89
DCCS shifting	Weak	0.50	0.84
	Strong	0.45	1.18
FIST match shifting	Weak	0.47	1.07
	Strong	0.45	1.21
FIST explan shifting	Weak	0.38	0.97
	Strong	0.71	1.50
Dibbets updating	Weak	0.69	1.18
	Strong	0.27	1.03
FAT updating	Weak	0.50	1.23
	Strong	0.33	0.52

Table 8.16: *SI score means and standard deviations for 5-year-old children demonstrating weak and strong EF across the battery of EF measures used. N.B. DCCS shifting performance was not included due to the ceiling performance of this age group*

EF skill	EF ability	Mean SI score	Standard deviation
FS inhibition	Weak	2.44	1.46
	Strong	1.67	1.92
RDBD inhibition	Weak	2.50	1.69
	Strong	2.00	1.69
FIST match shifting	Weak	2.00	1.79
	Strong	2.29	1.59
FIST explan shifting	Weak	2.33	1.83
	Strong	2.00	1.61
Dibbets updating	Weak	2.00	1.67
	Strong	2.21	1.72
FAT updating	Weak	2.35	1.66
	Strong	1.19	1.73

Table 8.17: *SI score means and standard deviations for 6-year-old children demonstrating weak and strong EF across the battery of EF measures used. N.B. DCCS shifting performance was not included due to the ceiling performance of this age group*

EF skill	EF ability	Mean SI score	Standard deviation
FS inhibition	Weak	2.43	1.65
	Strong	1.88	1.90
RDBD inhibition	Weak	2.56	1.71
	Strong	1.67	1.80
FIST match shifting	Weak	2.00	1.73
	Strong	2.17	1.83
FIST explan shifting	Weak	1.69	1.84
	Strong	2.44	1.72
Dibbets updating	Weak	1.55	1.86
	Strong	2.45	1.70
FAT updating	Weak	1.69	1.75
	Strong	2.44	1.79

Relationship between EF ability and SI justifications

Tables 8.18-8.20 display the results of ANOVAs investigating the effects of EF and age on SI justifications. Tables 8.21-8.23 report the means and standard deviations of SI justifications for children demonstrating weak and strong EF ability across the age groups. Again, the criterion for significance was set at 0.01 and as before, children were divided into the same strong vs. weak EF groups used in the CVT analyses. Thus the DCCS shifting ability of the 5- and 6-year-olds was not included in these analyses. There was a main effect of age. However, there were no main effects of EF and no interaction effects. 1-tailed t-tests revealed that the SI justifications of the 5- and 6-year-olds were significantly greater than the scores of the 4-year olds, $\underline{t}(47.763) = 3.237$, $\underline{p}<0.001$, and $\underline{t}(47.176) = 3.580$, $\underline{p}< 0.001$, respectively. However the SI justifications of the 5- and 6-year-olds did not differ significantly, $\underline{t}(59) = 0.436$, $\underline{p}>0.60$. Again, the unequal distribution of N across

DCCS groups means that analyses of shifting EF using this measure should be cautiously considered.

Table 8.18: *Results of 3 (age group) x 2 (inhibitory EF level) ANOVAs on the SI justifications measure*

	df	F	p	partial Eta²
Age group				
FS	2,83	5.545	**0.005**	0.118
RDBD	2,83	3.189	0.046	0.071
EF level				
FS	1,83	0.696	0.406	0.008
RDBD	1,83	0.995	0.321	0.012
Age group x EF level				
FS	2,83	0.003	0.997	0.000
RDBD	2,83	0.936	0.396	0.022

Table 8.19: *Results of 3 (age group) x 2 (shifting EF level) ANOVAs on the SI justifications measure. N.B. Shifting analyses did not include the age group variable.*

	df	F	p	partial Eta²
Age group				
FIST match	2,83	5.355	**0.006**	0.114
FIST explan	2,83	4.380	0.016	0.095
EF level				
DCCS	1,26	0.545	0.467	0.021
FIST match	1,83	0.106	0.746	0.001
FIST explan	1,83	0.744	0.391	0.009
Age group x EF level				
FIST match	2,83	0.016	0.984	0.000
FIST explan	2,83	0.699	0.500	0.017

Table 8.20: *Results of 3 (age group) x 2 (updating EF level) ANOVAs on the SI justifications*

	df	$\underline{F}$	$\underline{p}$	partial Eta^2
Age group				
Dibbets	2,83	5.230	**0.007**	0.112
FAT	2,83	5.133	**0.008**	0.110
EF level				
Dibbets	1,83	2.056	0.155	0.024
FAT	1,83	0.013	0.908	0.000
Age group x EF level				
Dibbets	2,83	0.699	0.500	0.017
FAT	2,83	2.606	0.080	0.059

Table 8.21: *SI justification means and standard deviations for 4-year-old children demonstrating weak and strong EF across the battery of EF measures used.*

EF skill	EF ability	Mean SI justification	Standard deviation
FS inhibition	Weak	0.17	0.71
	Strong	0.40	1.27
RDBD inhibition	Weak	0.00	0.00
	Strong	1.00	1.73
DCCS shifting	Weak	0.00	0.00
	Strong	0.32	1.04
FIST match shifting	Weak	0.24	0.97
	Strong	0.27	0.91
FIST explan shifting	Weak	0.19	0.87
	Strong	0.43	1.13
Dibbets updating	Weak	0.23	0.83
	Strong	0.27	1.03
FAT updating	Weak	0.32	1.04
	Strong	0.00	0.00

Table 8.22: *SI justification means and standard deviations for 5-year-old children demonstrating weak and strong EF across the battery of EF measures used. N.B. DCCS performance was not included due to the ceiling performance of this age group*

EF skill	EF ability	Mean SI justification	Standard deviation
FS inhibition	Weak	1.22	1.48
	Strong	1.50	1.73
RDBD inhibition	Weak	1.25	1.83
	Strong	1.36	1.50
FIST match shifting	Weak	1.25	1.61
	Strong	1.43	1.56
FIST explan shifting	Weak	1.42	1.68
	Strong	1.28	1.53
Dibbets updating	Weak	1.09	1.58
	Strong	1.47	1.58
FAT updating	Weak	1.59	1.70
	Strong	1.00	1.35

Table 8.23: *SI justification means and standard deviations for 6-year-old children demonstrating weak and strong EF across the battery of EF measures used. N.B. DCCS performance was not included due to the ceiling performance of this age group*

EF skill	EF ability	Mean SI justification	Standard deviation
FS inhibition	Weak	1.36	1.55
	Strong	1.65	1.87
RDBD inhibition	Weak	1.56	1.71
	Strong	1.47	1.77
FIST match shifting	Weak	1.43	1.51
	Strong	1.54	1.79
FIST explan shifting	Weak	1.08	1.55
	Strong	1.83	1.79
Dibbets updating	Weak	0.91	1.58
	Strong	1.85	1.73
FAT updating	Weak	0.92	1.50
	Strong	1.94	1.77

BPVS sub-sample

The preceding analyses were then repeated and restricted to a sub-sample of children given the BPVS. This enabled partialling out of standardised BPVS scores, which can be used as a measure of verbal intelligence and which were found to related to CVT performance, $r=0.333$, $p<0.031$. However, because this group was mainly comprised of 5-year-olds, the effects of age were not investigated but were co-varied out along with the standardised BPVS scores. Table 8.24 presents the performance of the sub-sample on all the measures.

Table 8.24: *Mean scores and standard deviations achieved for all of the tasks given to the subset of the 4-, 5- and 6-year-olds in Experiment 6 who received the BPVS.*

N	32
Age in months	64.63 (5.74)
SI score/4	1.69 (1.75)
SI justification/4	1.19 (1.55)
CVT score/25	19.53 (4.03)
Frog-Simon Inhib EF/20	17.72 (2.28)
Red-Blue dog Inhib EF/28	23.84 (4.95)
DCCS Shift EF/6	5.66 (1.15)
FIST Shift EF match/12	9.13 (3.42)
FIST Shift EF explan/12	6.81 (3.59)
Dibbets Update EF/3	2.25 (0.98)
Farm Update EF/11	8.81 (1.66)
BPVS standardised score	109.78 (11.15)

Relationship between EF ability and CVT performance

Tables 8.25-8.27 display the results of ANOVAs investigating the effects of EF and maxims on CVT performance in the BPVS sub-sample. However, because these analyses only considered two main effects, the criterion for significance was lowered to the 0.05 level. Tables 8.28-8.30 report the estimated marginal means and standard errors of CVT scores for children demonstrating weak and strong EF ability across the maxims when the effects of age and BPVS scores were taken into account.

Children's inhibitory EF assessed using the Frog Simon task was classed as strong if scores for the task were 19 or greater and weak if these were less than 19. Inhibitory EF assessed using the Red Dog Blue Dog task was classed as strong if scores for the task were 26 or greater and weak if these were less than 26. Children's shifting EF assessed using the DCCS task was classed as strong if scores for the task were 6 and weak if these were less than 6. Shifting EF assessed using FIST matching scores was classed as strong if scores for the task were 11 or greater and weak if these were less than 11. Shifting EF assessed using FIST explanation scores was classed as strong if scores for the task were 8 or greater and weak if these were less than 8. Children's updating EF assessed using the Dibbets task was classed as strong if training scores were 3 and weak if these were less than 3. Children's updating EF assessed using the FAT was classed as strong if scores were 9 or greater and weak if these were less than 9. As before, weak and strong division criteria were selected on the basis that they enabled as equal a split as possible in the number of children assigned to the two EF ability groups for each task. Type of maxim had five levels: First Quantity vs. Second Quantity vs. Quality vs. Relation vs. Politeness.

For weak versus strong ability groups respectively for the Frog Simon inhibitory task, N was 18:14 and for the Red Dog Blue Dog inhibitory task, N was 17:15. For weak versus strong ability groups respectively for the FIST scores shifting measure, N was 16:16 and for the FIST explanation shifting measure, N was 17:15. Performance on the DCCS shifting task was at ceiling, thus DCCS scores were excluded from these analyses. For weak versus strong ability groups respectively for the Dibbets updating task, N was 12:20 and for the FAT updating task, N was 14:18.

The main effects of performance on the Red dog-blue dog inhibitory EF task and the Dibbets updating EF task and of maxims, found in the main sample were also revealed in the BPVS sub-sample. There were no interaction effects. High performers on the Red dog-blue dog inhibitory EF task and the Dibbets updating EF task attained significantly greater CVT scores than low performers on these tasks. Scheffe tests could not be conducted on the maxim scores because of the covariation of age and BPVS. However, estimated marginal means were concordant with the relationship uncovered in the main sample: performance on the Maxims of First and Second Quantity appeared to be poorer than performance on the Maxims of Quality, Relation and Politeness.

A partial correlation controlling for the effect of standardised BPVS scores and age in months was conducted to investigate a relationship between DCCS performance and CVT scores in the BPVS subsample. A significant positive association was revealed, $r=0.356$, $p<0.05$. Correlations focusing on the relationship between DCCS performance and the individual maxims represented in the CVT revealed that DCCS performance was strongly related to scores for the Maxim of Second Quantity, $r=0.519$, $p<0.01$, and was also significantly associated with scores for the Maxim of Quality, $r=0.360$, $p<0.05$.

Table 8.25: *Results of 2 (inhibitory EF level: FS scores <19 =weak vs. FS scores ≥19 =strong; RDBD scores <26 =weak vs. updating EF scores ≥ 26 =strong) x 5 (type of maxim) ANCOVAs on the CVT measure controlling for age and BPVS scores in the BPVS sub sample.*

	df	F	p	partial Eta²
EF level				
FS	1,148	3.250	0.073	0.021
RDBD	1, 148	14.150	**0.001**	0.087
Type of maxim				
FS	4,148	5.387	**0.001**	0.127
RDBD	4,148	5.624	**0.001**	0.132
EF level x Type of maxim				
FS	4,148	0.516	0.724	0.014
RDBD	4,148	0.414	0.798	0.011

Table 8.26: *Results of 2 (shifting EF level: FIST match scores <11 =weak vs. FIST match scores ≥ 11 =strong; FIST explan scores <8 =weak vs. FIST match scores ≥ 8 =strong) x 5 (type of maxim) ANCOVAs on the CVT measure controlling for age and BPVS scores in the BPVS sub sample*

	df	F	p	partial Eta²
EF level				
FIST match	1,148	0.479	0.490	0.003
FIST explan	1,148	0.018	0.895	0.000
Type of maxim				
FIST match	4,148	5.087	**0.001**	0.121
FIST explan	4,148	4.963	**0.001**	0.118
EF level x Type of maxim				
FIST match	4,148	0.663	0.619	0.018
FIST explan	4,148	0.251	0.909	0.007

Table 8.27: *Results of 2 (updating EF level: Dibbets scores <3 =weak vs. Dibbets scores =3 =strong; FAT scores <9 =weak vs. updating EF scores ≥ 9 =strong) x 5 (type of maxim) ANCOVAs on the CVT measure controlling for age and BPVS scores in the BPVS sub sample*

	df	F	p	partial Eta²
EF level				
Dibbets	1,148	10.314	**0.002**	0.065
FAT	1, 148	0.067	0.796	0.000
Type of maxim				
Dibbets	4,148	5.276	**0.001**	0.125
FAT	4,148	4.759	**0.001**	0.114
EF level x Type of maxim				
Dibbets	4,148	0.754	0.557	0.020
FAT	4,148	0.676	0.610	0.018

Table 8.28: Estimated marginal mean *CVT scores and standard errors across the maxims for children in the BPVS sub sample demonstrating weak and strong inhibitory EF on the Frog Simon (FS) and Red dog blue dog (RDBD) tasks when the effects of age and BPVS scores were taken into account.*

EF measure	EF ability	Maxim	Mean CVT score	Standard error
FS inihibition	Weak	1	3.44	0.25
		2	3.38	0.25
		3	3.88	0.25
		4	4.05	0.25
		5	4.10	0.25
	Strong	1	3.29	0.28
		2	3.79	0.28
		3	4.29	0.28
		4	4.37	0.28
		5	4.65	0.28
RDBD inhibition	Weak	1	3.09	0.25
		2	3.44	0.25
		3	3.67	0.25
		4	3.85	0.25
		5	3.97	0.25
	Strong	1	3.70	0.26
		2	3.70	0.26
		3	3.70	0.26
		4	3.70	0.26
		5	3.70	0.26

Table 8.29: Estimated marginal mean *CVT scores and standard errors across the maxims for children in the BPVS sub sample demonstrating weak and strong shifting EF on the FIST measures when the effects of age and BPVS scores were taken into account. N.B. DCCS performance was not included due to the ceiling performance of this subgroup*

EF measure	EF ability	Maxim	Mean CVT score	Standard error
FIST match shifting	Weak	1	3.12	0.26
		2	3.62	0.26
		3	3.94	0.26
		4	4.31	0.26
		5	4.25	0.26
	Strong	1	3.63	0.26
		2	3.50	0.26
		3	4.19	0.26
		4	4.07	0.26
		5	4.44	0.26
FIST explan shifitng	Weak	1	3.26	0.26
		2	3.67	0.26
		3	4.08	0.26
		4	4.26	0.26
		5	4.32	0.26
	Strong	1	3.51	0.27
		2	3.44	0.27
		3	4.04	0.27
		4	4.11	0.27
		5	4.37	0.27

Table 8.30: Estimated marginal mean *CVT scores and standard errors across the maxims for children in the BPVS sub sample demonstrating weak and strong updating EF on the Dibbets and FAT tasks when the effects of age and BPVS scores were taken into account.*

EF measure	EF ability	Maxim	Mean CVT score	Standard error
Dibbets updating	Weak	1	2.84	0.29
		2	3.42	0.29
		3	3.59	0.29
		4	4.09	0.29
		5	3.92	0.29
	Strong	1	3.70	0.23
		2	3.65	0.23
		3	4.35	0.23
		4	4.25	0.23
		5	4.60	0.23
FAT updating	Weak	1	3.37	0.28
		2	3.72	0.28
		3	3.94	0.28
		4	4.29	0.28
		5	4.08	0.28
	Strong	1	3.38	0.25
		2	3.44	0.25
		3	4.16	0.25
		4	4.10	0.25
		5	4.55	0.25

Relationship between EF ability and SI scores

Table 8.31 displays the results of ANOVAs investigating the effect of EF on SI scores. As before, the criterion for significance was set at 0.05. Table 8.32 reports the estimated marginal means and standard errors of SI scores for children demonstrating weak and strong EF ability when the effects of age and BPVS scores were taken into account.. Children were divided into the same strong vs. weak EF groups used in the CVT analyses. Thus again, data from the DCCS shifting task was not included in these analyses. There were no main effects of EF and no interaction effects. A partial correlation controlling for the effect of standardised BPVS scores was conducted to investigate a relationship between DCCS performance and SI scores in the BPVS subsample. This did not reveal a significant association, r=0.074, p>0.30.

Table 8.31: *Results of 2 (EF level) ANCOVAs on the SI score measure controlling for age and BPVS scores in the BPVS sub sample*

	F	p	partial Eta^2
EF level			
FS	0.573	0.455	0.020
RDBD	0.171	0.683	0.006
FIST match	3.400	0.076	0.108
FIST explan	3.937	0.057	0.123
Dibbets	0.464	0.501	0.016
FAT	0.001	0.970	0.000

Note: All dfs=1,28.

Table 8.32: Estimated marginal mean *SI scores and standard errors for children in the BPVS sub sample demonstrating weak and strong EF across the battery of EF tasks used when the effects of age and BPVS scores were taken into account. N.B. DCCS performance was not included due to the ceiling performance of this subgroup*

EF skill	EF ability	Mean SI score	Standard error
FS inhibition	Weak	1.90	0.42
	Strong	1.41	0.47
RDBD inhibition	Weak	1.56	0.44
	Strong	1.84	0.47
FIST match shifting	Weak	1.13	0.42
	Strong	2.24	0.42
FIST explan shifting	Weak	1.12	0.41
	Strong	2.33	0.43
Dibbets updating	Weak	1.96	0.51
	Strong	1.52	0.39
FAT updating	Weak	1.70	0.49
	Strong	1.68	0.43

Relationship between EF ability and SI justifications

Table 8.33 displays the results of ANOVAs investigating the effect of EF on SI justifications. Again, the criterion for significance was set at 0.05 and as before, children were divided into the same strong vs. weak EF groups used in the CVT analyses. Thus data from the DCCS shifting task was not included in these analyses. Table 8.34 reports the estimated marginal means and standard errors of SI justifications for children demonstrating weak and strong EF ability when the effects of age and BPVS scores were taken into account. There were no main effects of EF and no interaction effects. A partial correlation controlling for the effect of standardised BPVS scores was conducted to investigate a relationship between DCCS performance and SI justifications in the BPVS subsample. This did not reveal a significant association, $r=0.098$, $p>0.30$.

Table 8.33: *Results of 2 (EF level) ANCOVAs on the SI justification measure controlling for age and BPVS scores in the BPVS sub sample*

	F	p	partial Eta²
EF level			
FS	0.018	0.895	0.001
RDBD	0.187	0.669	0.007
FIST match	0.816	0.374	0.028
FIST explan	0.908	0.349	0.031
Dibbets	0.025	0.875	0.001
FAT	0.172	0.681	0.006

Note: All dfs=1,28.

Table 8.34: Estimated marginal mean *SI justifications and standard errors for children in the BPVS sub sample demonstrating weak and strong EF across the battery of EF tasks used when the effects of age and BPVS scores were taken into account. N.B. . DCCS performance was not included due to the ceiling performance of this subgroup*

EF skill	EF ability	Mean SI justification	Standard error
FS inhibition	Weak	1.15	0.39
	Strong	1.23	0.44
RDBD inhibition	Weak	1.06	0.41
	Strong	1.33	0.44
FIST match shifting	Weak	0.93	0.41
	Strong	1.45	0.41
FIST explan shifting	Weak	0.92	0.40
	Strong	1.49	0.42
Dibbets updating	Weak	1.25	0.47
	Strong	1.15	0.37
FAT updating	Weak	1.33	0.45
	Strong	1.08	0.40

Inter-task correlations

Table 8.35 presents inter-task correlations present once the effects of age had been partialled out. These were derived from data generated by the main sample of 89 children tested. The CU tasks correlated significantly with each other, with the SI and CVT measures correlating at the 0.01 level when SI scores were used, $r=0.309$, and at the 0.05 level when SI justifications were used, $r=0.231$.

The two inhibitory EF measures (the Red Dog-Blue Dog task and the Frog Simon task) did not correlate significantly with each other, $r=0.154$, $p>0.07$. Neither did the two updating EF measures (the Dibbets task and the FAT), $r=0.116$, $p>0.10$. However the shifting EF measures correlated significantly. The DCCS measure correlated at the 0.01 level with both the FIST score measure, $r=0.428$, and the FIST explanation measure, $r=0.348$. The 2 FIST measures themselves (scores and explanations) also demonstrated strong associations, $r=0.857$, $p<0.001$.

With the exception of a relationship between performance on the FAT updating EF Task and the Frog Simon Inhibitory EF Task ($r=0.320$, $p<0.01$), a relationship between performance on the FAT updating EF task and the FIST matching score shifting EF measure ($r=0.203$, $p<0.05$) and a relationship between performance on the FAT updating EF task and the FIST explanation score shifting EF measure ($r=0.208$, $p<0.05$), EF tasks did not demonstrate significant relations with other EF measures designed to focus on differentiable components of EF.

Comparison of CVT Maxim performance to chance

The performance of the main sample on the maxims reflected in the CVT was compared to chance levels. Performance was found to be significantly above chance for all maxims, Maxim of First Quantity - $t(88) = 5.787$, $p<0.001$, Maxim of Second Quantity - $t(88) = 9.641$, $p<0.001$, Maxim of Quality - $t(88) = 12.947$, $p<0.001$, Maxim of Relation- $t(88) = 16.217$, $p<0.001$, Maxim of Politeness- $t(88) = 18.766$, $p<0.001$.

Table 8.35: *Task score intercorrelations with age in months partialled out (n=89)*

	SIsco (CU)	SIjust (CU)	CVT (CU)	Dog (InhEF)	FroSi (InhEF)	DCCS (ShiEF)	FISTsc (ShiEF)	FISTex (ShiEF)	Dibb (UpdEF)	FAT (UpdEF)
SIsco(CU)	-									
SIjust(CU)	**0.811****	-								
CVT(CU)	**0.309****	**0.231***	-							
Dog(InhEF)	-0.002	-0.030	**0.263****	-						
FroSi(InhEF)	-0.057	0.094	-0.031	0.154	-					
DCCS(ShiEF)	0.003	0.048	0.060	0.022	-0.093	-				
FISTsc(ShiEF)	-0.028	0.062	0.000	0.089	0.118	**0.428****	-			
FISTex(ShiEF)	0.079	0.112	0.047	0.158	0.126	**0.348****	**0.857****	-		
Dibb(UpdEF)	0.068	0.140	**0.232***	-0.024	-0.061	0.047	-0.083	-0.095	-	
FAT(UpdEF)	0.101	0.171	**0.216***	0.061	**0.320****	0.088	**0.203***	**0.208***	0.116	-

N.B. SIsco(CU): Assessment of CU using SI scores, SIjust(CU): Assessment of CU using SI justifications, CVT: Assessment of CU using CVT scores, Dog(InhEF): Assessment of Inhibitory EF using Red Dog-Blue Dog Task scores, FroSi(InhEF): Assessment of Inhibitory EF using Frog Simon Task scores, DCCS(ShiEF): Assessment of Shifting EF using Dimensional Change Card Sort Task scores, FISTsc(ShiEF): Assessment of Shifting EF using FIST scores, FISTex(ShiEF): Assessment of Shifting EF using appropriate number of FIST explanations, Dibb(UpdEF): Assessment of Updating EF using Dibbets Task, FAT: (UpdEF): Assessment of Updating EF using Farmyard Animals Task, *Correlation is significant at the 0.05 level (1-tailed). **:Correlation is significant at the 0.01 level (1-tailed).

8.4 Discussion

This study was concerned with providing a more detailed analysis of the relationship between the different EF abilities and CU than had been presented in the previous experiments. Children were given both the general and specific CU tasks used in the preceding experiments in addition to the inhibitory, shifting and updating EF tasks used in Experiments 2-5 and three further EF measures each of which was assumed to reflect a different dimension of the three components of EF. The multitude of EF and CU measures presented, enabled a replication test of the EF-CU associations previously reported, using alternative EF and CU measures. It also allowed for the reliability of the previous task-specific associations to be examined. Furthermore, the large number of EF and CU tasks employed provided a means for analysis of the validity of the EF and CU measures themselves. Additionally, a sub-sample of children were given a vocabulary measure which also served as a measure of verbal intelligence. This allowed more stringent examination of relationships found between EF and CU measures by enabling the covariance of verbal IQ levels.

In support of the masked competence account of the emergence of CU, a relationship was found between inhibitory EF, assessed in terms of Red dog-blue dog task performance, and the demonstration of CU assessed using the CVT and between updating EF, assessed in terms of performance on the Dibbets task and the demonstration of CU assessed using the CVT. Moreover, the effects of inhibition and updating EF on CVT scores were found to remain significant even after the influences of age and verbal IQ had been controlled for. Covarying out the effects of age and verbal IQ uncovered a further relationship between shifting EF, assessed in terms of DCCS performance, and the demonstration of CU assessed using the CVT.

Relationships had been revealed between the shifting and updating EF components and CU in preceding experiments in this thesis, in line with the findings from Experiment 6. Experiment 2 revealed a relationship between updating EF measured using the Dibbets task and CU assessed using an SI task, whilst Experiments 3 and 5 found evidence of a relationship between shifting EF assessed using the DCCS and a general measure of CU - the CVT. As well as providing further support for the relationship between CU and the updating and shifting components of EF, Experiment 6 produced evidence of a previously uncovered relationship between inhibitory EF assessed using the Red dog blue dog task and CU measured using the CVT.

Experiment 6 provided support for the relationship between shifting EF and CU by replicating the task association found in Experiments 3 and 5 between performance on the DCCS measure of shifting EF and the CVT measure of CU. In Experiment 6, this association was found in data produced by a sub-sample of children given the BPVS and was revealed following covariation of age and vocabulary scores. Children typically pass the DCCS at around 4 years of age, the youngest age group in Experiments 3, 5 and 6. It had previously been suggested (Section 6.4) that children who had been found to perform poorly on the DCCS might have been demonstrating atypical development, and that the relationship between DCCS and CVT performance could have been attributable to an external factor influencing both shifting EF and CU rather than a direct shifting EF-CU relationship. However, the fact that the shifting EF-CU relationship was evident when score variation attributable to verbal IQ was removed, indicates that the shifting EF-CU relationship was not being mediated by verbal IQ. No relationship was found between performance on the FIST shifting EF Task and success on a measure of CU. This concords with the findings of Nilsen and Graham (2008), when a referential communication task was used as the CU measure.

Nevertheless, in contrast to expectations, the specific task performance association which had previously provided support for the relationship between updating EF and CU was not replicated in the current study. In Experiment 2, performance on the Dibbets updating task had demonstrated relations with performance on the SI measure of CU. However, this was not found in Experiment 6, with performance on the Dibbets updating task instead demonstrating relations with performance on the CVT measure of CU Therefore, whilst the results of Experiment 6 strengthen the validity of the conceptual relation previously proposed between updating EF and CU, they do not provide support for the reliability of the task-specific association.

Both the Dibbets updating task and the SI measure of CU were presented in the first two testing sessions in Experiment 6, as they were in Experiment 2, which indicates that the extended number of testing sessions in Experiment 6 was not masking task associations. Furthermore, there was no interaction effect of age and performance on the Dibbets updating EF task on SI scores, suggesting that the relationship was not being masked by inclusion of additional data from the younger 4-year-old age group included in Experiment 6 but not Experiment 2.

A comparison of the data produced for the Dibbets updating EF task during Experiments 2 and 6 revealed that a greater proportion of children were classified as having achieved strong updating training/a "good level of updating training" in Experiment 6 than were classified as having reached this level in Experiment 2. Whereas 54 out of 89 children (60.7%) achieved this level in Experiment 6, only 32 out of 62 children (51.6%) achieved this level in Experiment 2. The greater proportion of children achieving the highest level of updating training in Experiment 6 is even more striking when one considers that not only did the latest experiment include a younger 4-year-old age group not included in Experiment 2, but the criterion set for achieving strong updating training had been raised from a bar of the correct location of the kitten in 7 consecutive trials employed in Experiment 2 to a new bar introduced in Experiment 5 and employed in Experiment 6, of the correct location of the kitten in 8 consecutive trials. Although it is not clear exactly why more children were achieving a higher level of updating training in Experiment 6, it is possible that the consequential reduction in score variance weakened demonstration of the relationship between performance on the Dibbets updating EF task and SI scores.

However, children's performance on the Dibbets updating EF task in Experiment 6 was also comparatively high in relation to their performance on the same task in Experiment 3 in which only 32 out of 60 children (53.3%) achieved strong training and their task performance in Experiment 5 in which only 20 out of 38 children (52.6%) achieved strong training. Nevertheless, Experiment 6 revealed evidence of a relationship between performance on the Dibbets updating EF task and CVT scores which had previously alluded demonstration in Experiments 3 and 5. This thus weakens the argument that the enhanced updating EF competence demonstrated in Experiment 6 and its consequential reduction of task score variance, acted to mask the relation between performance on the Dibbets updating EF task and SI scores.

The FAT updating EF task did not appear to demonstrate relations with measures of CU performance in Experiment 6. However, the FAT also appeared to be unrelated to performance on the Dibbets updating EF task. Furthermore, relations were found between FAT performance and scores on the Frog Simon Inhibitory EF task, the FIST matching score shifting EF measure and the FIST explanatory shifting

EF measure. The apparent independence of the FAT and the other updating EF task in Experiment 6, in conjunction with the discovery of relations between the FAT and both inhibitory and shifting EF tasks, serves to cast doubt on the validity of the FAT as a measure of updating EF ability.

Experiment 6 provided support for a relationship between Inhibitory EF and CU by demonstrating an association between performance on the Red dog-blue dog inhibitory EF task and performance on the CVT measure of CU. The relationship between scores on the Red dog-blue dog inhibitory EF task and success on a measure of CU found in Experiment 6, is consistent with the relationship between performance on the Red dog-blue dog inhibitory EF task and competence on a referential communication CU task reported by Nilsen and Graham (2008).

However, Experiment 6 did not provide evidence of a relationship between performance on the Frog-Simon Inhibitory EF task and either the SI or CVT measures of CU. The lack of relation between performance on the Frog-Simon task and SI tasks in line with the findings of Experiment 2. The apparent independence of performance on the CU and Frog Simon tasks might reflect the fact that the Frog Simon task was not providing an accurate measure of inhibitory ability. Although instructions for the Frog Simon task required children to exert inhibitory ability to overcome pre-potent tendencies and allow conflicting responses in accordance with instructions, children were not under time pressure to respond. The result was that some children took a noticeably long time to co-ordinate their responses to each trial, producing persuasive evidence of poor inhibitory ability, despite eventually responding correctly in accord with instructions. However, only accuracy of responses was used as a measure of inhibitory ability and not response delay evidence. Support for the suggestion that the Frog-Simon task was not providing an accurate measure of inhibitory EF is provided by the weak correlation it demonstrated with performance on the Red dog-blue dog inhibition EF measure.

The presentation of multiple tasks to assess each of three proposed components of EF and to measure CU, enabled the validity of the EF and CU measures used in this study to be investigated through inspection of task correlations following the partialling out of age. The SI and CVT measures of CU were strongly correlated, both when SI scores were used as the SI task performance measure and when these were replaced with the more conservative measure of SI justifications. Thus the SI and CVT tasks appeared to be reflecting the same construct, providing support for their validity as measures of CU. Strong correlations were also apparent between performance on the DCCS shifting EF and FIST shifting EF tasks. This was the case both when FIST matching scores were used as the FIST task performance measure and when these were replaced with the more conservative measure of FIST explanations. Thus the DCCS and FIST tasks also appeared to be measuring the same construct, providing support for their validity as measures of shifting EF.

However, performance on the Frog-Simon inhibitory EF and Red Dog-Blue Dog inhibitory EF tasks was not strongly related. Similarly weak associations emerged between the Dibbets updating EF and FAT updating EF tasks. The validity of the inhibitory and updating EF tasks was therefore unclear. Indeed, as mentioned previously, despite demonstrating a lack of association with the Dibbets updating EF task, the FAT updating EF measure appeared to demonstrate strong relations with the Frog Simon Inhibitory EF task, the FIST matching score shifting EF measure and the FIST explanatory shifting EF measure. It thus seems that the FAT updating EF task might be a complex measure more reflective of multiple skills than a single specific aspect of EF. Indeed, difficulties which children appeared to encounter during early piloting of the FAT, would seem to provide an indication of the nature of some of the confounding demands exerted by the task. Piloting revealed that a considerable proportion of children, most notably from the younger age-groups, demonstrated a large degree of difficulty in identifying the "last" animal in FAT trials, despite the inclusion of two introductory scenes specifically designed to illustrate the meaning of the concept. Later adaptations of the task used purple rectangular borders to highlight the "last" animal(s) and children were told that they could use the these purple "shapes" to identify which animal(s) was or were last. However, the very act of having to use the purple border to recognise the "last" animal(s) might well have created a cognitive burden which was subsequently reflected in task performance. Furthermore, due to the large number of different farm animals required for the task, and the young age of the children tested, a notable proportion of children experienced difficulty naming one or two of the animals shown in the FAT (most notably the turkey and the goose). However, children needed to be able to name all the animals in order to identify those animals when they came out last. Although the experimenter would eventually label an animal if a child failed to do so spontaneously, children might not have been motivated to input externally-given labels to update their mental representations of a scene from the FAT. Naming difficulties and trouble with grasping the concept of "last" might thus also have been reflected in FAT performance, confounding the degree to which this task provided an assessment of updating EF.

However, although the Dibbets updating EF task was adapted from a task originally designed as a measure of shifting EF (Dibbets & Jolles 2006), the fact that it did not demonstrate clear relations with either the DCCS or FIST shifting EF tasks, both of which appeared to demonstrate strong validity, suggests the Dibbets task was not reflecting shifting EF and was thus providing a less confounded assessment of updating EF.

Although partial correlations were found between performance on the Frog Simon Inhibitory EF task and scores on the FAT updating measure and between both FIST shifting EF measures and the FAT updating measure, for the most part, EF tasks did not demonstrate relationships with other EF measures gauging theoretically distinct components. This provides support for the differentiated inhibitory, shifting and updating EF construct proposed by Miyake et al. (2000) and is concordant with the findings of Experiments 1 and 3.

In Section 5.4 the suggestion was raised that separate components of EF might be serving different roles in the emergence of CU. This followed the discovery that updating EF appeared to be related to the appreciation of SIs in Experiment 2, but unlike shifting EF, was not found to be related to CVT performance in Experiment 3. It was therefore suggested that updating EF might play a rather narrow role in CU, associated specifically with appreciation of the First Maxim of Quantity, which is focused upon in the SI task. It was proposed that shifting EF ability plays a more general role associated with appreciation of all of the conversational maxims which are reflected in the CVT. However, Experiment 6 revealed that all three components of EF were related to CVT scores. This thus suggests that rather than acting completely independently, the three components of EF are being engaged simultaneously, playing complementary roles in the emergence of CU. It could be that CU engages inhibitory EF ability to enable the inhibition of default literal interpretations of communication where necessary, that shifting EF ability is employed to enable switching between literal and contextually enriched interpretations when required and that updating EF ability is relied on to ensure that mental representations of the communicative situation reflect the current state of information provided.

As expected, age was found to significantly enhance the performance of children on all CU measures. However, the improvements appeared to manifest themselves in differences between the CU performance of the 4-year-olds and the older age-groups. The CU of the 5- and 6-year-olds did not appear to differ significantly. Furthermore, detailed analysis of CVT performance supported the pattern of maxim appreciation uncovered in Experiments 3 and 5 of this thesis and reported by Siegal, Iozzi and Surian (2009) Experiment 2 and Surian, Baron-Cohen and van der Lely (1996). Children demonstrated significantly better performance on CVT items reflecting the Maxims of Quality, Relation and Politeness than on items reflecting the First and Second Maxim of Quantity. This suggests that awareness of the Maxims of Quality, Relation and Politeness emerges earlier on in development than awareness of the two Quantity Maxims. However, the criticism of CVT items reflecting the Maxim of First Quantity discussed in Section 5.4 indicates that any conclusions regarding children's maxim appreciation based on their CVT performance should disregard evidence pertaining to the Maxim of First Quantity.

Although analyses indicated relationships existed between CVT performance and scores on the Red Dog-Blue Dog inhibitory EF task, the DCCS shifting task and the Dibbets updating EF task, it was possible that the positive influence of EF was restricted to improvement on certain maxims reflected in the CVT rather than general CVT performance. More fine-grained analyses indicated that the positive influence of inhibitory and updating EF performance was generalised across the maxims reflected in the CVT. However, correlations indicated that the relationship between performance on the DCCS shifting task and the CVT arose from specific positive associations between DCCS performance and scores for CVT items reflecting the Maxim of Second Quantity and the Maxim of Quality. That DCCS performance appeared to demonstrate a specific relationship with CVT items reflecting the Maxim of Second Quantity is surprising given that the DCCS training given in Experiment 4 did not promote scores for CVT items reflecting this maxim. However, the specific relationship found between DCCS performance and CVT items reflecting the Maxim of Quality is consistent with the finding that the DCCS training in Experiment 4 appeared to promote performance for CVT items reflecting the Maxim of Quality to significantly above chance levels.

As mentioned in Sections 5.4, 6.4 and 7.7, Siegal, Iozzi and Surian (2009) investigated the contribution that inhibitory and shifting aspects of EF made to the bilingual advantage for CVT performance. The day-night task employed in Experiment 1 of this thesis, and the DCCS used in Experiments 1 and 3-6 of this thesis, were used to assess inhibitory and shifting ability respectively. Siegal, Iozzi and Surian failed to find a relationship between bilingualism and inhibitory ability, but found that Italian-Slovenian bilinguals and Slovenian monolinguals outperformed Italian monolinguals on shifting ability. However, entering shifting ability as a covariate was not found to eliminate the bilingual superiority in CVT performance. The results of Experiment 6 suggest that a future study investigating the contribution of EF to the bilingual CVT advantage might benefit from including the Red dog-blue dog inhibitory EF and the Dibbets updating EF tasks.

The participants in Experiment 6 were found to be performing above chance on all of the maxims reflected in the CVT and their CVT performance was compared to that of the Italian monolinguals in Siegal, Iozzi and Surian (2009) Experiment 1. The 4- to 6-year-olds tested in this study (mean age 66.79 months) achieved means scores of 3.31, 3.39, 4.08, 4.16 and 4.42 for groups of CVT items assessing the appreciation of the maxims of First Quantity, Second Quantity, Quality, Relation and Politeness respectively. This can be contrasted with Siegal et al.'s sample of 4- to 6-year-olds (mean age 64 months), who achieved mean scores of 3.37, 3.26, 3.84, 3.84 and 4.26 respectively in these trials. The Siegal et al. sample appear to be scoring lower for all but the Maxim of First Quantity. However, although the sample of Siegal et al. was younger, this was by less than 3 months. Such a slight age disadvantage would not be expected to result in the fairly consistent display of reduced performance across the different groups of CVT items. Although, the relevant comparison of the CVT performance of the Siegal et. al. sample to the performance of the participants in Experiment 3 of this thesis ought to be acknowledged. The Siegal et. al sample were 3 months older than the children in Experiment 3, and outperformed them on all maxims reflected in the CVT.

The performance inferiority of the Siegal et al. sample in comparison to the children in Experiment 6 is particularly surprising given the difference in CVT task demands favouring the Siegal et al. sample. In the Siegal et al. study, children were directed to identify the silly or rude responses in each statement pair, whereas children in Experiment 6 were asked to identify the appropriate statement each time. It is likely that the silly or rude responses are more salient to the children precisely because of their inappropriateness. This could mean that children in Experiment 6 who were asked to identify the appropriate statements, had to exert inhibitory ability to overcome their attention to the inappropriate responses, to enable them to respond correctly in this study. This inhibitory demand would not have been made of the Siegal et al. sample, who in contrast, were asked to identify the inappropriate responses.

8.5 Conclusions

Experiment 6 provided considerable support for the masked competence account of CU. Relationships were discovered between tasks assessing inhibitory, shifting and updating components of EF and a broad measure of CU – the CVT. All three components of EF proposed by Miyake et al. were thus found to demonstrate relations to CU.

Chapter 9: Summary of findings regarding the relationship between executive functioning and conversational understanding

9.1 Introduction

This thesis provides details of six experiments conducted to elucidate the relationship between executive functioning (EF) and conversational understanding (CU). The six experiments, involving a total of 384 children, sought to provide answers for the following questions:

1. Is there a relationship between EF and the expression of CU?
2. Does ToM play a role in the relationship between EF and CU?
3. Does EF training promote the emerging expression of CU?
4. Are there distinct EF components?

This chapter will review the findings that have been reported for the experiments conducted and outline the implications that these results have on theoretical positions concerning the emergence of CU. The chapter will conclude with some limitations of the current studies and future directions for research.

9.2 Is there a relationship between executive functioning and the emerging expression of conversational understanding?

Many previous studies indicated that children demonstrate CU when task processing costs are minimised (Chierchia et al., 2001; Feeney, Scrafton, Duckworth & Handley, 2004; Guasti et al., 2005; Papafragou & Musolino, 2003; Papafragou & Tantalou, 2004; Pouscoulous, Noveck, Politzer & Bastide, 2007). Removing the need to independently represent alternative interpretations of scalar implicatures (SIs), training a focus on the appropriateness of communication (felicity), enhancing the relevance of implicature generation, reducing the complexity of the implicature terms used and enabling children to express their understanding of the terms through their actions rather than verbal responses, promotes young children's SI ability. Similarly, Meroni and Crain (2003) found that lengthening the amount of time children spent processing "garden-path" instructions promotes their ability to use the task context to influence their interpretation of the instructions. Further, Beck, Robinson and Freeth (2007) found that removing children's need to make an explicit decision as to whether they should delay their response to an ambiguous message to await additional information permits them to demonstrate sensitivity to ambiguity.

This collection of evidence suggests that there might well be a relationship between children's EF ability, which serves to control and regulate information processing mechanisms, and their ability to demonstrate CU. Nilsen and Graham (2008) investigated this more closely by presenting children with a CU task assessing their ability to use common ground information when forming and interpreting communication, as well as tasks linked to three differentiable components of EF proposed by Miyake et. al. (2001). The EF components Miyake et. al. propose comprise the ability to inhibit prepotent or automatic responses, the ability to shift between alternative mental representations of the world and the ability to update information in working memory. Nilsen and Graham found that children's ability to inhibit prepotent responses was related to their CU, but did not find a relationship between CU and their ability to manipulate information in working memory, or between CU and their ability to shift between alternative representations of the world.

Experiment 1 of this thesis examined the EF-CU relationship further by considering the relationship between 4-, 5- and 6-year-old's appreciation of SIs as a measure of CU and their shifting and inhibitory abilities as measures of EF. Experiment 1 employed different CU and EF tasks to those used by Nilsen and

Graham (2008) and presented control conditions along-side the experimental manipulation in the CU task to assess the validity of the SI task. The superior performance demonstrated in the control conditions relative to the experimental condition of the SI task, indicated that the experimental manipulation was providing a valid assessment of children's ability to compute SIs. However, neither performance on the day-night task measure of inhibitory EF, nor performance on the Dimensional Change Card Sort (DCCS) measure of shifting EF was significantly related to CU. The additional weak relationships found between EF and ToM measures contrast with the significant associations reported in the literature suggesting that the day-night and DCCS tasks may not have been sensitive enough measures to predict CU.

Experiment 2 thus presented new assessments of EF focusing on inhibitory and updating abilities: the Frog Simon inhibitory task and the Dibbets updating task. Performance on the Dibbets updating task was found to be positively related to the SI appreciation of 5- and 6-year-olds. Interestingly, the amount of variance in SI scores accounted for by updating ability doubled when analysis focused on a restricted sample identified by their superior updating performance. The better the children were at updating, the greater the role that updating EF ability was assigned in computing SIs. Not only does this finding demonstrate the significance of updating EF ability in the expression of SI appreciation, but it also highlights that other factors are playing a role, and are more responsible for the level of SI appreciation demonstrated when updating EF ability is less advanced.

Experiment 3 presented a new measure of CU: the CVT, based on the measure of Surian, Baron-Cohen, and van der Lely (1996). The CVT provides a general assessment of CU by examining sensitivity to a range of Gricean maxims. The CVT contrasts with the SI task employed in the previous two experiments which provides a narrow measure of CU as a consequence of its focus on appreciation of the Maxim of First Quantity. In addition to the inhibitory and updating EF tasks employed in Experiment 2, Experiment 3 also presented the DCCS shifting EF task used in Experiment 1. There was a significant relationship between CVT performance and shifting EF but not inhibitory or updating EF.

It is interesting that updating ability did not appear to be related to the CVT general measure of CU in Experiment 3, given that it was found to be related to the narrow SI measure of CU in Experiment 2. However, the SI task assesses appreciation of only one component of the CVT: Grice's First Maxim of Quantity. The CVT requires appreciation of four more of Grice's conversational maxims, in addition to the First Maxim of Quantity. It could be that updating ability plays a rather narrow role in CU, associated specifically with the First Maxim of Quantity, whilst shifting ability plays a more general role associated with appreciation of all of the conversational maxims. Shifting ability was not measured in Experiment 2, as Experiment 1 indicated that the task was too easy for the 5- and 6-year-olds tested. However, had a more age-appropriate measure been employed, shifting ability might have been found to be significantly related to SI scores. Such a scenario fits in well with the general finding that the Maxim of First Quantity is grasped after the rest of the conversational maxims (Siegal, Iozzi, & Surian, 2008; Surian, Baron-Cohen, & van der Lely, 1996). One would expect appreciation of a maxim to emerge later on if it placed additional demands on EF.

Experiment 4 was designed to examine the relationship between DCCS and CVT performance using a DCCS training study with 3- and 4-year-olds. However, significant improvements in DCCS performance did not result in significant improvements in CVT scores. It is unlikely that this was due to the younger age-group tested in this study, as the relationship did not emerge when analyses were split by age. However, Experiment 3 had indicated that the effect of shifting ability on CVT performance was rather small, accounting for only 3.10 % of the variance in CVT scores. Thus, one might expect to see an effect of DCCS training on CVT performance if a greater sample size was employed.

Experiment 5 was conducted to investigate the effect of bilingualism upon the relationship between EF and CVT performance in 4- and 5-year-olds. Much evidence has been produced to support the proposal that bilinguals display advanced EF (Bialystok & Codd, 1997; Bialystok & Majumder, 1998; Bialystok & Martin, 2004; Bialystok & Senman, 2004; Bialystok & Shapero, 2005; Feng, Diamond & Bialystok, 2007). Establishing that a population who demonstrate enhanced EF also possess advanced CU, would provide an alternative way of supplying support for the proposal that EF promotes CU. Siegal, Iozzi and Surian (2009) found that bilingual Italian-Slovenian 4-, 5- and 6-year-olds attained significantly higher CVT scores than Italian and Slovenian monolinguals of the same age. However, Siegal et al. did not find that the bilingual superiority in CU was attributable to enhanced EF abilities. Experiment 5 was thus conducted to further investigate the effect of bilingualism upon EF ability and performance on the CVT, and to examine the relationship between EF and CVT proficiency.

Experiment 5 provided additional evidence that DCCS scores were significantly related to English CVT performance. Furthermore, the bilingual children were found to demonstrate a shifting benefit comparative to the monolinguals, albeit not reaching a level of significance. Both the DCCS-CVT relationship and the non-significant enhanced bilingual shifting emerged once the effects of English vocabulary ability, which varied between the English monolingual and Italian-English bilingual children, were partialled out. However, English vocabulary ability appeared to demonstrate a mediatory role in the relationship between shifting EF and English CVT performance. Thus the non-significant bilingual shifting benefit revealed when English vocabulary ability was partialled out, did not correspond to a bilingual CVT advantage. Furthermore, as in Experiment 3, there was no demonstration of a relationship between CVT performance and either inhibitory or updating ability.

Selection of more balanced bilinguals whose English language proficiency was more comparable to the that of the English monolinguals in this study, removing the necessity for partialling out the effects of language proficiency, might have revealed a bilingual advantage for English CVT performance. More balanced bilinguals might also have demonstrated a significant level of enhanced shifting, increasing the likelihood that a CVT advantage would be found. Alternatively, the need for partialling out the effects of language proficiency would also have been removed if the native language proficiency of the bilinguals had been comparable to that of the monolinguals, and the EF tasks had been presented to the bilinguals in their native language. This might have allowed relationships to emerge between EF and performance on the bilinguals' native language CVT.

Experiment 6 was concerned with providing a detailed analysis of the relationship between the different EF abilities and CU. Children were presented with both the general and specific CU tasks used in the preceding experiments in addition to the inhibitory, shifting and updating EF tasks used in Experiments 2-5 and three further EF measures each of which reflected a different dimension of the three aspects of EF. These three new measures comprised the Red dog-Blue dog (RDBD) inhibitory task and Flexible Item Selection Task (FIST) shifting task used by Nilsen and Graham (2008) and the Farmyard Animals Task (FAT) updating Task designed for Experiment 6. A sub-sample of children were also given a vocabulary scale serving as a measure of verbal intelligence, which allowed more stringent examination of relationships found between EF and CU measures by enabling the covariance of verbal IQ levels.

A new relationship was found between inhibitory EF assessed in terms of performance on the RDBD and CU assessed using the CVT. An anticipated relationship, first indicated in Experiment 2, was revealed between updating EF, assessed in terms of performance on the Dibbets task and CU assessed using the CVT. Moreover, the effects of inhibition and updating EF on CVT scores were found to remain significant even after the influences of age and verbal IQ had been controlled for. Covarying out the effects of age and verbal IQ uncovered a further relationship between shifting EF, assessed in terms of DCCS performance, and the demonstration of CU assessed using the CVT.

In line with the findings from Experiment 6, significant relationships had been reported between two of the three EF components and CU in Experiments 2, 3 and 5 of this thesis: Experiment 2 revealed a relationship between updating EF measured using the Dibbets task and the computation of SIs, whilst Experiments 3 and 5 produced evidence of a relationship between shifting EF assessed using the DCCS and the CVT as a general measure of CU. However, Experiment 6 lent further support for the relationship proposed between updating EF and CU by providing evidence based on performance on a different CU task: the CVT. Furthermore, a new relationship was revealed between inhibitory EF assessed using a new measure: the Red dog blue dog task and performance on the CVT.

Nevertheless, in contrast to expectations, the specific task performance associations which had previously provided support for the relationship between updating EF-CU was not replicated in Experiment 6. Therefore, the results of Experiment 6 strengthen the validity of the updating EF-CU conceptual relations previously proposed, although it does not provide support for the reliability the task-specific association previously found.

Aside from correlations involving an impure measure of updating in Experiment 6, performance on the inhibition, shifting and updating EF tasks in Experiments 1-3, 5 and 6 was not found to be significantly related, supporting the suggestion that EF is composed of differentiable skills. The results of Experiment 2 and 3 had prompted suggestion that separate components of EF might be serving different roles in the emergence of CU. This followed the discovery that updating EF ability appeared to be related to the appreciation of SIs in Experiment 2, but unlike shifting EF ability, was not found to be related to CVT performance in Experiments 3 or 5. However, Experiment 6 revealed that all three components of EF were related to CVT scores. This pattern of results thus suggests that rather than acting completely independently, the three components of EF are being engaged simultaneously, playing complementary roles in the emergence of CU.

Therefore, it appears that a considerable amount of evidence has been produced to support the proposal that significant relationships exist between EF and CU, that all three differentiable components of EF are involved in this relationship and that it is demonstrated in regards to both specific and general aspects of CU.

9.3 Does theory of mind play a role in the relationship between executive functioning and conversational understanding?

Since CU is thought to require appreciation of communicative intentions, ToM was expected to demonstrate strong relations with CU. Indeed, much evidence had provided support for such a claim. Individuals with autism, who are thought to possess ToM deficits, have been found to demonstrate impaired CU (Joliffe & Baron-Cohen, 1999; Dennis, Lazenby, & Lockyer, 2001; Frith, 1989; Noveck, Guelminger, Georgieff, & Labruyere, 2007). Furthermore, levels of ToM have been found to predict CU in children with autism (Sodian & Frith, 1992; Surian, et al., 1996; Martin & McDonald, 2003), in deaf children (Tedoldi, Surian & Siegal, 2005), in adults with Schizophrenia (Langdon, Davies, & Coltheart, 2002), in patients with right hemisphere brain damage (Winner et al. 1998) and in typically developing children (Happé, 1993).

However, a wealth of studies in the literature also indicate that ToM demonstrates a relationship with EF (Mitchell & Lacohee, 1991; Ozonoff et al., 1991; Davis & Pratt, 1995; Frye et al., 1995; Diamond & Taylor, 1996; Hughes, 1998a; Hughes, 1998b; Leslie & Polizzi, 1998; Carlson & Moses, 2001; Wellman, Cross, & Watson, 2001; Zelazo et al., 2002; Hala, Hug & Henderson, 2003. The weight of evidence thus supporting relationships between CU and EF (discussed in Section 9.2), CU and ToM, ToM and EF, led Siegal and Surian (2004, 2007) to propose that ToM might be mediating the relationship between CU and EF.

More specifically, default processing biases were thought to direct selection of logical/linguistically determined speaker intentions in certain situations, but to focus on contextual information in other instances, and to be overcome as processing resources increased with age. Siegal and Surian (2004, 2007) proposed that the development of an EF system enabled the child to resist these processing biases allowing them to access logically rooted but contextually enriched interpretations.

However, the experiments in this thesis did not provide evidence to support a ToM-mediated account of the EF-CU relationship. Although the results of

Experiment 3 initially indicated that CU was associated with ToM, supporting the conceptualisation of CU in terms of the appreciation of communicative intentions, the relationship found between CU and ToM in Experiment 3 was actually subsumed by the effects of EF. This would not be expected if ToM was mediating the relationship between EF and CU.

Nevertheless, there were indications that performance on the ToM tasks employed in Experiments 1-3 was more reflective of fatigue and irrelevant processing costs than ToM ability. Although overall performance was very high for the first-order tasks, significantly more children passed the first, first-order ToM task they were presented with than passed the second, first-order ToM task presented in each experiment, suggesting that some of the variation in first-order ToM scores might have been reflecting fatigue rather than individual differences in ToM. This was especially likely given that the first-order ToM tasks used are typically passed by children who are of the same age as the participants taking part in those experiments. Furthermore, although overall ToM performance was around chance levels for the second-order tasks, as one might expect given that such tasks are normally passed by children slightly older or at the top-end of the age-range tested in the current set of experiments (i.e. 6- and 7-year-olds), significantly more children failed the first, second-order ToM task that they were presented with, than failed the second-order ToM task presented second. This is concordant with the fact that the second-order ToM task presented second, was designed to reduce the extent of non-ToM task demands (Sullivan, Zaitchik, & Tager-Flusberg, 1994). The uneven distribution of performance across second-order ToM tasks suggests that fatigue was unlikely to account for much of the second-order task score variation. However, it does suggest that a notable degree of score variation was likely to be reflecting irrelevant task processing costs rather than individual differences in ToM.

Since a fair degree of variance in ToM scores seems to reflect factors such as language comprehension rather than ToM ability (Bloom & German 2000), the failure to demonstrate a mediatory role for ToM in the EF-CU relationship could be attributable to the inappropriateness of the specific ToM measures used. However, there is little evidence to indicate a ToM task geared towards the precise age range of the 4- to 6-year-olds targeted in the current series of studies, due to their age suitability for the CU tasks presented. Nevertheless, a scale of ToM tasks put forward by Wellman and Liu (2004) proposes that children find tasks which assess appreciation of the difference between real and apparent emotion, more difficult than traditional first-order ToM tasks. Furthermore, Wellman and Liu indicated that the mean age at which children pass tasks measuring awareness of the differentiation between real and apparent emotion, is just over 5-years-old. This is younger than the age at which children are reported to pass second-order ToM tasks. Thus tasks assessing appreciation of the difference between real and apparent emotion, might have produced a greater degree of valid variation in ToM scores than the first- and second-order ToM tasks used in Experiments 1-3. A greater variation in ToM scores might have enabled significant relationships to be revealed between ToM and EF and between ToM and CU.

9.4 Does executive functioning training promote the emerging expression of conversational understanding?

The relationship consistently found between shifting EF and the CVT measure of CU in Experiments 3, 5 and 6 could be attributable to a third mediating factor which promotes both shifting EF and CU. Establishing that training shifting EF results in enhanced CVT performance would provide evidence of a more direct link between EF and CU.

A number of studies have managed to successfully improve children's EF abilities. Some of these studies have trained shifting EF using the DCCS measure found to relate to CVT performance in Experiments 3, 5 and 6: Dowsett and Livesey (2000), Kloo and Perner (2003), Mack (2007). Other studies have focused on different aspects of EF such as visuo-spatial and verbal working memory (WM) span: Klingberg et al. (2005) and self-regulatory private speech, self-inhibition and planning: Diamond et al. (2007).

Although EF training has not always been found to be successful (Fisher, & Happé, 2005; Rueda et al., 2005), the DCCS training program used by Kloo and Perner (2003) appeared to be effective, and was based on the very task which was found to be related to CVT performance in Experiments 3,5 and 6. Thus, the EF training given in Experiment 4 of this thesis was based on the program used by Kloo and Perner (2003). It was initially intended that Experiment 4 would also include CVT training to investigate the possibility that the relationship between EF and CU stemmed from the positive influence of CU on EF. However, a pilot study indicated that a variety of CVT training methods did not raise CVT performance above chance levels.

The training given in Experiment 4 appeared to lead to a significant increase in shifting EF, assessed and trained using the DCCS task, although a control training condition would be required to establish that such effects were not the consequence of more general training effects. Whilst pre-training DCCS performance had been at significantly below-chance levels, post-training levels were at significantly greater than chance levels, indicating the attainment of DCCS competence. However, in contrast to expectations, multiple varied analyses failed to indicate that DCCS training resulted in enhanced CVT performance, that improvements in EF led to significant corresponding rises in CVT scores, that DCCS performance post-training affected CVT scores or improvement or even that pre-training DCCS scores were related to pre-training CVT performance.

Nevertheless, tests indicated that although pre-training CVT scores were merely at chance levels, post-training CVT scores were significantly better than chance. This was attributable to the improvement from chance to above chance levels for performance on CVT items reflecting the maxims of quality and Politeness and is consistent with the theory that a degree of CVT improvement had followed DCCS training. The CVT improvement from chance levels prior to DCCS training to significantly above chance levels, post-training, provides some support for the suggestion that CVT performance improved following DCCS training. Although, as indicated above, a control training condition would be required to establish that such effects were not the consequence of more general training effects. However, the fact that the pre- to post-training CVT improvements were not significant suggests that the influence of EF might be fairly restricted, so that a larger number of participants would be required to reveal a significant effect. Indeed this would be consistent with the small effect size reported for the DCCS-CVT relationship in Experiment 3 (partial $Eta^2 = 0.031$),.

9.5 Are there distinct components of executive functioning?

As indicated in Section 2.1, there is considerable dispute regarding the structural nature of EF during childhood. Miyake et al (2000) proposed that although the EF abilities of inhibition, shifting and updating were moderately correlated in adults, they were nevertheless clearly distinguishable, leading them to present a 3-factor model of EF in adulthood. However, it is not clear that EF exhibits a fractionated structure during childhood. Research with children and adolescents between the ages of 2 and 21 years indicates that EF can be differentiated into component parts during childhood (Espy, & Bull, 2005; Espy, Kaufman, McDiarmid, & Glisky, 1999; Hongwanishi, Happaney, Lee, & Zelazo, 2005; Huizinga, Dolan, & van der Molen, 2006; Lehto, Juujarvi, Kooistra, & Pulkkinen, 2003). However, a more recent study with children between the ages of 2- and 6-years-of-age found that multifactor models did not account for significantly more variance in EF scores, than a univariate model (Wiebe, Espy, & Charak, 2008). Preference for parsimony led Wiebe et al. to conclude that a univariate model provides the best account of childhood EF.

In line with Miyake et al.'s 3-factor model of EF, analyses conducted on the EF task data produced in Experiments 1-3 and 5 of this thesis consistently failed to demonstrate significant relationships between children's inhibitory, shifting and updating EF ability. Experiment 4 only assessed the shifting aspect of EF. Furthermore, although children's performance on the FAT updating task employed in Experiment 6 was found to be related to their performance on the Frog Simon inhibitory task and the FIST switching measures, difficulties encountered during pilot testing of the FAT and detailed in Section 8.4, suggested that this merely reflected the unsuitability of the FAT as a measure of updating EF. Rather than forming a focused measure of updating, the FAT appears to be a complex task making a variety of processing demands. Thus, the data presented in this thesis supports the suggestion that EF is composed of distinct components during childhood.

9.6 Theoretical implications

Beal and Flavell (1984) and Robinson and Whittaker (1986) put forward a conceptual change account of CU. They argued that young children's apparent inability to consider the logical elements of a message in light of contextual factors, reflected the inability of young children to conceptually differentiate between that which is said: the logical/literal meaning (LM) and that which is meant: the intended meaning (IM).

However, recent research into the emergence of CU has indicated that young children in fact do possess early LM-IM differentiation. Appreciation of this distinction seems to be restricted with regard to certain contexts and response modalities, suggesting that the understanding is less likely to be the potentially conscious, explicit appreciation of adults, but rather, an unconscious, implicit knowledge.

A guiding theoretical framework of this thesis is that information processing limitations may be masking children's knowledge, preventing it from being exploited during explicit (conscious) response consideration, in line with a performance account of CU development (Surian, 1995). A masked competence account of CU has been proposed which suggests that processing restrictions affect the ability to reason about the mind (ToM), hindering accurate inference of speaker intentions (CU). As children grow older these restrictions are thought to be overcome by the development of EF abilities (Siegal & Surian, 2004; 2007). According to this analysis, ToM mediates the relationship between EF and CU because CU is conceptualised as an aspect of ToM, depending upon the ToM skill of interpreting intentions. EF is thought to enable the biases directing intention interpretation to be overpowered, in this way promoting CU. For example, the evolutionary pressure for rapid language development might have created a processing bias to select logical, linguistically determined speaker intentions in certain situations e.g. directed communication. An alternative bias to derive these intentions solely from contextual information might be exhibited in other instances, for example when listening to accounts of communication, as in a narrative. Both of these biases might be overcome as processing resources increase with age. Siegal and Surian suggest that the development of an EF system allows children to overcome such processing biases by enabling the inhibition of default interpretations. The inhibition of default interpretations is thought to facilitate access to contextually enriched but logically supported interpretations of speaker intentions.

The findings produced from Experiments 1-6 of this thesis appear to provide partial support for the Masked Competence account of the emergence of CU. As indicated in Section 9.2, there is much evidence for a relationship between EF-CU, involving all three of Miyake et. al's differentiable components of EF and in regards to both specific and general aspects of CU. However, the role of ToM in this relationship is not clear. The results of Experiment 3 indicated that CU was associated with ToM, supporting the conceptualisation of CU in terms of the appreciation of communicative intentions. However, the relationship found between CU and ToM in Experiment 3 was actually subsumed by the effects of EF which would not be expected if ToM was mediating the relationship between EF and CU. It has however, been suggested that the ToM measures used were not age-appropriate, and thus ToM might be found to play a mediatory role if more sensitive tasks were used with this age-range.

However, it should be noted that a masked competence account of CU has been challenged. Beck, Robinson and Freeth (2007) suggest that reducing the judgemental processing demands of CU tasks does not enable young children to reveal implicit knowledge. They argue that the subsequent apparent demonstration of

CU merely reflects the presence of other abilities which do not involve representation of CU. For example, as detailed in Section 1.5.2, Beck et al. found that presenting an ambiguity detection task which did not require a decision to be made, appeared to enable children to demonstrate a competence which they were unable to reveal in a similar task containing a decision-making aspect. However, they propose that the apparent enhanced performance merely results from the children's ability to wait until they can accurately identify items. Beck et. al. suggest that such performance indicates recognition that items cannot be identified when information is ambiguous, but not an understanding of what ambiguity actually means. In other words, Beck et. al. argue that passing such a task does not require children to represent indistinct information as ambiguous. They consider that children can pass the task without recognising that ambiguous information can represent multiple possible referents.

Nevertheless, researchers have enhanced the performance of young children, by reducing the non-judgemental processing demands of CU tasks. For example, as detailed in Section 1.5.2, Chierchia et al. (2001) presented children with a scenario for which the strong descriptive term "and" was appropriate and then asked them to judge the better description from a report containing a false SI entailing "not and" and an account which did not evoke an SI, which was consistent with the meaning "and". 3- to 6-year-olds were found to display a preference for the description which did not evoke the false SI. Similarly, Papafragou and Tantalou (2004) asked children to recommend whether characters should be awarded prizes on the basis of judgements concerning the SIs entailed by characters' performance descriptions. They reported that 4- and 5-year-olds were negatively evaluating characters whose descriptions contained SIs entailing the non-completion of tasks at significantly above chance levels. It is unclear why children would reveal a preference for descriptions not evoking false SIs in Chierchia et al.'s study if they were not computing the inappropriate SIs. Similarly, it seems strange that children would demonstrate a bias for awarding only those characters whose performance descriptions did not entail SIs indicating non-completion of tasks in Papafragou and Tantalou's study, if the inappropriate SIs were not being computed. The results of such studies thus support the suggestion that that early CU is being masked by limited processing resources. This concurs with the demonstration of EF-CU relations in the set of studies comprising this thesis, despite the use of CU tasks with reduced processing demands. The SI task used in Experiments 1, 2 and 6 promoted the relevance of SI computation and was accompanied by felicity training whilst the CVT employed in Experiments 3-6 provided children with contrasting statement pairs to choose between, removing the need for independent representation of contrasting meanings. That EF should continue to exhibit strong relations to CU in such processing-minimised conditions, indicates that it plays an integral role in the demonstration of CU.

The findings presented in this thesis also have a bearing upon the hypothesised structure of EF and thereby provide clarification of the possible role of EF in CU. As detailed in Section 2.1 and mentioned in Section 9.5, Miyake et al (2000) proposed a 3-factor model of EF comprising inhibitory, shifting and updating abilities. However, Miyake's model was based on the analysis of adult data, and contention remains regarding the unified versus fractionated structure of EF during childhood (Espy, & Bull, 2005; Espy, Kaufman, McDiarmid, & Glisky, 1999; Hongwanishi, Happaney, Lee, & Zelazo, 2005; Huizinga, Dolan, & van der Molen, 2006; Lehto, Juujarvi, Kooistra, & Pulkkinen, 2003; Wiebe, Espy, & Charak 2008). EF task data produced during this thesis consistently failed to demonstrate significant relationships between children's inhibitory, shifting and updating EF ability. Thus, the data presented in this thesis suggests a fractionated account of childhood EF inline with the model of Miyake et al.

The differentiation apparent between the EF abilities measured in this study lends strength to the possibility that EF components might be affecting CU in different ways. However, Experiment 6 revealed that when differences in verbal IQ were removed, inhibitory, shifting and updating components of EF were all related to CVT scores. This suggests that rather than acting completely independently, the three components of EF are being engaged simultaneously, playing complementary roles in the emergence of CU. CU might engage inhibitory EF ability to enable the inhibition of default literal interpretations of communication where necessary. Shifting EF ability might be employed to enable switching between literal and contextually enriched interpretations when required. Updating EF ability might ensure that mental representations of the communicative situation reflect the current state of information provided.

9.7 Limitations and future directions for research

Since it has been argued that the failure to find a mediational role for ToM in the relationship between EF and CU might be attributable to the age-inappropriateness of the ToM tasks used in the experiments of this thesis, it would seem that future research ought to identify and employ ToM tasks which are more suitable for the 4- to 6-year-old age range. As reported in Sections 5.4 and 9.3, Wellman and Liu (2004) suggest that children pass ToM tasks which assess appreciation of the difference between real and apparent emotion at just over 5-years-of-age, which indicates that these tasks might be ideal.

However, although this thesis has provided a considerable degree of evidence to suggest that EF plays a role in the emergence of CU, the findings are limited by the extent to which the concept of EF is understood. As indicated in Section 2.1, the concept of EF is hotly contested. Various proposals involve unified (Carlson, Moses, & Hix, 1998) and fractionated (Tranel, Anderson, & Benton, 1994) constructs, and even the proposal that EF might be better conceptualised in terms of a problem solving framework (Zelazo, Carter, Reznik, & Frye, 1997). Separate contention concerns the unitary versus compound nature of the EF structure during childhood (Lehto, Juujarvi, Kooistra & Pulkkinen, 2003; Wiebe, Espy & Charak, 2008) leaving open the possibility for later changes to its constitution during the course of development. However, even the methods used to investigate such structural claims are questioned, with neuropsychological and factor-analytic approaches both receiving criticism (Miyake et al., 2000; Zelazo & Muller, 2002).

Banich (2009) proposes an integrated model of EF research in a bid to overcome the wide extent of controversy hampering this area of investigation. This model seeks to link evidence found regarding the neurobiological (neural underpinning), computational (information processing) and psychological (cognitive construct) basis of EF. For example, Banich points out that computational models of EF conceptualise dompaninergic connections between the basal ganglia and frontal cortex as acting as a gate preventing or allowing information stored in working memory to escape enabling new information to enter (O'Reilly 2006). However Banich also highlights neurological research which indicates that the posterior portion of the dorsolateral prefrontal cortex would be likely to be affected by such gating as this region of the brain appears involved in creating and maintaining attentional sets (Herrington et al. 2009). Furthermore, Banich notes evidence from children relating to psychological and computational models of EF which indicates that the ability to create abstract representations of categories affects the ability to shift (Kharitonova, Chien, Colunga, & Munakata, in press). Banich suggests that initial representations might be weak, gaining strength following practice.

Banich links these three areas of EF research by suggesting that greater light might be shed on manipulation in one domain through investigation in another. For example, she suggests that the effects of EF training, which often do not reveal themselves behaviourally in the short term, might be more apparent initially in brain imaging data revealing the activation of additional brain regions following training. Such a holistic outlook is likely to cut down on the potential for dispute within the field of EF and so serve to promote understanding of this complex domain.

Indeed, the integrated research model of Banich (2009) has implications for the shifting EF training study employed in Experiment 4 in which improvements in EF were not found to lead to corresponding improvements in CU. The data in Experiment 3 revealed that the effect size of the relationship between shifting EF and CVT performance was fairly small (partial Eta^2 = 0.031), indicating that a training effect would have been more likely to emerge if a larger training sample had been tested. Unfortunately, because inclusion in the study required poor performance on a pre-training shifting task, almost half of the children initially tested had to be excluded from the study, diminishing the final sample size. However, future research testing a larger final sample might well reveal that training shifting EF promotes CU. Nevertheless, Banich's suggestion that the effects of training might, in the short-term, be more noticeable through inspection of non-behavioural measures, indicates that brain imaging data might have provided valuable insight in Experiment 4. Such data might have revealed the inclusion of additional brain regions in task processing following training, e.g. the part of the brain responsible for shifting EF might have demonstrated greater activation during CU tasks following shifting training. This would be likely to entail subsequent, albeit perhaps delayed, CU improvement.

Further studies could be conducted into the relationship between EF and CU using a wider variety of CU tasks, such as those focused on the interpretation of garden path sentences in context (Meroni & Crain, 2003) or isomorphic sentences (Musolino & Lidz, 2006). Investigation of the EF-CU relationship in populations thought to demonstrate diminished EF or CU would also help to shed light on the nature of the association between these two factors. It would also be interesting to investigate the nature of the EF-CU relation in populations with impaired EF e.g. children with ADHD (Bravo, Martin & Dominguez, 2008) and in populations with impaired CU e.g. children with autism (Dennis, Lazenby, & Lockyer, 2001).

Future studies could also employ more complex designs. For example, an experiment could be conducted with a before-and-after, within-participants, priming design. More specifically a priming paradigm could be used to assess whether CU required inhibition of default logical interpretations. Using the experimental design of Houdé and Guichart (2001), such a study could be conducted using a chronometric paradigm in which older, CU competent children complete a two-part prime-probe task. The first part of the task could present non-literal phrases, serving to prime inhibition (if this the mechanism used for CU) of the literal/logical interpretations. For example, children could be presented with phrases which are metaphors such as "Max is a real rock" and asked to indicate whether the meaning is good or bad. The second part of the task could present literal phrases for which the child must resist the (potentially) primed logical inhibition. For example, children could be presented with accurate phrases such as "Max is a naughty boy" and asked to indicate whether the meaning is good or bad. The key would be to compare the reaction times of the children to the literal phrase when it follows the inhibition-priming CU phrase, to their reaction times to the literal phrase in a control condition in which the literal phrase precedes the CU phrase (and so avoids negative priming effects). It would be predicted that longer comparative reaction times would be demonstrated for interpretation of literal phrases following non-literal phrases, indicating a negative priming effect. Such a finding would support the theory that developing inhibitory ability plays a role in the emergence of CU.

Another study could use dual-tasking methodology to assess whether EF components play a role in the demonstration of CU. Children could be given a CU task along-side a concurrent EF component task. The component task should fully occupy their resources for that dimension of EF, preventing its deployment to the CU task. For example, children could be required to perform an inhibitory task such as Luria's tapping task (1973), whilst responding to the CVT. However, to avoid the overlap in auditory processing that might be expected if both tasks were performed concurrently, on-screen subtitles could be used to present the questions and statement-pair responses given in the CVT.

In summary, the relationships found between childhood EF and CU in this thesis provide a good basis for further research into the role of EF in the emergence of CU. There is great scope for future research in a wide range of areas, involving different aspects of CU and EF, a variety of experimental methods and with regard to both typical and atypical development. Such a program of research should do much to promote our understanding of the nature and course of cognitive development.

References

Abutalebi, J., & Green, D. (2007). Bilingual language production: The neurocognition of language representation and control. *Journal of Neurolinguistics, 20,* 242-275.

Ackerman, B. P. (1993). Children's understanding of the speaker's meaning in referential communication. *Journal of Experimental Child Psychology, 55,* 56–86.

Apperly, I.A., Back, E., Samson, D. & France, L. (2008). The cost of thinking about false beliefs: Evidence from adult performance on a non-inferential theory of mind task. *Cognition, 106,* 1093-1108.

Bach, L. J., Happe, F., Fleminger, S., & Powell, J. (2000). Theory of mind: Independence of executive function and the role of the frontal cortex in acquired brain injury. *Cognitive Neuropsychiatry, 5,* 175 – 192.

Baddeley, A. (1996). Exploring the central executive. *The Quarterly Journal of Experimental Psychology, 49(a),* 5-28.

Baillargeon, R., DeVos, J., & Graber, M. (1989). Location memory in 8-month-old infants in a nonsearch AB task: Further evidence. *Cognitive Development, 4,* 345- 367.

Baldwin, D. A. (1993). Early referential understanding: Infants' ability to recognize referential acts for what they are. *Developmental Psychology, 29,* 832-843.

Banich, M. (2009). Executive Function: The search for an integrated account. *Current Directions in Psychological Science, 18,* 89-94.

Barke, E., & Perry-Williams, D. E. (1938). A further study of the comparative intelligence of children in certain bilingual and monoglot schools in South Wales. *British Journal of Developmental Psychology, 8,* 63-77.

Baron-Cohen, S. (1989). The autistic child's theory of mind: A case of specific developmental delay. *Journal of Child Psychology and Psychiatry, 30,* 285-298.

Baron-Cohen, S., Leslie, A.M., & Frith, U. (1985). Does the autistic child have a 'theory of mind'? *Cognition, 21,* 37-46.

Baron-Cohen, S., O'Riordan, M., Stone, V., Jones, R., & Plaisted, K. (1999). Recognition of faux pas by normally developing children and children with Asperger Syndrome or high-functioning autism. *Journal of Autism and Developmental Disorders, 29,* 407-418.

Beal, C., & Flavell, J. (1984). Development of the ability to distinguish communicative intention and literal message meaning. *Child Development, 55,* 920-928.

Beck, S.R., Robinson, E.J., & Freeth, M. (2008). Can children resist making interpretations when uncertain? *Journal of Experimental Child Psychology, 99,* 252-270.

Ben-Zeev, S. (1977). The influence of bilingualism on cognitive strategy and cognitive development. *Child Development, 48,* 1009-1018.

Bernard, S., & Deleau, M. (2007). Conversational perspective-taking and false belief attribution: A longitudinal study. *British Journal of Developmental Psychology, 25,* 443-460.

Bialystok, E. (1986). Factors in the growth of linguistic awareness. *Child Development, 57,* 498-510.

Bialystok, E. (1988). Levels of bilingualism and levels of linguistic awareness. *Developmental Psychology, 24,* 560-567.

Bialystok, E. (1999). Cognitive complexity and attentional control in the bilingual mind. *Child Development, 70,* 636-644.

Bialystok, E. (2001). *Bilingualism in Development: Language, literacy & Cognition.* New York: Cambridge University Press.

Bialystok, E. (2009). Bilingualism: The good, the bad, and the indifferent. *Bilingualism: Language and Cognition, 12,* 3-11.

Bialystok, E., & Codd, J. (1997). Cardinal limits: Evidence from language awareness and bilingualism for developing concepts of number. *Cognitive Development, 12,* 85-106.

Bialystok, E., & Majumder, S. (1998). The relationship between bilingualism and the development of cognitive processes in problem-solving. *Applied Psycholinguistics, 19,* 69-85.

Bialystok, E., & Martin, M. (2004). Attention and inhibition in bilingual children: Evidence from the dimensional change card sort task. *Developmental Science, 7,* 325-339.

Bialystok, E., Martin, M., & Viswanathan, M. (2005) Bilingualism across the lifespan: the rise and fall of inhibitory control. *International Journal of Bilingualism, 9,* 103-119.

Bialystok, E., & Senman, L. (2004). Executive processes in appearance-reality tasks: The role of inhibition of attention and symbolic representation. *Child Development*, *75*, 562-579.

Bialystok, E., & Shapero, D. (2005). Ambiguous benefits: The effect of bilingualism on reversing ambiguous figures. *Developmental Science*, *8*, 595-604.

Blair, C., Zelazo, P. D., & Greenberg, M. (2005). The measurement of executive function in early childhood. *Developmental Neuropsychology*, *28*, 561-571.

Bloom, P., & German, T. (2000). Two reasons to abandon the false belief task as a test of theory of mind. *Cognition*, *77*, B25-B32.

Bloomfield, L. (1933). *Language*. New York: Holt.

Bott, L., & Noveck, I. A. (2004). Some utterances are underinformative: The onset and time course of scalar inferences. *Journal of Memory and Language*, *51*, 437-457.

Bravo, T. M., Martin, M., & Dominguez, M. (2008). "Hot" and "Cool" executive dysfunction in children with attention deficit hyperactivity disorder (ADHD). Clinical Neurophysiology, 119, e157.

Britt, M. A. (1994). The interaction of referential ambiguity and argument structure in the parsing of prepositional phrases. *Journal of Memory and Language*, *33*, 251-283.

Butterworth, G. E. (1977). Object disappearance and error in Piaget's Stage IV task *Journal of Experimental Child Psychology*, *3*, 391-401.

Campbell, R., & Sais, E. (1995). Accelerated metalinguistic (phonological) awareness in bilingual children. *British Journal of Developmental Psychology*, *13*, 61-68.

Carlson, S. M., & Meltzoff, A. N. (2008). Bilingual experience and executive functioning in young children. *Developmental Science*, *11*, 282–298.

Carlson, S. M., & Moses, L. J. (2001). Individual differences in inhibitory control and children's theory of mind. *Child Development*, *72*, 1032-1053.

Carlson, S. M., Moses, L. J., & Hix, H. R., (1998). The role of inhibitory processes in young children's difficulties with deception and false belief. *Child Development*, *69*, 672-691.

Carrow, S. M. A. (1957). Linguistic functioning of bilingual and monolingual children. *Journal of Speech and Hearing Disorders*, *22*, 371-380.

Carruthers, P. (1996). Autism as mindblindness: An elaboration and partial defence. In P. Carruthers and P. K. Smith (Eds.), *Theories of theories of mind* (pp. 257-273). Cambridge UK: Cambridge University Press.

Casteel, M. and Simpson, B. (1991). Textual coherence and the development of inferential generation skills. *Journal of Research in Reading, 14,* 116-129.

Chen, H., & Ho, C. (1986). Development of Stroop Interference in Chinese-English bilinguals. *Journal of Experimental Psychology: Learning, Memory & Cognition, 12,* 397-401.

Chierchia, G., Crain, S., Guasti, M. T., Gualmini, A., & Meroni, L. (2001). The acquisition of disjunction: Evidence for a grammatical view of scalar implicatures. In A. H. J. Do, L. Dominguez, & A. Johansen (Eds.), *Proceedings of the 25th Boston University Conference on Language Development* (pp. 157-168). Somerville, MA: Cascadilla Press.

Clark, H. H., & Carlson, T. B. (1981). Context for comprehension. In J. Long & A. D. Baddeley (Eds.), *Attention and performance IX* (pp. 313-330). New York: Academic Press.

Clark, H. H., & Marshall, C. R. (1981). Definite reference and mutual knowledge. In A. K. Joshi, B. Webber & I. A. Sag (Eds.), *Elements of discourse understanding* (pp.10-63). Camridge: Cambridge University Press.

Clements, W. A., & Perner, J. (1994). Implicit understanding of belief. *Cognitive Development, 9,* 377-395.

Costa, A., Miozzo, M., & Caramazza, A. (1999). Lexical selection in bilinguals: Do words in bilingual's lexicon compete for selection? *Journal of Memory and Language, 41,* 365-397.

Cromdal, J. (1999). Childhood bilingualism and metalinguistic skills: Analysis and control in young Swedish-English bilinguals. *Applied Psycholinguistics, 20,* 1-20.

Cummins, J. (1978). Metalinguistic development of children in bilingual education programs: Data from Irish and Canadian Ukranian-English programs. In M. Paradis (Ed.) *The fourth Lacus forum* (pp. 29-40). Columbia, South Carolina: Hornbeam Press.

Dale, P., & Crain-Thoreson, C. (1993). Pronoun reversals: Who, when and why? *Journal of Child Language, 20,* 573-589.

Davis, H., & Pratt, C. (1995). The development of children's theory of mind: The working memory explanation. *Australian Journal of Psychology, 47*, 25-31.

De Neys, W., & Schaeken, W. (2007). When people are more logical under cognitive load: dual task impact on scalar implicature. *Experimental Psychology 54*, 128-133.

Deák, G. O., Ray, S. D., & Brenneman, K. (2003). Children's peservaerative appearance-reality errors are related to emerging language skills. *Child Development, 74*, 944-964.

Dempster, F. N. (1981). Memory span: Source of individual and developmental differences. *Psychological Bulletin, 89*, 63-100.

Dennis, M., Lazenby, A. L., & Lockyer, L. (2001). Inferential language in high-function children with autism. *Journal of Autism and Developmental Disorders 31*, 47-54.

Dews, S., Winner, E., Kaplan, J., Rosenblatt, E., Hunt, M., Lim, K., McGovern, A., Qualter, A., & Smarsh, B. (1996). Children's understanding of the meaning and functions of verbal irony. *Child Development, 67*, 3071-3085.

Diamond, A., Barnett, S., Thomas, J. & Munro, S. (2007). Preschool Program Improves Cognitive Control. *Science, 318*, 1387-1388.

Diamond, A., & Kirkham, N.Z. (2005). Not quite as grown-up as we like to think: Parallels between cognition in childhood and adulthood. *Psychological Science, 16*, 291-297.

Diamond, A., & Taylor, C. (1996). Development of an aspect of executive control: Development of the abilities to remember what I said and to 'Do as I say, not as I do'. *Developmental Psychobiology, 24*, 315–334.

Diaz, R. M. (1983). Thought and two languages: The impact of bilingualism on cognitive development. *Review of Research in Education, 10*, 23-54.

Dibbets, P., & Jolles, J. (2006). The switch task for children: Measuring mental flexibility in young children. *Cognitive Development, 21*, 60-71.

Dijkstra, A., Grainger, J., & Van Heuven, W. J. B. (1999). Recognition of cognates and interlingual homographs: The neglected role of phonology. *Journal of Memory and Langauge, 41*, 496-518.

Dodwell, P. C. (1961). Children's understanding of number concepts: Characteristics of an individual and of a group test. *Canadian Journal of Psychology, 15*, 191-205.

Dowsett, S. M., & Livesey, D. J. (2000). The development of inhibitory control in preschool children: Effects of "executive skills" training. *Developmental Psychobiology, 36*, 161-174.

Doyle, A.B., Champagne, M. & Segalowitz, N. (1977). Some issues in the assessment of linguistic consequences of early bilingualism. *Working Papers in Bilingualism, 14,* 21-30. Reprinted in M. Paradis, (Ed.), (1978) *Aspects of bilingualism*, Columbia, South Carolina: Hornbeam Press, 13-20.

Duncan, J., Johnson, R., Swales, M., & Freer, C. (1997). Frontal lobe deficits after head injury: Unity and diversity of function. *Cognitive Neuropsychology, 14,* 713-741.

Dunn, L. M., & Dunn, L. M. (2000). *Peabody Test di Vocabolario Recettivo.* Torino, Italy: Omega (Adapted by Stella, G., Pizzoli, C., & Tressoldi, P. E.).

Dunn, L. M., Dunn, L. M., Whetton, C., & Burley, J. (1997). *British Picture Vocabulary Scale: Second edition (BPVS-II).* Windsor, Berks: NFER-Nelson.

Elkind, D. (1961). The development of quantitative thinking: A systematic replication of Piaget's studies. *Journal of Genetic Psychology, 98,* 3746.

Ellis, A., & Young, A. (1988). *Human Cognitive Neuropsychology.* Hove, UK: Lawrence Erlbaum Associates.

Emmorey, K., Luk, G., Pyers, J. E., & Bialystok, E. (2008). The source of enhanced cognitive control in bilinguals. *Psychological Science, 19,* 1201-1206.

Engle, R.W., Kane, M.J., & Tuholski, S.W. (1999). Individual differences in working memory capacity and what they tell us about controlled attention, general fluid intelligence and functions of the prefrontal cortex. In A. Miyake & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 102-134). New York: Cambridge University Press.

Eskritt, M., Whalen, J., & Lee, K. (2008). Young children's recognize violations of the Gricean maxims. *British Journal of Developmental Psychology, 26,* 435-443.

Espy, K. A., & Bull, R. B. (2005). Inhibitory processes in young children and individual variation in short-term memory. *Developmental Neuropsychology, 28*, 669-688.

Espy, K. A., Kaufmann, P. M., McDiarmid, M. D., & Glisky, M. L. (1999). Executive functioning in pre-school children: Performance on A-Not-B and other delayed response format tasks. *Brain and Cognition 41*, 178-199.

Feeney, A., Scrafton, S., Duckworth, A., & Handley, S.J. (2004). The story of some: Everyday pragmatic inference by children and adults. *Canadian Journal of Experimental Psychology*, 58, 90-101.

Feldman, C., & Shen, M. (1971). Some language-related cognitive advantages of bilingual five-year-olds. *Journal of Genetic Psychology, 118*, 235-244.

Feng, X., Diamond, A., & Bialystok, E. (2007). *Manipulating information in working memeory: An advantage for bilinguals.* Poster presented at the biennial meeting of the Society for Research in Child Development, Boston, MA.

Filippova, E,. & Astington, J.W. (2008). Further development in social reasoning revealed in discourse irony understanding. *Child Development, 79,* 126-138.

Fisher, N., & Happé, F. (2005). A training study of theory of mind and executive function in children with autistic spectrum disorders. *Journal of Autism and Developmental Disorders, 35*, 757-771.

Flavell, J. (1988). The development of children's knowledge about the mind: From cognitive connections to mental representations. In J. W. Astington, P. L. Harris and D. R. Olson (Eds.) *Developing theories of mind* (pp244-270). Cambridge: Cambridge University Press.

Flavell, J., Green, F., & Flavell, E. (1986). Development of knowledge about the appearance-reality distinction. *Monographs of the Society for Research in Child Development, 51, No.1, Serial No. 212.*

Friedman, N. P., Miyake, A., Corley, R. P., Young, S. E., DeFries, J. C., & Hewitt, J. K. (2006). Not all executive functions are related to intelligence. *Psychological Science, 17*, 172-179.

Friend, M., & Bryant, J. (2000). A developmental lexical bias in the interpretation of discrepant messages. *Merill-Palmer Quarterly-Journal of Developmental Psychology, 46,* 342-369.

Frith, C. D. (1992) *The cognitive neuropsychology of schizophrenia.* LEA: London.

Frith, U. (1989). *Autism: explaining the Enigma.* Oxford: Blackwell.

Fritzley, V. H., & Lee, K. (2003). Do young children always say yes to yes-no questions? A metadevelopmental study of the affirmation bias. *Child Development, 74,* 1297-1313.

Frye, D., Zelazo, P. D., & Palfai, T. (1995). Theory of mind and rule-based reasoning. *Cognitive Development, 10,* 483-527.

Galambos, S. J., & Goldin-Meadow, S. (1990). The effects of learning two languages on levels of metalinguistic awareness. *Cognition, 34,* 1-56.

Galambos, S. J., & Hakuta, K. (1988). Subject-specific and task specific characteristics of metalinguistic awareness in bilingual children. *Applied Psycholinguistics, 9,* 141-162.

Garnsey, S. M., Pearlmutter, N. J., Myers, E., & Lotocky, M. A. (1997). The contributions of verb bias and plausibility to the comprehension of temporarily ambiguous sentences. *Journal of Memory and Language, 37,* 58-93.

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin, 134,* 31-60.

Gauvain, M., & Greene, J. (1994). What do young children know about objects? *Cognitive Development, 9,* 311-329.

Genesee, F., Boivin, I., & Nicoladis, E. (1996). Bilingual children talking with monolingual adults: A study of bilingual communicative competence. *Applied Psycholinguistics, 17,* 427-442.

Genesee, F., Nicoladis, E., & Paradis, J. (1995). Language differentiation in early bilingual development. *Journal of Child Language, 22,* 611-631.

Genesee, F., Tucker, G. R., & Lambert, W. E. (1975). Communication skills in bilingual children. *Child Development, 46,* 1010-1014.

Gerstadt, C., Hong, Y., & Diamond, A., (1994). The relationship between cognition and action: Performance of children 3 ½ - 7 years old on a stroop-like day-night task. *Cognition, 53,* 129-153.

Godefroy, O., Cabaret, M., Petit-Chenal, V., Pruvo, J.-P., & Rousseaux, M. (1999). Control functions of the frontal lobes: Modularity of the central-supervisory system? *Cortex, 35,* 1-20.

Goertz, P. J. (2003). The effects of bilingualism on theory of mind development. *Bilingualism: Language and cognition, 6,* 1-15.

Gollan, T. H., & Acenas, L. A. (2004). What is a TOT?: Cognate and translation effects on tip-of-the-tongue states in Spanish-English and Tagalog-English bilinguals. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 30,* 246-269.

Gollan, T., Forster, K. I., & Frost, R. (1997). Translation priming with different scripts: masked priming with cognates and non-cognates in Hebrew-English bilinguals. *Journal of Experimental Psychology: Learning, Memory & Cognition, 23,* 1122-1139.

Gollan, T. H., Montoya, R. I., Fennema-Notestine, C., Morris, S. K., (2005). Bilingualism affects picture naming but not picture classification. *Memory & Cognition, 33,* 1220-1234.

Grant, D. A., & Berg, E. A. (1948). A behavioural analysis of degree of impairment and ease of shifting to new responses in a Weigl-type card sorting problem. *Journal of Experimental Psychology, 39,* 401-411.

Grice, P. (1975). Logic and conversation. Reprinted in P. Grice (1989) *Studies in the way of words* (pp. 22-40). Cambridge, Massachusetts: Harvard University Press.

Grosjean, F. (1989). Neurolinguists, beware! The bilingual is not two monolinguals in one person. *Brain and Language, 36,* 3-15.

Guasti, M. T., Chierchia, G., Crain, S., Foppolo, F., Gualmini, A., & Meroni, L. (2005). Why children and adults sometimes (but not always) compute implicatures. *Language and Cognitive Processes, 20,* 667-696.

Hadwin, J., Baron-Cohen, S., Howlin, P., & Hill, K. (1997). Does teaching a theory of mind have an effect on social communication in children with autism? *Journal of Autism and Developmental Disorders. 27,* 519-538.

Hala, S., Hug, S., & Henderson, A. (2003). Executive functions and false belief understanding in preschool children: Two tasks are harder than one. *Journal of Cognition and Development, 4,* 275-298.

Happé, F. (1993). Communicative competence and theory of mind in autism: A test of relevance theory. *Cognition, 48.* 101-119.

Happé, F., & Loth, E. (2002). 'Theory of mind' and tracking speakers' intentions. *Mind and Language, 17,* 24–36.

Harris, C. W. (1948). An exploration of language skill patterns. *Journal of Educational Psychology, 32,* 351-364.

Hernandez, A. E., Dapretto, M., Mazziotta, J., & Bookheimer, S. (2001). Language switching and language representation in Spanish-English bilinguals: An fMRI study. *NeuroImage. 14,* 510-20.

Herrington, J. D., Heller, W., Mohanty, A., Engels, A., Banich, M. T., Webb, A. G., & Miller, G. A. (2009). *Lateralization of asymmetric brain function in emotion and depression.* Manuscript submitted for publication.

Holmboe, K., Fearon, R. M. P., Csibra, G., Tucker, L., & Johnson, M. H. (2008). "Freeze-Frame": A new infant inhibition task and its relation to frontal cortex tasks in infancy and early childhood. *Journal of Experimental Child Psychology, 100*, 89-114.

Hongwanishi, D., Happaney, K., Lee, W., & Zelazo, P. (2005). Assessment of hot and cool executive function in young children: Age related changes and individual differences. *Developmental Neuropsychology, 28*, 617-644.

Hood, H. B. (1962). An experimental study of Piaget's theory of the development of number in children. *British Journal of Psychology. 53*, 273-286.

Horn, L. R. (1989). *A natural history of* negation. Chicago, Illinois: University of Chicago Press.

Houdé O, Guichart E (2001). Negative priming effect after inhibition of number/length interference in a Piaget-like task. *Developmental Science. 4*, 119 –123.

Hughes, C. (1998a) Executive function in preschoolers: Links with theory of mind and verbal ability. *British Journal of Developmental Psychology, 16*, 233-253.

Hughes, C. (1998b). Finding your marbles: Does preschoolers' strategic behaviour predict later understanding of mind? *Developmental Psychology, 34*, 1326–1339.

Hughes, C., & Graham, A. (2002). Measuring executive functions in childhood: Problems and solutions? *Child and Adolescent Mental Health, 7*, 131-142.

Huizinga, M., Dolan, C. V., & van der Molen, M. W. (2006). Age related changes in executive function: Developmental trends and a latent variable analysis. *Neuropsychologia, 44*, 2017-2036.

Huttenlocher, P. (1979). Synaptic density in human prefrontal cortex – developmental change and effects of aging. *Brain Research, 163*, 195-205.

Huttenlocher, P., & Dabholkar, A. (1997). Developmental anatomy of prefrontal cortex. In N. A. Krasnegor, G. R. Lyon & P. S. Goldman-Rakic (Eds.), *Development of the prefrontal cortex: Evolution, neurobiology and behaviour* (pp. 69-83). Baltimore, M.D.: Brookes.

Jacques, S., & Zelazo, P.D. (2001). The Flexible Item Selection Task (FIST): A measure of executive function in preschoolers. *Developmental Neuropsychology, 20,* 573-591.

Jolliffe, T., & Baron-Cohen, S. (1999). The Strange Stories Test: A replication with high-functioning adults with autism or Asperger syndrome. *Journal of Autism and Developmental Disorders, 29,* 395-404.

Kharitonova, M., Chien, S., Colunga, E., & Munakata, Y. (in press). More than a matter of getting "unstuck": Flexible thinkers use more abstract representations than peserverators. *Developmental Science.*

Kimberg, D.Y., & Farah, M.J., (1993). A unified account of cognitive impairments following frontal lobe damage: The role of working memory in complex, organised behaviour. *Journal of Experimental Psychology: General, 122,* 411-428.

Klingberg, T., Fernell, E., Olesen P. J., Johnson, M., Gustafsson, P., Dahlström, K., Gillberg, C. G., Forssberg, H., & Westerberg, H. (2005). Computerized training of working memory in children with ADHD--a randomized, controlled trial. *Journal of the American Academy of Child and Adolescent Psychiatry. 44,* 177-186.

Kloo, D., & Perner, J. (2003). Training transfer between card sorting and false belief understanding: Helping children apply conflicting descriptions. *Child Development, 74,* 1823-1839.

Kovács, A.M. (2008). Early bilingualism enhances mechanisms of false-belief reasoning. *Developmental Science, 12,* 48-54.

Kovács, A.M., & Mehler, J. (2009). Cognitive gains in 7-month-old bilingual infants. *Proceedings of the National Academy of Sciences, 106,* 6556-6560.

Landers, W. F. (1971). Effects of differential experience on infants' performance in a Piagetian stage IV object-concept task. *Developmental Psychology, 5,* 48-54.

Langdon, R., Davies, M., & Coltheart, M. (2002). Understanding minds and understanding communicated meanings in schizophrenia. *Mind and Language, 17,* 68-104.

Lee, E., Torrance, N., & Olson, D. R. (2001). Young children and the say/mean distinction: Verbatim and paraphrase recognition in narrative and nursery rhyme contexts. *Journal of Child Language, 28*, 531-543.

Lehto, J., Juujarvi, P., Kooistra, L., & Pulkkinen, L. (2003). Dimensions of executive functioning: Evidence from children. *British Journal of Developmental Psychology, 21*, 59-80.

Leslie, A. M., & Polizzi, P. (1998). Inhibitory processing in the false-belief task: Two conjectures. *Developmental Science, 1*, 247–254.

Levin, H. S., Culhane, K.A., Hartmann, J., Evankovich, K., Mattson, A. J., Harward, H., Ringholz, G., Ewing-Cobbs, L., & Fletcher, J. M., (1991). Developmental changes in performance on tests of purported frontal lobe functioning. *Developmental Neuropsychology, 7*, 377-395.

Logan, G. D., & Burkell, J. (1986). Dependence and independence in responding to double stimulation: A comparison of stop, change, and dual-task paradigms. *Journal of Experimental Psychology: Human Perception and Performance, 12*, 549–563.

Luciana, M., & Nelson, C., (1998). The functional emergence of prefrontally-guided working memory systems in four- to eight-year-old children. *Neuropsycholgia, 36*, 273-293.

Luria, A. (1973). *The Working Brain: An Introduction to Neuropsychology.* London: Penguin.

Mack, W. (2007). Improving postswitch performance in the dimensional change card-sorting task: The importance of the switch and of pretraining by redescribing the test cards. *Journal of Experimental Child Psychology, 98*, 243-251.

MacNamara, J. (1966). *Bilingualism and Primary Education.* Edinburgh: Edinburgh University Press.

Martin, I., & McDonald, S. (2004). An exploration of causes of non-literal language problems in individuals with Asperger syndrome. *Journal of Autism and Developmental Disorders, 34*, 311-328.

Martin-Rhee, M.M., & Bialystok, E. (2008). The development of two types of inhibitory control in monolingual and bilingual children. *Bilingualism: Language and Cognition, 11*, 81-93.

McGarrigle, J., & Donaldson, M. (1974). Conservation accidents. *Cognition, 3,* 341-350.

McKenna, F., & Sharma, D. (1995). Intrusive cognitions: An investigation of the emotional stroop task. *Journal of Experimental Psychology: Learning, Memory and Cognition, 21,* 1595-1607.

Meroni, L., & Crain, S. (2003). How children avoid kindergarten paths. *Proceedings of 4th Tokyo Conference on Psycholinguistics* (pp. 159-184). Tokyo, Japan: Hitsuji Shobo.

Mezzacappa, E. (2004) Alerting, orienting, and executive attention: Developmental properties and sociodemographic correlates in an epidemiological sample of young, urban children. Child Development, 75, 1373-1386.

Miller, S. A. (2009). Children's understanding of second order mental states. *Psychological Bulletin, 135,* 749-773.

Mitchell, D. (1987). Lexical guidance in human parsing: Locus and processing characteristics. In M. Coltheart (Ed.), *Attention and performance XII: The psychology of reading* (pp. 601-618). Hillsdale, New Jersey: Erlbaum.

Mitchell, P., & Lacohee, H. (1991). Children's early understanding of false belief. *Cognition, 39,* 107–127.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41,* 49-100.

Morton, J. B., & Harper, S. N. (2007). What did Simon say? Revisiting the bilingual advantage. *Developmental Science, 10,* 719-726.

Musolino, J., & Lidz, J. (2003). The scope of isomorphism: Turning adults into children. *Language Acquisition, 11,* 277-291.

Musolino, J., & Lidz, J. (2006). Why Children aren't universally successful with Quantification. *Linguistics, 44,* 817-852.

Nilsen, E.S., & Graham, S.A. (2009). The relations between children's communicative perspective-taking and executive functioning. *Cognitive Psychology, 58,* 220–249.

Norman, D. A., & Shallice, T., (1986). Attention in action: Willed and automatic control of behaviour. In R. J. Davidson, G. E. Schwartz, & D. Shapiro (Eds.), *Consciousness and self regulation, Volume 4* (pp. 1-18). New York: Plenum Press.

Noveck, I. (2001). When children are more logical than adults: Experimental investigations of scalar implicature. *Cognition, 78*, 165-188.

Noveck, I. A., & Guelminger, R., Georgieff, N., & Labruyere, N. (2007). What autism can reveal about Every....not sentences. *Journal of Semantics 24*, 73-90.

Noveck, I.A., & Posada, A. (2003). Characterizing the time course of an implicature: An evoked potentials study. *Brain and Language, 85*, 203-210.

O'Reilly, R. C. (2006). Biologically based computational models of high-level cognition. *Science, 314*, 91-94.

Oh, S., & Lewis, C. (2008). Korean preschoolers' advanced inhibitory control and its relation to other executive skills and mental state understanding. *Child Development*, *79*, 80-99.

Olson, D. R., & Hildyard, A. (1981). Assent and compliance in children's language. In W. P. Dickson (Ed.), *Children's oral communication skills* (pp. 313-335). New York: Academic Press.

O'Neill, D. K. (1996). Two-Year-Old Children's Sensitivity to a Parent's Knowledge State When Making Requests. *Child Development, 67*, 659-677.

Onishi, K.H., & Baillargeon, R. (2005). Do 15-month-old infants understand false beliefs? *Science, 308*, 255-258.

Ozonoff, S., Pennington, B. F., & Rogers, S. J. (1991). Executive function deficits in high-functioning autistic individuals: Relationship to theory of mind. *Journal of Child Psychology and Psychiatry*, 32, 1081-1105.

Papafragou, A., & Musolino, J. (2003). Scalar implicatures: Experiments at the semantics-pragmatics interface. *Cognition, 86*, 253-282.

Papafragou, A., & Tantalou, N. (2004). Children's computation of implicatures. *Language Acquisition, 12*, 71-82.

Pearson, B. Z., Fernández, S., & Oller, D. K. (1993). Lexical development in bilingual infants and toddlers: Comparison to monolingual norms. *Language Learning, 43*, 93-120.

Pennington, B. F. (1997). Dimensions of executive functions in normal and abnormal development. In N. A. Krasnegor, G.R. Lyon, & P.S. Goldman-Rakic (Eds.), *Development of the Prefrontal Cortex: Evolution, neurobiology, and behaviour* (pp. 265-281). Baltimore: Paul H. Brooks Publishing Co., Inc.

Perner, J., & Lang, B. (1999). Development of theory of mind and executive control. *Trends in Cognitive Sciences, 3,* 337 – 344 .

Perner, J., & Lang, B. (2002). What causes 3-year-olds' difficulty on the dimensional change card sorting task? *Infant and Child Development, 11,* 93-105.

Perner, J., & Wimmer, H. (1985). "John thinks that Mary thinks that…": Attribution of second-order beliefs by 5- to 10-year-old children. *Journal of Experimental Child Psychology, 39,* 437–471.

Perner, J., Lang, B., & Kloo, D. (2002). Theory of mind and self-control: more than a common problem of inhibition. *Child Development, 73,* 752-67.

Piaget, J. (1952). *The child's conception of number.* London: Routledge and Kegan Paul.

Piaget, J. (1954). *The construction of reality in the child* (Margaret Cook, Trans.). New York: Basic Books, Inc.

Piaget, J. (1975). *The child's conception of the world.* Totowa, NJ: Littlefield, Adams.

Piaget, J., & Inhelder, B. (1956). *The child's conception of space.* London: Routledge & Kegan Paul.

Piaget, J., & Inhelder, B. (1969). *The psychology of the child.* New York: Basic Books.

Pickup, G. J. (2008). Relationship between theory of mind and executive function in schizophrenia: A systematic review. *Psychopathology, 41,* 206-213.

Pouscoulous, N., Noveck, I., Politzer, G., & Bastide, A. (2007). A developmental investigation of processing costs in implicature production. *Language Acquisition 14,* 347-375.

Prado, J., & Noveck, I.A. (2006). How reaction times measures elucidate the matching bias and the way negations are processed. *Thinking and Reasoning, 12,* 309-28.

Quinn, P. C., & Eimas, P. D. (1996). Perceptual organisation and categorization in young infants. In C. Rovee-Collier & L. P. Lipsitt (Eds.), *Advances in infancy research, Volume 10* (pp. 1-36). Norwood, NJ: Ablex.

Reid, L. (1996). The effects of focusing young children's attention on the literal meaning. *Merill-Palmer Quarterly-Journal of Developmental Psychology, 42,* 295-318.

Ricciardelli, L. A. (1992). Bilingualism and cognitive development in relation to threshold theory. *Journal of Psycholinguistic Research, 21,* 301-316.

Rice, C., Koinis, D., Sullivan, K., Tager-Flusberg, H., & Winner, E. (1997). When 3-year-olds pass the appearance-reality test. *Developmental Psychology, 33*, 54-61.

Robinson, E., Goelman, H., & Olson, D. (1983). Children's understanding of the relation between expressions (what was said) and intentions (what was meant). *British Journal of Developmental Psychology, 1*, 75-86.

Robinson, E., & Whittaker, S. (1986). Children's conceptions of meaning-message relationships. *Cognition, 22*, 41-60.

Rodriguez-Fornells, A., Van Der Lugt, A., Rotte, M., Britti, B., Heinze, H. J., & Münte, T. F. (2005). Second language interferes with word production in fluent bilinguals: Brain potential and functional imaging evidence. *Journal of Cognitive Neuroscience, 17,* 422-433.

Rose, S., & Blank, M. (1974). The potency of context in children's cognition: An illustration through conservation. *Child Development, 45*, 499-502.

Rowe, A. D., Bullock, P. R., Polkey'C. E., & Morris, R.G. (2001). Theory of mind impairments and their relationship to executive functioning following frontal lobe excisions. *Brain, 124,* 600-616.

Rueda, M. R., Rothbart, M. K., McCandliss, B. D., Saccomanno, L., & Posner, M. I. (2005). Training, maturation, and genetic influences on the development of executive attention. *Proceedings of the National Academy of Sciences USA, 102*, 14931-14936.

Sabbagh, M. A., Moses, L. J., & Shiverick, S. M. (2006). Executive functioning and preschoolers' understanding of false beliefs, false photographs, and false signs. *Child Development, 77*, 1034-1049.

Sabbagh, M. A., Xu, F., Carlson, S. M., Moses, L. J., & Lee, K. (2006). The development of executive functioning and theory of mind: A comparison of Chinese and U.S. preschoolers. *Psychological Science, 17*, 74-81.

Sapp, F., Lee, K., & Muir, D. (2000). Three-year-olds' difficulty with the appearance--reality distinction: is it real or is it apparent? *Developmental Psychology 36*, 547-560.

Scargle, J. (2000). Publication Bias: The 'file drawer' problem in scientific inference. *Journal of Scientific Exploration, 14*, 91-106.

Scholl, B. J., & Leslie, A. M. (1999). Modularity, development and "theory of mind". *Mind and Language 14*, 131-153.

Sekerina, I., Stromswold, K., & Hestvik, A. (2004). How do adults and children process referentially ambiguous pronouns? *Journal of Child Language, 3*, 123-152.

Shallice, T. (1988). *From neuropsychology to mental structure*. New York: Cambridge University Press.

Siegal, M., & Beattie, K. (1991). Where to look first for children's knowledge of false beliefs. *Cognition, 38*, 1-12.

Siegal, M., Butterworth, G., & Newcombe, P. A. (2004). Culture and children's cosmology. *Developmental Science, 7*, 308-324.

Siegal, M., Iozzi, L., & Surian, L. (2009). Bilingualism and conversational understanding in young children. *Cognition, 110*, 115-122.

Siegal, M., & Surian, L. (2004). Conceptual development and conversational understanding. *Trends in Cognitive Sciences, 8*, 534-538.

Siegal, M., & Surian, L. (2007). Conversational understanding in young children. In E. Hoff & M. Shatz (Eds.), *Blackwell handbook of language development* (pp. 304-323). Oxford: Blackwell.

Simon, J. R., & Small, A. M. (1969). Processing auditory information: Interference from an irrelevant cue. *Journal of Applied Psychology, 53*, 433-435.

Singer, B., & Bashir, A. (1999). What are executive functions and self-regulation and what do they have to do with language learning disorders? *Language, Speech, and Hearing Services in Schools, 30*, 265-273.

Smedslund, J. (1964). Concrete reasoning: A study of intellectual development. *Monographs of the Society for Research in Child Development, 29*, No. 2, Serial No. 93.

Sodian, B., & Frith, U. (1992). Deception and sabotage in autistic, retarded and normal children. *Journal of Child Psychology and Psychiatry 33*, 591-605.

Sperber, D., & Wilson, D. (1986). *Relevance: Communication and Cognition.* Cambridge, MA: Blackwell, Oxford and Harvard University Press (Second edition 1995).

Sperber,D., & Wilson, D. (2002). Pragmatics, modularity and mind-reading. *Mind and Language 17*, 3-23.

Stroop. J. R. (1935). Studies of interference in serial verbal reactions. *Journal of*

Experimental Psychology, 18, 643-662.

Sullivan, K., Zaitchik, D., & Tager-Flusberg, H. (1994). Preschoolers can attribute second order false beliefs. *Developmental Psychology, 30,* 395-402.

Surian, L. (1995). Children's ambiguous utterances: A re-examination of processing limitations on production. *Journal of Child Language, 22,* 151-169.

Surian, L., Baron-Cohen, S., & van der Lely, H. K. J. (1996). Are children with autism deaf to Gricean maxims? *Cognitive Neuropsychiatry, 1,* 55-71.

Surian, L., & Leslie, A. M. (1999). Competence and performance in false belief understanding: A comparison of autistic and three-year-old children. *British Journal of Developmental Psychology, 17*, 141–155.

Swanson, H. L. (1996). Individual and age-related differences in children's working memory. *Memory and Cognition, 24*, 70-82.

Tedoldi, M., Surian, L., & Siegal, M. (2005). Deafness and the development of pragmatic competence. Poster presented at the XIIIth Trieste Symposium on Perception and Cognition.

Topál, J., Gergely, G., Miklósi, A., Erdöhegyi, A., & Csibra, G. (2008). Infants' perseverative search errors are induced by pragmatic misinterpretation. *Science 321,* 1831-1834.

Tranel, D., Anderson, S. W., & Benton, A., (1994). Development of the concept of "executive function" and its relationship to the frontal lobes. In F. Boller & J. Grafman (Eds.), *Handbook of neuropsychology, Volume 9* (pp. 125-148). Amsterdam: Elsevier Science.

Trueswell, J. C. (1996). The role of lexical frequency in syntactic ambiguity resolution. *Journal of Memory and Language, 35,* 566-585.

Trueswell, J. C., Sekerina, I., Hill, N. M., & Logrip, M. L. (1999). The kindergarten-path effect: Studying on-line sentence processing in young children. *Cognition, 73,* 89-134.

Van Gompel, R. P. G., & Pickering, M. J. (2001). Lexical guidance in sentence processing: A note on Adams, Clifton and Mitchell (1998). *Psychonomic Bulletin and Review, 8*, 851-857.

Vygotsky, L. (1962). *Thought and language.* Cambridge, MA: The MIT Press.

Wechsler, D. (1974). *Wechsler Intelligence Scale for Children-Revised.* New York: Psychological Corporation.

Wellman, H. M., Cross, D., & Watson, J. (2001). Meta-analysis of theory of mind development: the truth about false belief. *Child Development, 72*, 655-684.

Wellman, H., & Liu, D. (2004). Scaling of Theory-of-Mind tasks. *Child Development 75,* 523-541.

Welsh M. C., Pennington B. F., Grossier D. B. (1991). A normative-developmental study of executive function: A window on prefrontal function in children. *Developmental Neuropsychology, 7*, 131–149.

Wiebe, S., Espy, K. A., & Charak, D. (2008). Using confirmatory factor analysis to understand executive control in preschool children: I. Latent structure. *Developmental Psychology, 44*, 575-587.

Winner, E., Brownell, H., Happé, F., Blum, A., & Pincus, D. (1998). Distinguishing lies from jokes: Theory of mind deficits and discourse interpretation in right hemisphere brain-damaged patients. *Brain and Language, 62*, 89-106.

Woolfe, T., Want, S. C., & Siegal, M. (2002). Signposts to development: Theory of mind in deaf children. *Child Development, 73,* 768-778.

Wright, I., Waterman, M., Prescott, H., & Murdoch-Eaton, D. (2003). A new Stroop-like measure of inhibitory function development: Typical developmental trends. *Journal of Child Psychology and Psychiatry, 44,* 561-575.

Yadzi, A. A., German, T. P., Defeyer, M., & Siegal, M. (2006). Competence and performance in belief-desire reasoning across two cultures: The truth, the whole truth, and nothing but the truth about false belief? *Cognition, 100,* 343-368.

Yelland, G. W., Pollard, J., & Mercuri, A. (1993). The metalinguistic benefits of limited contact with a second language. *Applied Psycholinguitsics, 14,* 423-444.

Zelazo, P. D. (1999). Language, levels of consciousness, and the development of intentional action. In P. D. Zelazo, J. W. Astington & D. R. Olson (Eds.), *Developing theories of intention: Social understanding and self control* (pp. 95–118). Mahwah, NJ: Lawrence Erlbaum Associates.

Zelazo, P. D. (2006). The dimensional change card sort (DCCS): A method of assessing executive function in children. *Nature Protocols, 1,* 297-301.

Zelazo, P. D., Carlson, S. M., & Kesek, A. (in press). The development of executive function in childhood. In C. Nelson & M. Luciana (Eds.), *Handbook of developmental cognitive neuroscience.* Cambridge, MA: MIT Press.

Zelazo, P. D., Carter, A., Reznik, J. S., & Frye, D. (1997). Early development of executive function: A problem solving framework. *Review of General Psychology, 1,* 198-226.

Zelazo, P. D., Frye, D., & Rapus, T. (1996). An age-related dissociation between knowing rules and using them. *Cognitive Development, 11*, 37-63.

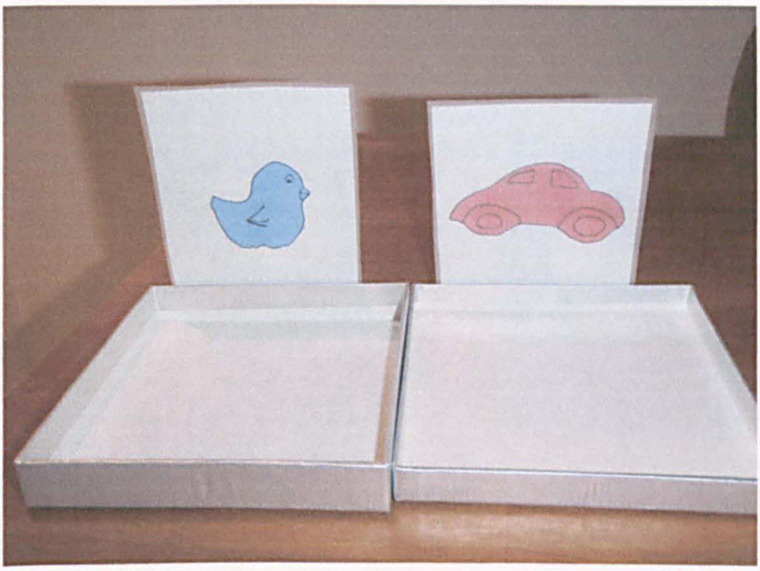
Zelazo, P. D., Jacques, S., Burack, J., & Frye, D. (2002). The relation between theory of mind and rule use: Evidence from persons with autism-spectrum disorders. *Infant and Child Development (Special Issue: Executive function and its development), 11*, 171-195.

Zelazo, P. D., & Müller, U. (2002). Executive function in typical and atypical development. In U. Goswami (Ed.), *Handbook of childhood cognitive development* (pp. 445-469). Oxford: Blackwell.

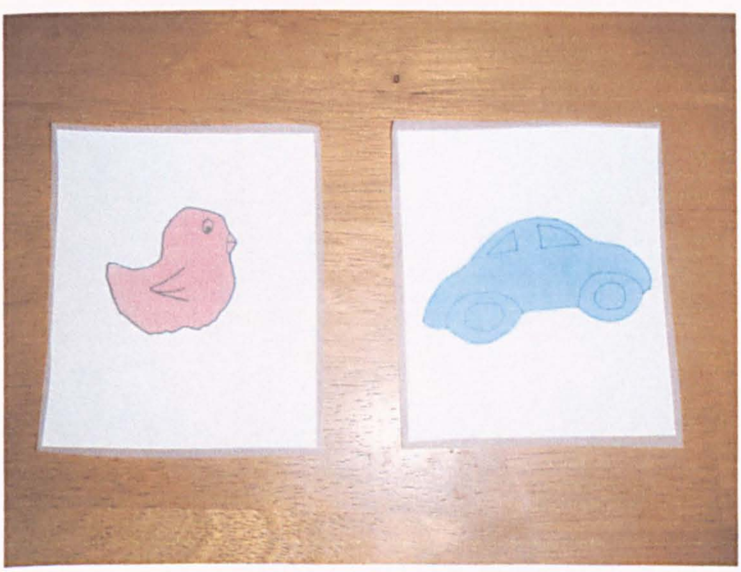
Table of Appendices

page

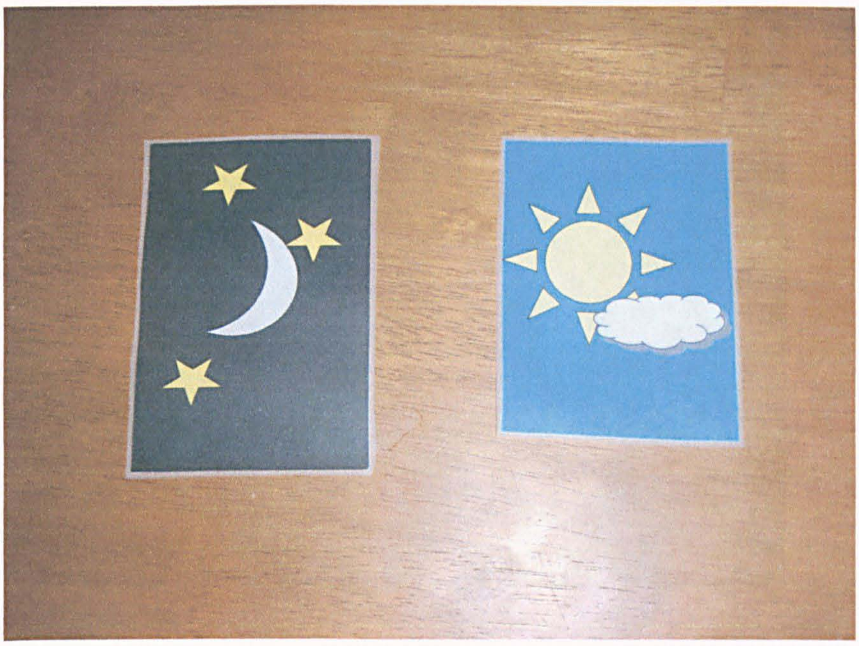
Appendix Ia: DCCS target cards.



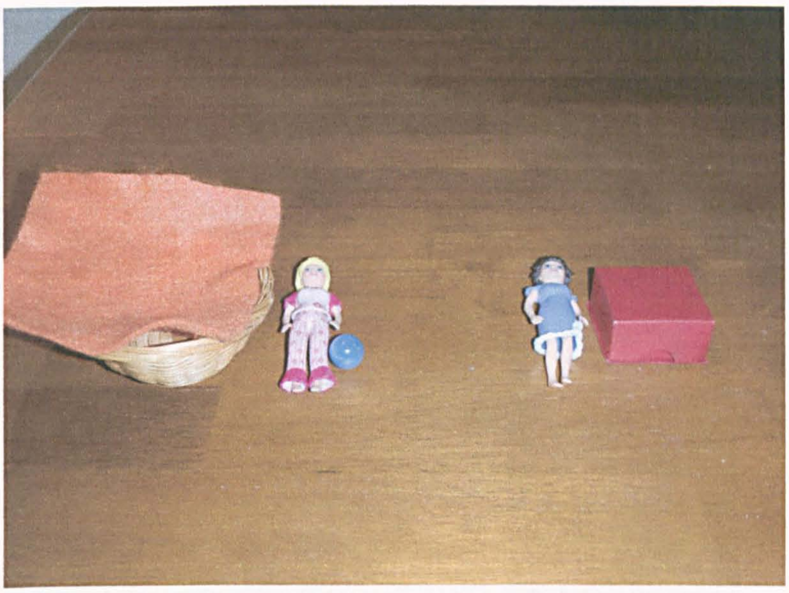
Appendix Ib: DCCS test cards.



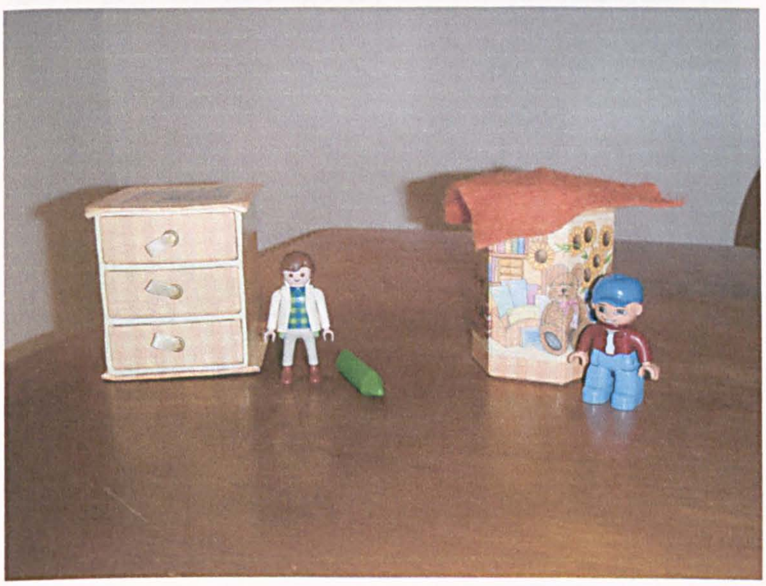
Appendix II: Day-Night task cards.



Appendix IIIa: Sally-Ann first-order false belief task materials.



Appendix IIIb: Max-ToM first-order false belief task materials.



Appendix IVa: SI task Set 1 Control trials - The puppet says Teddy put <u>all</u> of the hoops on the pole.

Appendix IVb: SI task Set 2 Control trials - The puppet says Teddy put <u>all</u> of the hoops on the pole.

Appendix IVc: SI task Set 3 Control trials - The puppet says Teddy put <u>some</u> of the hoops on the pole.

Appendix IVd: SI task Set 4/SI trials - The puppet says Teddy put <u>some</u> of the hoops on the pole.

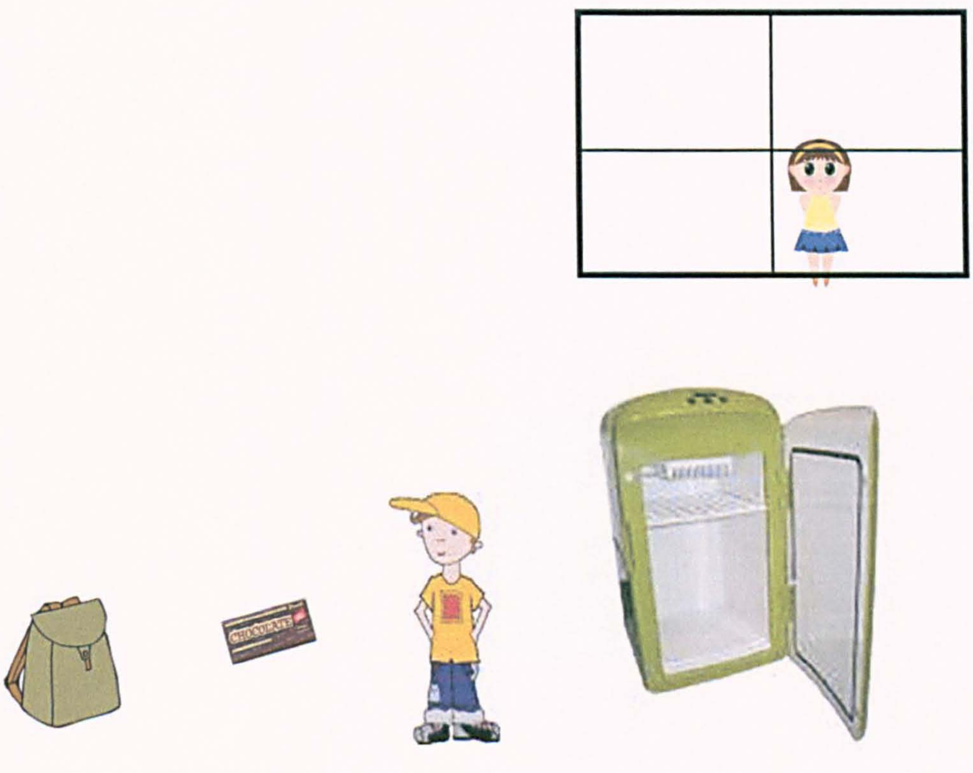
Appendix Va: Perner second-order theory of mind task materials.

Appendix Vb: Sullivan et. al second-order theory of mind task materials.

Picture 1

Picture 2

Picture 3



Picture 4

Picture 5

Appendix VI: Frog Simon task slide series illustrating frog location on trials.

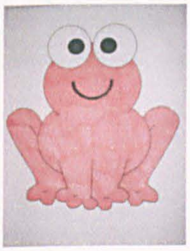
Slide 1……………………………………………..

Slide 2 ……………………………………………

Slide 3……………………………………………..

Slide 4………………………………………………

Slide 5……………………………………………



Slide 6……………………………………………

Slide 7……………………………………………

Slide 8……………………………………………

Slide 9……………………………………………

Slide 10……………………………………..

Slide 11…………………………………………..

Slide 12……………………………………………

Slide 13……………………………………………

Slide 14……………………………………………

Slide 15...

Slide 16...

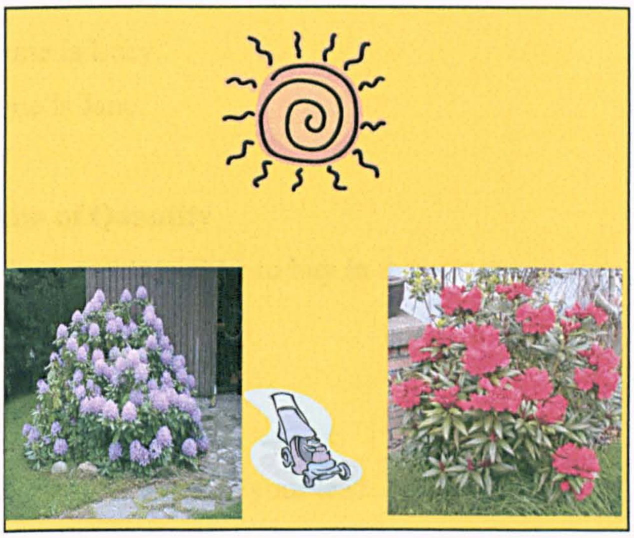
Slide 17...

Slide 18...

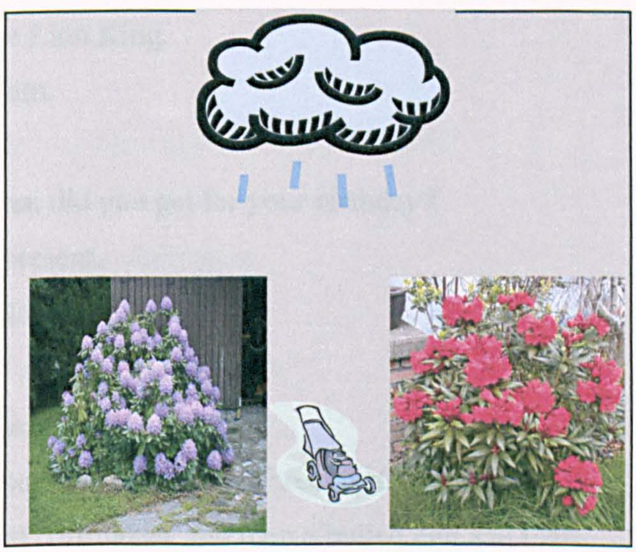
Slide 19……………………………………………

Slide 20………………………………………………

AppendixVIIa: Dibbets task updating sun slide



AppendixVIIb: Dibbets task updating ran slide



Appendix VIII: CVT Script.

MARK: Hello children, my name is Mark. I'm going to put some questions to two friends of mine. First, let's meet them:
LUCY: My name is Lucy.
JANE: My name is Jane.

A- First Maxim of Quantity

1 MARK : What would you like to buy in this pet-shop?
LUCY : An animal.
JANE : A cat.

2 MARK : How would you like your tea?
LUCY: With milk.
JANE : In a cup.

3 MARK: What do you usually have for lunch?
LUCY: Some food.
JANE: A sandwich.

4 MARK: What did you see last night at the cinema?
LUCY: The Lion King.
JANE: A film.

5 MARK: What did you get for your birthday?
LUCY: A present.
JANE: A bicycle.

B- Second Maxim of Quantity

6 MARK: What did you have for breakfast?
LUCY: I had cornflakes, and then a boiled egg and toast.
JANE: A hard boiled egg cooked in hot water in a sauce pan.

Appendix VIII: CVT Script.

7 MARK: Who is your best friend?
LUCY: Peter is my best friend. He wears trousers.
JANE: Sam is my best friend. We go to school together.

8 MARK: Which baby animals do you like?
LUCY: I like puppies.
JANE: I like puppies which are animals with four legs and a tail.

9 MARK: Where did you go this morning?
LUCY: I went to the art room and I had fun.
JANE: I went to school and I didn't stay at home.

10 MARK: What is your favourite colour?
LUCY: Yellow: it's a colour of a colour.
JANE: Blue: it's the colour of the sea.

C– Maxim of Quality

11 MARK: Where do you live?
LUCY: I live on the moon.
JANE: I live in a town.

12 MARK: Do you have any brothers or sisters?
LUCY: Yes, I have 500.
JANE: Yes, I have 2 brothers.

13 MARK: Have you seen my dog?
LUCY: Yes, he is in the garden.
JANE: Yes, he is in the clouds.

14 MARK: Why don't you play with me?
LUCY: Because I have to go home for tea.
JANE: Because I am playing with a Martian.

Appendix VIII: CVT Script.

15 MARK: Is there any more chocolate?
LUCY: Yes, It's all in my tummy.
JANE: Yes, I saved you a piece of mine.

D - Maxim of Relation

16 MARK: What did you do on holiday?
LUCY: I rode my bicycle all day.
JANE: My trousers were blue.

17 MARK: What did you do at school?
LUCY: We had a bath.
JANE: We drew some pictures.

18 MARK: What food do you like?
LUCY: I like the sea.
JANE: I like ice-cream.

19 MARK: What do you like watching on TV?
LUCY: I like cartoons.
JANE: I like sandwiches.

20 MARK: What game do you know to play?
LUCY: I know how to play football.
JANE: I know your name.

E- Maxim of Politeness

21 MARK: Do you like my t-shirt?
LUCY: It's nice.
JANE: It' s awful.

Appendix VIII: CVT Script.

22 MARK: Would you like a piece of my cake?
LUCY: Yes please.
JANE: No, it makes me sick.

23 MARK: May I draw with your pencil?
LUCY: No, you can't even draw.
JANE: No, I left it at home.

24 MARK: Would you like to play with me?
LUCY: No, you are too stupid.
JANE: No, I'm too tired.

25 MARK: Will you help me clean up my room?
LUCY: No, do it yourself.
JANE: Yes, just hold on a second.

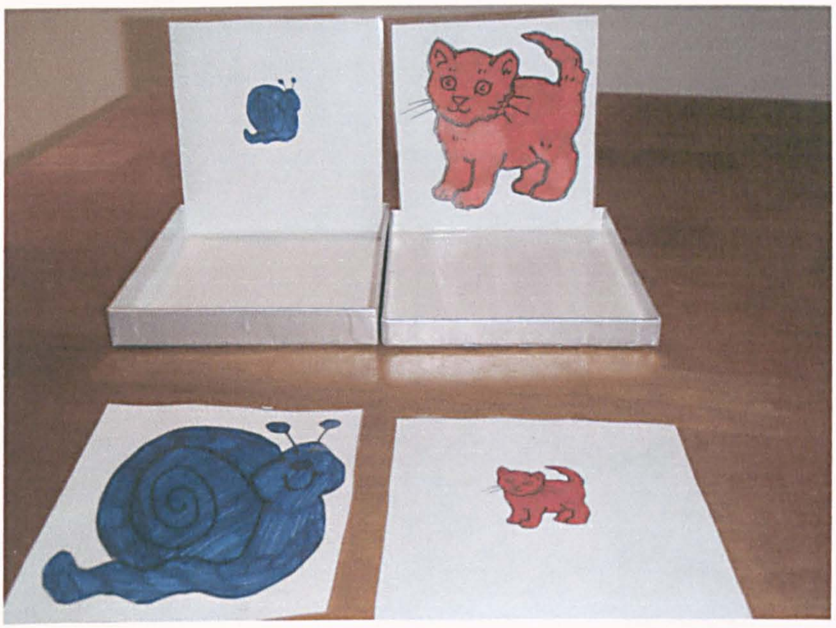
Appendix IX: CVT Question Sequence

Item Number	Question	Maxim Violation
1	What would you like to buy in this pet-shop?	First Maxim of Quantity
13	Have you seen my dog?	Maxim of Quality
24	Would you like to play with me?	Maxim of Politeness
8	Which baby animals do you like?	Second Maxim of Quant
5	What did you get for your birthday?	First Maxim of Quantity
23	May I draw with your pencil?	Maxim of Politeness
12	Do you have any brothers or sisters?	Maxim of Quality
21	Do you like my t-shirt?	Maxim of Politeness
18	What food do you like?	Maxim of Relation
25	Will you help me clean up my room?	Maxim of Politeness
14	Why don't you play with me?	Maxim of Quality
2	How would you like your tea?	First Maxim of Quantity
19	What do you like watching on TV?	Maxim of Relation
7	Who is your best friend?	Second Maxim of Quantity
10	What is your favourite colour?	Second Maxim of Quantity
22	Would you like a piece of my cake?	Maxim of Politeness
16	What did you do on holiday?	Maxim of Relation
15	Is there any more chocolate?	Maxim of Quality
9	Where did you go this morning?	Second Maxim of Quantity
17	What did you do at school?	Maxim of Relation
6	What did you have for breakfast?	Second Maxim of Quantity
3	What do you usually have for lunch?	First Maxim of Quantity

Appendix IX: CVT Question Sequence

Item Number	Question	Maxim Violation
11	Where do you live?	Maxim of Quality
20	What game do you know to play?	Maxim of Relation
4	What did you see last night at the cinema?	First Maxim of Quantity

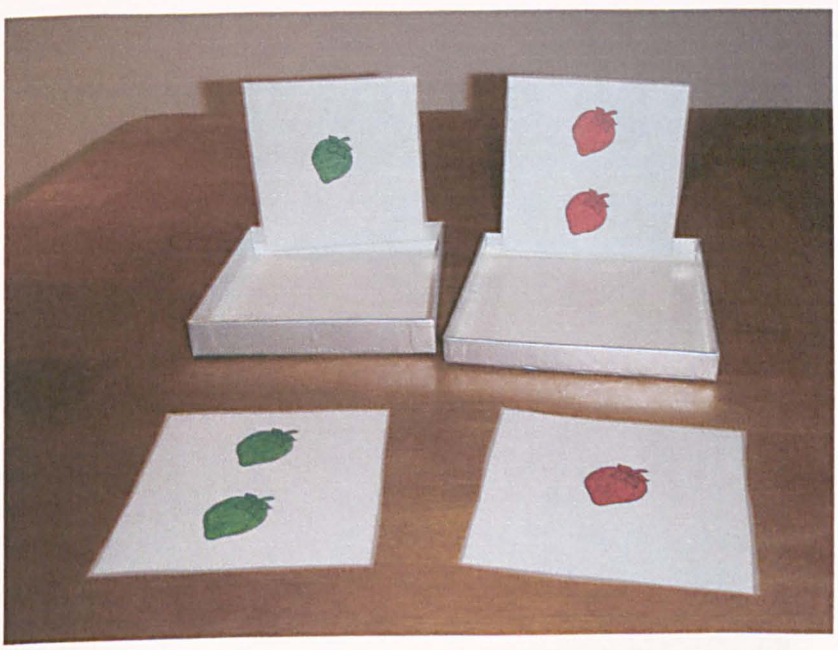
Appendix Xa: Set 1 Pre/post training DCCS 2 box cards.



Appendix Xb:Set 2 Pre/post training DCCS 2 box cards.

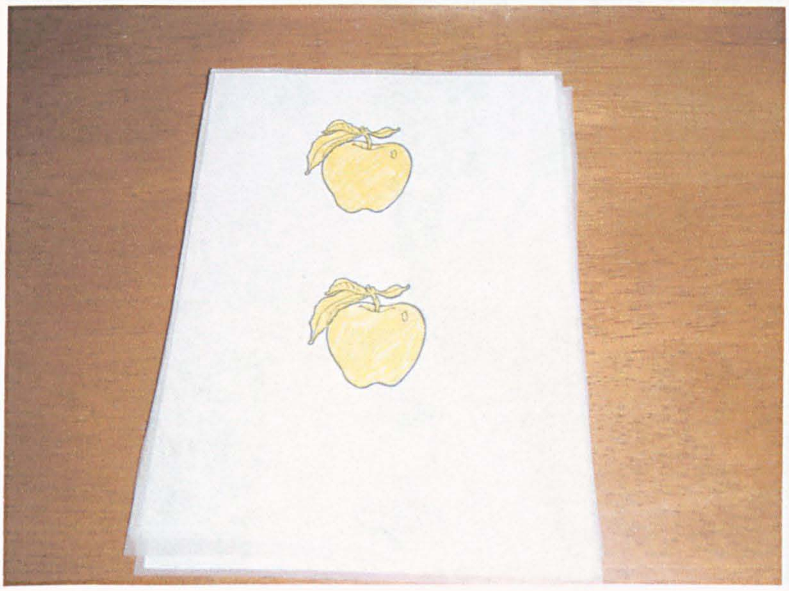
Appendix Xc: Set 1 training I DCCS 2 box cards.

Appendix Xd: Set 2 training I DCCS 2 box cards.



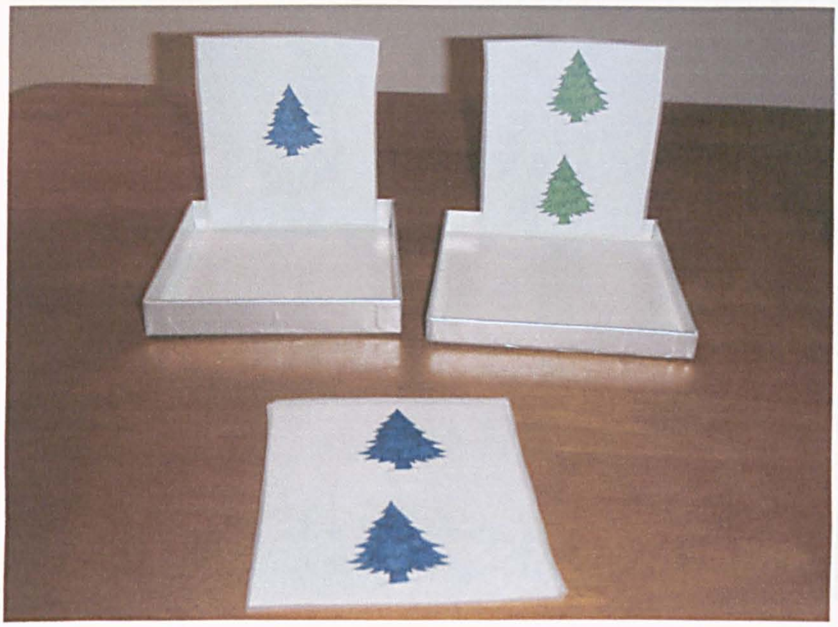
Appendix Xe: Training II DCCS 2 box cards.

Set 1.

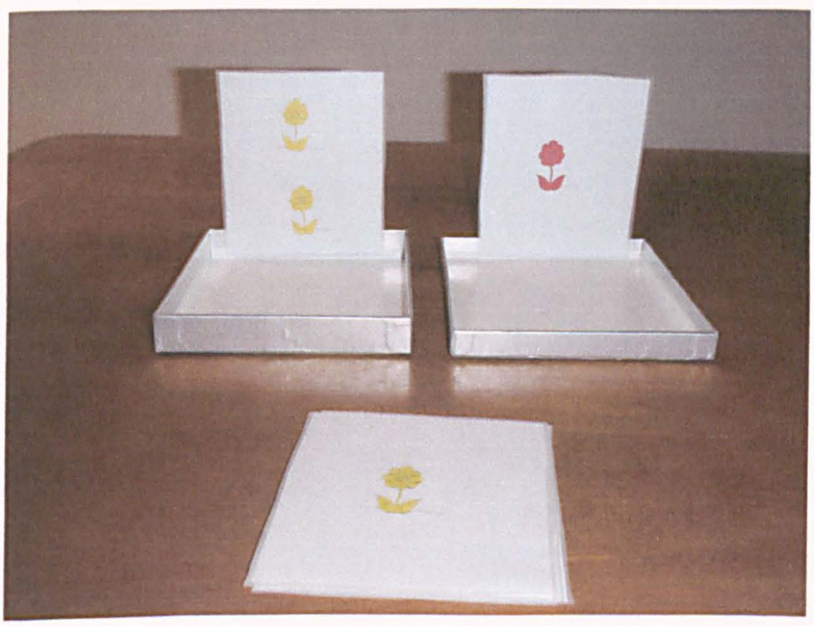


Set 2.

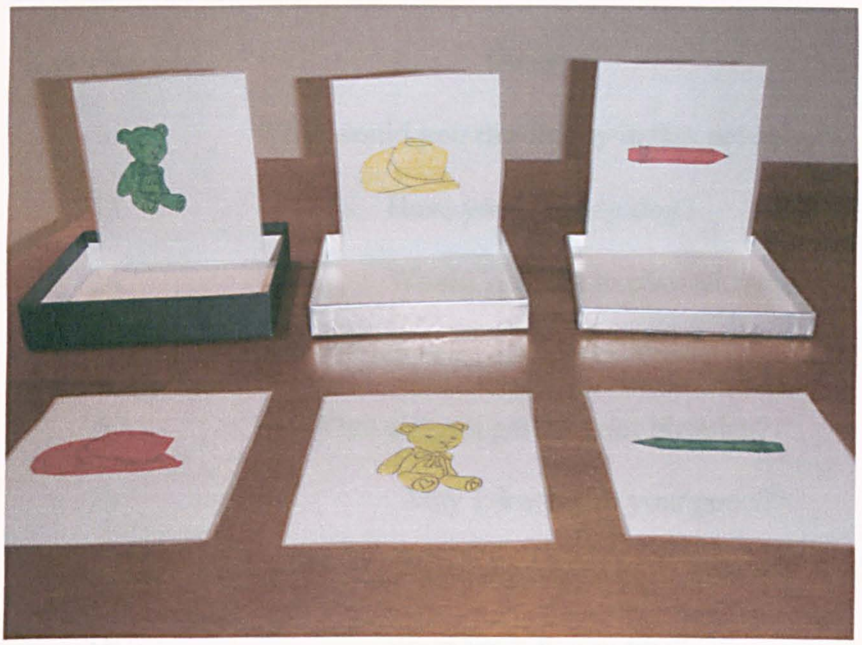
AppendixXf: Set 1 Training III DCCS 2 box cards.



AppendixXg: Set 2 Training III DCCS 2 box cards.



AppendixXh: 3 box post-training DCCS cards.



Appendix XI: Pre/post-training CVT used for PreCVT, PostCVTOld and PostCVTNew

CVT question sequence - Series A

Item Number	Question	Maxim Violation
1	What would you like to buy in this pet-shop?	First Maxim of Quantity
13	Have you seen my dog?	Maxim of Quality
24	Would you like to play with me?	Maxim of Politeness
8	Which baby animals do you like?	Second Maxim of Quantity
5	What did you get for your birthday?	First Maxim of Quantity
23	May I draw with your pencil?	Maxim of Politeness
12	Do you have any brothers or sisters?	Maxim of Quality
18	What food do you like?	Maxim of Relation
14	Why don't you play with me?	Maxim of Quality
2	How would you like your tea?	First Maxim of Quantity
19	What do you like watching on TV?	Maxim of Relation
7	Who is your best friend?	Second Maxim of Quantity

Appendix XI: Pre/post-training CVT used for PreCVT, PostCVTOld and PostCVTNew

CVT question sequence - Series B

Item Number	Question	Maxim Violation
25	Will you help me clean up my room?	Maxim of Politeness
10	What is your favourite colour?	Second Maxim of Quantity
22	Would you like a piece of my cake?	Maxim of Politeness
16	What did you do on holiday?	Maxim of Relation
15	Is there any more chocolate?	Maxim of Quality
9	Where did you go this morning?	Second Maxim of Quantity
17	What did you do at school?	Maxim of Relation
6	What did you have for breakfast?	Second Maxim of Quantity
3	What do you usually have for lunch?	First Maxim of Quantity
11	Where do you live?	Maxim of Quality
20	What game do you know to play?	Maxim of Relation
4	What did you see last night at the cinema?	First Maxim of Quantity

Appendix XII: CVT script amendments for Italian children

Section A- First Maxim of Quantity

The question in Item 2 was changed from "How would you like your tea?" to "How would you like your milk?" The responses were the same as before: "With milk" versus "In a cup".

One of the responses in Item 3 was altered. Although the question and one of the answers remained identical to the English version: "What do you usually have for lunch?" "Some food", the remaining response was changed from "A sandwich" to "Pasta".

Section B- Second Maxim of Quantity

Both responses in Item 6 were modified. Following the question "What did you have for breakfast?" The following two responses were given: "Milk with biscuits" and "Milk, heated in a small pot, with round sweet biscuits".

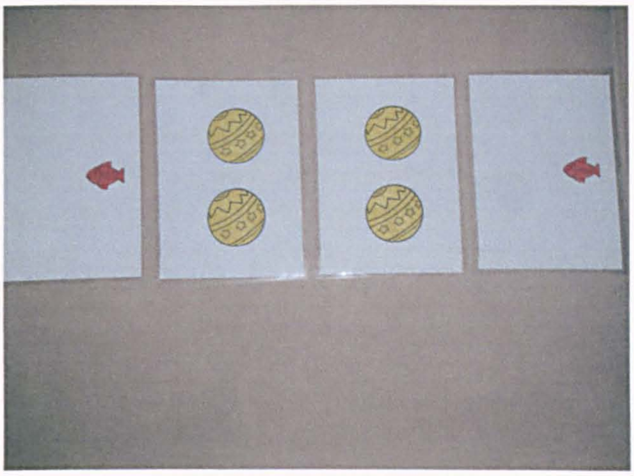
Appendix XIII: Red dog-blue dog task stimuli

Name = 'Blue'

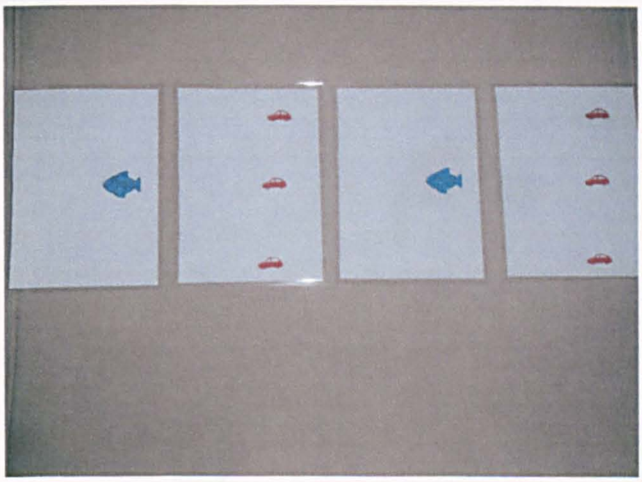
Name = 'Red'

Appendix XIV: FIST demonstration, criterion and test trial cards

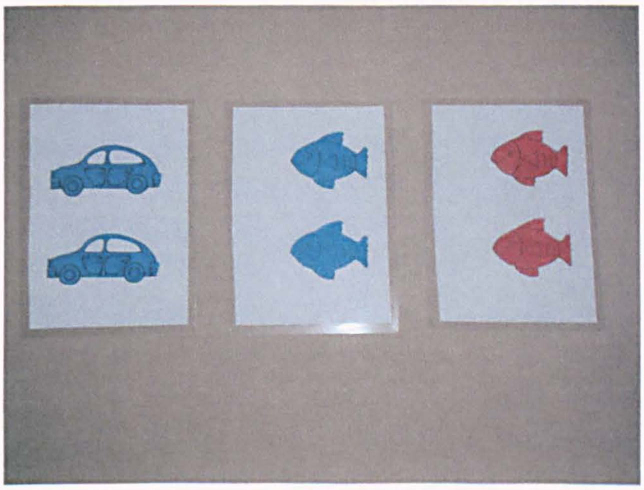
Demonstration trial:
ACDB



Second criterion trial:
ACBD



Test trial



Appendix XV: FAT updating task

a) Slide A

Appendix XV: FAT updating task

b) Slide B

c) Slide C