Cognitive Flexibility in Preschool Children

Does bilingualism have an impact on executive functions?

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April 2008

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Abstract

Recent research has demonstrated an advantage for bilingual preschoolers on a number of tasks related to the control of behavior and attention (executive functions). However the exact nature of an eventual advantage is not known. The present study compared the performance of preschool children who were regularly exposed to two or more languages, with children who were only exposed to one language, on tasks that place demands on vocabulary, reasoning, response inhibition, flexible rule use, and visual working memory span.

The objective of the investigation was to explore the question of how experience with more than one language may be related to the development of cognitive flexibility, or the ability to generate and shift ideas and responses. Our hypothesis was that the bilingual children would have an advantage related to cognitive flexibility as measured on the DCCS-AG, a task related to flexible rule use in the presence of distraction. We were interested in differences between the groups related to response inhibition and working memory, for the purpose of identifying the component of the problem responsible for an eventual bilingual advantage. We were additionally interested in the interrelatedness of the tasks, for support this might provide for alternative accounts of the development of executive functions.

Our hypothesis was not supported: the bilingual children did not have an advantage with regard to cognitive flexibility. Among the youngest children, the bilinguals had a significant advantage in visual working memory span, but this advantage disappeared as the children got older, and did not reach significance in the overall sample. Among children older than 4 ½ years, monolingual children had a significant advantage in tasks related to flexible rule use and vocabulary. Tasks related to response inhibition and vocabulary correlated with the flexibility task. When we had controlled for the effects of age, only vocabulary correlated with the flexibility task. The interrelatedness of the tests is discussed in terms of various accounts of the structure of executive functions in development. The role of language in the development of cognitive flexibility is considered.

Ackowledgements

I wish to thank my advisor, Dr. Tor Endestad for his encouragement now and in my first semester, and for his focused guidance. I also wish to thank Professor Stephen von Tetzchner and Dr. Barbara Olsnes for advice and help in procuring tests. I wish to thank the staff at Deutsche Kindergarten, Davinas Barnehage, Bamsebo Barnehage, Barnebo Barnehage, Frydenhaug Barnehage, Almelia Barnehage, Blindern Barnestuer, and Eilert Sundt Barnehage for helping me recruit participants and finding time and room for me to test the children. I wish to thank all the parents for their generosity, both in terms of taking the time to fill out the questionnaire and letting me test their children. Finally, I wish to thank all the children who participated for their curiosity and willingness to try the tasks.

Introduction

Early childhood is a time of considerable development in the areas of language, intention, self-control, and social understanding (Zelazo, Astington, & Olson, 1999); "substantial maturation in prefrontal structures and functional systems allows rapid acquisition of executive competencies" (Espy, & Bull, 2005 p 670). Are these achievements related to language? What if the child is learning to speak in two languages? Is there an impact of bilingualism on the development of executive functions? Exploring such a relationship requires foraging into two areas of research, that of bilingualism and that of executive functions, and that we look at both from a developmental perspective. What follows is a brief introduction to these two areas and some issues relevant to a discussion of an eventual connection between executive functions and bilingualism.

Bilingualism

In 2006, 6.9% of pupils in Norwegian pre- and elementary schools were either born in another country or had at least one parent who was born outside of Norway. In 2001, 148 different mother tongues were represented among language minorities in Norwegian schools (Moafi, 2007). As Abutalebi and Green point out, "A substantial proportion of the human population speaks more than one language" (2007, p. 242). This means that there are many parents who have to make active linguistic decisions for their child, and for whom questions regarding the effects of exposing a child to two languages have personal relevance. Parents are typically concerned that the experience of learning two languages will lead to cognitive or linguistic confusion; or make it more difficult to learn the dominant language; these fears may reflect folk wisdom about the fragility of language learning (Bialystok, 2001). It is important that the people who advise parents about such matters have access to research about child bilingual development and its eventual effects. Such knowledge is also important for professionals involved in the teaching and care of small children as well as people who make decisions about policy. Unfortunately such studies are few, compared with those conducted on monolingual children (Goldstein, 2006).

Research about bilingual development is critical for professionals involved in assessing language and cognitive development. For example, being raised bilingually does not cause or worsen language disorders, nor does it inoculate children against having a language disorder. But it does complicate the process of assessing their language skills(Goldstein, 2006). It is important that a delay in speaking is not misattributed to a child being raised bilingually, since this could delay the commencement of interventions.

The idea that bilingualism may have an effect on development has long engaged researchers, educators and politicians (Baker, 2002). For example the educationalist, Laurie (1890 p 15 in Hoffman, 1991) wrote, “If it were possible for a child to live with two languages at once equally well, so much the worse. His intellectual and spiritual growth would not thereby be doubled but halved. Unity of mind and character would have great difficulty in asserting itself under such circumstances”. During the early 20th century, linguists, doctors and sociologists warned that bilingualism would lead to stuttering, left-handedness, moral or intellectual inferiority or social marginalization. Hoffman (1991) points out that people’s attitudes towards bilingualism may reflect attitudes towards the minorities in their midst, and towards immigration, and that these attitudes may be influenced by nationalism. Saer (1927 in Baker, 2002) called bilingualism a mental handicap that would lead to mental confusion, while Arsenian (1937 in Baker, 2002) expressed a more optimistic view: “two different words in two different language systems for the same referent may carry different connotations and put the bilingual person in contact with two worlds of experience”. Peal and Lambert (1962) found an advantage for bilinguals on intelligence tests, which these researchers described as mental reorganization.

Definitions of bilingualism

The word bilingualism is composed of the Latin bi, meaning two, and lingua, meaning tongue, or language. Two languages. But what is a language? As Li Wei (2007) points out, language is not only a systematic set of units to create meaning; languages are socially defined. There are variations within and between languages; at what point are there two languages? Relevant for a study related to bilingualism is the distinction between language and dialect, which is usually based on size, prestige and mutual intelligibility. But there are dialects that are not mutually intelligible, such as the so-called dialects of Chinese, and languages whose speakers can understand each other quite well, such as Norwegian, Swedish and Danish (Li Wei, 2007).

Bloomfield (1933) defines bilingualism as “native-like control of two languages”, Mackey’s (1970 p 555) focus is on “the alternative use of two or more languages by the same individual”. Hamars and Blanc (1989) classify childhood bilinguality as a situation where the learning of two languages takes place at the same time as the general development of the child. Simultaneous bilinguality, in which the child has two mother tongues from the outset of language, is more likely to occur when the child's parents have different mother tongues. Consecutive childhood bilinguality, where the child acquires a second language after the basic acquisition of the mother tongue has been achieved, often happens through immigration or when the family belongs to a minority community (Hamars, & Blanc, 1989).

Bilingual language development

Social and linguistic issues such as the majority/minority status of the languages as well as the types of language input may influence proficiency in the respective languages (Romaine, 1995). In addition, the value the community places on the language may impact cognitive outcomes (Hamars, & Blanc, 1989). For example, bilingual children in an environment in which one language is not supported (referred to as a subtractive environment) may experience a decline in language skills (Goldstein, 2006). According to thresholds theory (Cummins, 1978), the level of proficiency in each of the languages may affect cognitive outcomes; with benefits occurring where there are high levels in both languages (referred to as *balanced bilinguals*). When there is native-like level in one of the languages (*dominant bilinguals*), there are neither positive nor negative effects of bilingualism. When there are low levels in both of the languages there may be negative cognitive effects. The term *semilingualism* has been used to describe this state of affairs. Hoffman (1991) points out that the use of this term may lead to negative expectations regarding bilingual competence.

Existing studies indicate that the speech and language development of bilingual children is similar, though not identical, to that of their monolingual peers (Goldstein, 2006). A survey of language development in children 18-35 months old found that children exposed to more than one language had similar phrase length as monolinguals, but smaller expressive vocabulary size (Rescorla, & Aschenbach, 2002). However, this study used a measure (total conceptual vocabulary, in which translational equivalents are counted only once) that may underestimate the size of a bilingual child's vocabulary. Bilingual children may have different capabilities in their different languages, which makes it difficult to assess their language skills. When comparable measures and comparable groups are used, bilingual and monolingual toddlers have similar expressive vocabulary sizes (Patterson, 2004). Existing research also indicates that language disorders are not more common in bilinguals than monolinguals and that if bilingual children do exhibit language disorders, those disorders will not be more severe than they are for monolinguals (Goldstein, 2006).

Neuropsychological aspects of bilingualism

Bilingualism may have a lasting effect on the brain. For example, bilingualism may delay the onset of symptoms of dementia (Bialystok, Craik, Freedman, 2007); or help to offset age-related losses in certain executive processes (Bialystok, E, Craik, Klein, & Viswanathan, 2004). Studies using a variety of techniques have established that both languages are simultaneously activated when a bilingual is engaged in a language task (see reviews by Abutalebi, & Green, 2007; Bialystok, 2001). Brain imaging techniques, such as ERP, fMRI and PET, have been used to answer questions about how the bilingual brain deals with cross-language interference as well as which areas are recruited when the bilingual person switches languages. There is agreement that the resolution of the cross-language competition involves inhibition (see review in Abutelabi, & Green, 2007) but it is not clear to which degree this involves lateral inhibition or top-down control operations. Abutalebi and Green (2007) argue that maintaining two languages systems may require several forms of cognitive control. Studies seeking to identify the cortical areas active during tasks in each of the languages have found differences in involvement depending on such factors as age of acquisition, proficiency level and type of task (Wartenburger, Heekeren, Abutalebi, Cappa, Villringer, & Perani, 2003).

Siegal, Pond, and Matsuo (2007) found an advantage for Japanese-English bilingual preschoolers related to conversational understanding. Yang and Lust (2005) found an advantage for bilingual children on a computerized Attentional Network Test (Posner, & Fan, 2004), which was developed to measure the efficiency of the attentional networks. Bialystok (2001) describes advantages for bilingual children in tasks containing misleading information with moderate conceptual demands. These include metalinguistic tasks (e.g. Ben-Zeev, 1977; Cummins, 1978); appearance-reality tasks (Bialystok, & Senman, 2004); concept of print tasks (Bialystok, 1999); and tasks related to number cardinality (Bialystok and Codd, 1997). An advantage was also demonstrated on a task requiring cognitive flexibility and rule use (Bialystok, 1999; Bialystok and Martin, 2004), which is usually considered under the rubric of executive function.

Executive functions

Cognitive flexibility is the ability to generate and shift ideas and responses (Lezak, Howieson, & Loring, 2004) and is central to executive functions. Executive functioning refers to higher order cognitive processes that aid in the monitoring and control of thought and action. These skills include response inhibition, interference suppression, planning, flexibility, and error correction and detection (e.g. Carlson, 2005). Maintaining goals in the face of conflict, switching between tasks and selecting amongst different responses emerge from the integration of the prefrontal cortex (prominently), the anterior cingulate cortex, the basal ganglia, and the inferior parietal lobule. These control operations are believed to be involved in bilingual language processing (Abutalebi, & Green, 2007).

The Wisconsin Card Sorting Task (WCST) is widely used to assess executive function in adults. In the WCST, participants sort a series of test cards that match different target cards on different dimensions. Participants must discover the sorting rule by trial and error, and after 10 correct responses the rule is changed (e.g. Gazzaniga, Ivry, & Mangun, 2002; Zelazo, Müller, Frye, & Markovitch, 2003). Many patient groups have difficulty with these shifts, including patients with Multiple Sclerosis, Parkinson’s Disease and patients with damage to the dorsolateral prefrontal cortex (Lezak, Howieson, & Loring, 2004). These patients exhibit perseveration, which is “the tendency to produce a particular response on successive trials, even when the context has changed and the response is no longer appropriate” (Gazzaniga, Ivry, & Mangun, 2002, p. G-7).

The development of executive functions in early childhood

Infants and preschool children also exhibit inflexibility, in different contexts at different ages. In the A-not-B error, (Piaget, 1954), infants (8-10 months) persist in searching for an object at its first location (A) despite having last seen the object conspicuously hidden at another location (B). Piaget attributed this error to an immature understanding of the object concept, but a contemporary interpretation is that infants have difficulty using a representation of an object’s location to override a prepotent response (e.g. Diamond, Kirkham, & Amso, 2002)). Children 3- to 4- years old have difficulty switching between incompatible perspectives on a single object- they perseverate in representing objects and situations in a particular way even when it is inappropriate to do so. Representational inflexibility has been shown in research on understanding false beliefs, appearance and reality tasks (see review in Zelazo et al., 2003), and in generating multiple labels for a single object (e.g. Doherty, & Perner, 1998). Children of this age also perseverate when asked to sort a set of cards according to changing rules (Zelazo, 2006).

There are a number of approaches to understanding the development of executive function and flexibility. The accounts assign differential importance to the involvement of working memory, response inhibition, attention (capacity and control), and/or language. For example, some accounts emphasize the simultaneous manipulation and maintenance of representations in working memory (Morten, & Munakata, 2002); others, the ability to inhibit a prepotent response (Diamond, A., Kirkham, N., & Amso, D. (2002). Wiebe, Espy, and Charak (2007) describe a single cognitive ability in preschoolers underlying tasks related to working memory and inhibitory control. These researchers suggest that this ability is general early in life, and differentiates into separable factors during school age, continuing to develop into young adulthood.

Other researchers emphasize the centrality of attentional resources to select critical information in the massive amounts of environmental stimuli (Posner, & Fan, 2004). Executive attention overlaps with the more general domain of executive function in childhood, and is important for children's self regulation (Rueda, Posner and Rothbart, 2005). The storage capacity of attention may be a limiting component in executive attention. Cowan and colleagues (2004) discern two dimensions of selective attention: the control of attention and its scope. These researchers suggest that in working memory, the scope of attention is crucial for its control. The scope, which differs between individuals, refers to the limit in the capacity of the focus of attention. This capacity is measured in storage tasks in which rehearsal is prevented. In children too young to rehearse, this capacity can be measured with simple storage tasks, such as digit span.

Other accounts emphasize the role of language in the regulation of behavior and attention. Cognitive Complexity and Control-Revised (CCC-R theory) postulates age-related increases in the complexity of rules the child can understand and use (Zelazo et al., 2003). In this account, top-down processes guide the use of more posterior processes in the control of attention and intention. Another way that language may influence cognitive flexibility may be through to the ability to redescribe a stimulus from two different perspectives (Perner, & Lang, 2002).

The Dimensional Change Card Sort

Because children 2-6 years old cannot complete the WCST, the Dimensional Change Card Sort (DCCS)(Frye, Zelazo, & Palfai, 1995) was developed to study cognitive flexibility in preschoolers. The DCCS is an example of the rule-use paradigm, which was developed in the 1920's by Vygotsky, Luria and Leontiev in their work on the verbal regulation of behavior (Zelazo, Müller, Frye, & Markovitch, 2003). In a rule-use task, participants are presented explicitly with rules and required to use them to guide their behavior. This paradigm doesn't require the participant to discover the rule, as the WCST does, which makes it easier to interpret errors. In the standard version of the DCCS, children are required to sort bivalent test cards according to one dimension (e.g. color), then to sort the same cards according to the other dimension (e.g. shape). Most 3-year-olds perseverate during the post-switch phase, regardless of which dimension is presented first. By age 5, most children succeed at this task (Zelazo, 2006). Correlational studies show that performance on the DCCS correlates with tasks assessing theory of mind (e.g. Perner, & Lang, 2002) and is impaired in children with autism spectrum disorders (Zelazo et al., 2003). Some studies have found an advantage for bilingual children on this task (Bialystok, 1999; Bialystok, & Martin, 2004). Others have not (Yang, & Lust, 2005).

Bilingualism and executive function

There have been a number of studies linking childhood bilingualism and executive functions. Bialystok (1999) found an advantage for bilingual children on the DCCS. Bialystok and Martin (2004) tested preschool children who were bilingual in Mandarin and English and found that they had an advantage on a computerized version of the DCCS requiring moderate representational demands but not in a more demanding condition. These researchers then tested French-English bilingual preschoolers on a manual version of this task and found an advantage for these youngsters when the target dimensions were perceptual but not semantic features of the stimulus. Bialystok and Martin attribute the bilingual youngsters' advantage in this task to better inhibitory control to ignore perceptual information. They suggest that the experience of having two simultaneously activated language systems, and only using one of them at a time, requires inhibition of the language system not currently appropriate. The experience of inhibiting attention to the currently irrelevant language system may be practice for the child, who becomes good at attentional inhibition.

Yang and Lust (2005) tested bilingual preschoolers on a computerized Attentional Network Test (ANT)(Posner, & Fan, 2004), which was developed to measure the efficiency of the attentional networks of alerting, orienting, and executive control, and on a manual form of the DCCS. These researchers found an advantage for the bilingual children on the ANT, but not on the DCCS. Yang and Lust (2005) attribute the advantage of bilingual children in misleading tasks to enhanced executive attention. Siegal, Pond, and Matsuo (2007) tested Japanese-English preschoolers on tasks related to scalar implicatures, which are considered a measure of conversational understanding, a task related to response inhibition, and a task related to cognitive flexibility (Card Sorting). They found the performance of bilingual youngsters to be superior to the monolinguals in the conversational understanding task, but not on the measures of executive function, i.e. inhibition and flexibility.

These studies involve a relationship between bilingualism and executive function, possibly related to control of attention. Earlier studies of bilingual children also point to an advantage for bilinguals when there is misleading information (e.g. Bialystok, 2001), suggesting that bilingual children may be less distractible. Perhaps this advantage comes as a result of having to ignore one language while using the other, in order to keep the languages apart. This resistance to distraction may give bilingual children an advantage when they have to switch rules. However, there may be other explanations for such an advantage, if it exists. For example, bilingual children have more synonyms, which may help them to redescribe a stimulus from different perspectives. They may also be more accustomed to adjusting their language to the needs of the conversational partner or the context, which requires flexibility. Adjusting their language to the demands of the situation also requires impulse control, so the bilingual children may be more adept at response inhibition. They may be more verbally advanced (if both languages are taken into account) through learning two languages, which may give them an advantage related to the use of language to guide behavior. Or the attentional demands of learning two languages may give them an advantage related to simple working memory storage or focus of attention.

We do not know if bilinguals have an advantage related to executive functions and there is uncertainty regarding the nature of an eventual advantage, and under what circumstances it may appear. This uncertainty parallels the fact that the integration of various factors in the development of these functions is not fully understood. Results from studies of bilingual children can help elucidate these functions and their eventual relation to language.

The present study

The present study compared the performance of preschool children who were regularly exposed to two or more languages, with children who were only exposed to one language, on tasks that place demands on vocabulary, reasoning, response inhibition, flexible rule use, and visual working memory span. The objective of the investigation was to explore the question of how experience with more than one language may be related to the development of cognitive flexibility. Our hypothesis was that the bilingual children would have an advantage related to cognitive flexibility as measured by the DCCS-AG, a new task related to flexible rule use in the presence of various levels of distraction. We were interested in other differences between the groups for the purpose of identifying the component of the problem responsible for an eventual bilingual advantage. We were additionally interested in the interrelatedness of the tasks for support this might provide for alternative accounts of the structure of executive function in the preschool years. For example, a correlation between a task requiring response inhibition and a rule-switching task might lend support for accounts emphasizing the ability to inhibit a prepotent response (Diamond, A., Kirkham, N., & Amso, D., 2002), whereas a high correlation between vocabulary and rule-switching may lend support to accounts emphasizing the role of language in the regulation of behavior and attention, such as Cognitive Complexity and Control-Revised theory (Zelazo et al., 2003); or the ability to redescribe a stimulus from different perspectives (Perner, & Lang, 2002). If all the tasks correlate with each other, this may support the idea of a single factor related to executive function in childhood (Wiebe, Espy, & Charak, 2007).

Method

Participants

There were 38 children in the study, consisting of 19 Norwegian monolinguals (12 boys and 7 girls) with a mean age of 56.5 months (SD=8.1); and 19 bilinguals (7 boys and 12 girls) with a mean age of 57 months (SD=8.5). 13 of the bilinguals had been exposed to two languages from birth. Two of the children were trilingual and one child was regularly exposed to four languages. The languages spoken by the bilinguals were French, German, Spanish, English, Swiss, Icelandic, Swedish, Russian, Macedonian and Norwegian.

We defined bilingualism as the regular reliance on two or more languages for purposes of communication; our definition focuses on use rather than competence. Inclusion criteria for the bilingual group were that two or more languages be used to communicate with the child every day, and that this have been the state of affairs for at least two years. We did not specify which particular language(s) should be in use besides Norwegian. Inclusion criteria for the monolingual group were that communication with the child occur exclusively in Norwegian, and the child has not had substantial exposure to another language. However, we did not include children who were bilingual in closely related languages, such as Norwegian, Danish and Swedish, except in combination with a non-Scandinavian language (see Li Wei's 2007 discussion on the distinction between language and dialect). We similarly did not include children in the monolingual group who had been regularly exposed to more than one Norwegian dialect.

Children aged 3 ½ to 6 were recruited through 7 preschools in an area of Oslo with a high socioeconomic status. Letters of information, questionnaires and consent forms were distributed to parents of all the children in the relevant age group. The materials were in Norwegian and English. It was not considered necessary to translate the materials into other languages since most parents living in this area are able to read Norwegian or English. The questionnaire was open ended and included items related to the child's age, sex, language exposure, the context(s) for language use, as well as the parents' mother tongue(s) and information about immigration. The study was evaluated by the Regional Committee for Medical Research Ethics.

Questionnaires and consent forms for 85 children were received and 65 of these children participated in the first testing. We had some difficulty recruiting monolinguals for the study, so the bilingual children were tested earlier. We suspected that the study held more interest for parents of bilinguals, so we wrote a second information letter where we stressed that monolinguals were also welcome. Still, relatively fewer parents of monolinguals responded and we suspect that the parents who did respond were either more interested in the subject matter, or more interested in research.

For 10 of the children, testing was either discontinued or the data excluded from the final analysis because the children were not able to complete the trial examples in the Columbia Mental Maturity Scale or because alliance was not achieved. An additional testing session was administered to complete a test of Norwegian receptive vocabulary, for which only partial scores had been obtained. 38 of the children completed the second testing session and data from both testing sessions for these children is included in the final analysis.

Independent-samples t-tests were conducted on scores on the Columbia Mental Maturity Scale (CMMS) and the British Picture Vocabulary Scale Second Edition (BPVS-II) to determine if there were differences between the groups. There was no significant difference in scores on the CMMS for monolinguals (M=120.6, SD=17.6) and bilinguals (M=126.4, SD=13.7). The magnitude of the difference was small/moderate (eta squared=.034).

There was no significant difference in t-scores on the BPVS-II for monolinguals (M=53.9, SD=11.2) and bilinguals (M=49.9, SD=11.2). The magnitude of the difference was small/moderate (eta squared=.034). This indicates that the groups were functioning at a comparable intellectual level and had similar Norwegian receptive vocabulary.

Materials and procedures

The children were tested individually on two occasions in a relatively quiet room in their preschool with a battery of neuropsychological tests that place demands on response inhibition (NEPSY Eyes Closed; Hand Game); flexible rule use in the face of distraction (Dimensional Change Card Sort-Alternating Games); Norwegian receptive vocabulary (BPVS-II); reasoning (Columbia Mental Maturity Scale); and visual working memory span (Picture Span). Although the language of testing was Norwegian, none of the tests required the children to talk. With the exception of the BPVS II, the tasks did not use verbal stimuli. This was to establish testing conditions that were as equal as possible for the bilinguals and the monolinguals. The children seemed involved in the tasks and cooperation was good. The first session took from 30-40 minutes, and the second session took 10-15 minutes. The children were rewarded with stickers at the end of the session.

NEPSY

Neuropsychological Assessment: 4-7 years (Korkman, 1988) was developed by integrating Luria's views with contemporary child neuropsychological traditions. The following two subtests from the impulse scale were used:

Banke og Håndflata (Hand Game)

In this task, the child inhibits an impulse to do the same as the experimenter and performs instead the opposite action (Korkman, 1988), for example, makes a fist when the experimenter makes a flat hand, and makes a flat hand when the experimenter makes a fist. There are 12 trials and the child gets one point for each correct hand position.

Lukke Øynene (Eyes Closed)

In this task, the child keeps her eyes closed for 40 seconds despite distractions such as the experimenter coughing, and knocking on the table. The child gets one point for each ten-second period the child can resist opening her eyes.

DCCS- Alternating Games

The Dimensional Change Card Sort (DCCS)(Zelazo, Müller, Frye, & Markovitch, 2003) is a card-sorting paradigm that is used to study executive function in 3-6 year olds. The test cards always have the same valences as the target cards, but the valences are reversed. For example, the test cards may depict red bunnies and blue cars, while the target cards depict blue bunnies and red cars. The correct placement of each test card depends on the sorting rule (colour versus shape). The children are always told the sorting rule, and the card is always labelled according to the relevant dimension only.

Previous studies that have sought to document an advantage for bilinguals related to cognitive flexibility have used the standard form of the DCCS (e.g. Bialystok, 1999; Bialystok, & Martin, 2004; Yang, & Lust, 1999), which basic recipe is that the child sorts a set of bivalent test cards according to one dimension and then sorts the same test cards to the same targets according to another dimension (e.g. Zelazo et al., 2003). However, it is impossible to determine if a failure to shift involves difficulty inhibiting the relevant rule, inhibiting the irrelevant dimension, or releasing inhibition to the now relevant dimension (that was previously irrelevant).

The DCCS-AG, which is the test used in the present study, deviates from the standard recipe in that there are two switches and the cards and targets are changed between games, with different levels of overlap. The purpose of this is to separate the various difficulties involved in the standard version, so that it is easier to interpret errors. This was important for identifying the component of the problem responsible for an eventual bilingual advantage.

We decided to use a manual rather than a computerized task because using concrete materials may be more conflicting and increase the possibility of finding bilingual-monolingual differences (E. Bialystok, personal communication, June 15, 2005). In addition, preschool children find the physical cards more engaging (P. D. Zelazo, 2006, personal communication, June 14, 2005). Because each phase functioned as the preswitch for the next phase, the task was discontinued if a phase was not achieved. The sorting rule was alternately color, then shape, then color. Each phase was 12 sorts, and a phase was considered achieved if a minimum of 8 out of 12 cards were sorted correctly. The test was discontinued if the 8/12 criterion was not met. This is because each phase functions as the preswitch for the next phase.

Materials

There were 5 sets of cards to allow for 6 phases, however the version used in the present study only had three phases; a new set was used for each phase except for the last phase. The cards to be sorted were 10.75 cm × 7 cm color drawings on laminated paper. Card set 1 included pink teddy bears, grey boats, grey teddy bears and pink boats. Card set 2 included yellow and purple birds and houses. Card set 3 included orange and green birds and houses. Card set 4 included red and blue fish and butterflies. Card set 5 (phase 5 and 6) included red and blue bunnies and cars. The drawings were intended to be simple, clearly discriminable and appealing to children.

Cards were sorted into trays that were the attached halves of an open box. The sorting trays were 11.5 cm long, 9.5 cm wide and 4 cm deep and were open at the forward end. A booklet made of stiff paper was attached to the far bottom inside edge of each tray in such a way that the pages stuck up. Target cards were affixed to the upturned pages of each booklet so that one target card was visible at a time, and turning the page both covered the already sorted cards and revealed a new target card. This allowed for ease and speed of administration. Speed is important because a delay improves children's performance on some tasks requiring inhibition (Diamond, Kirkham, Amso, 2002).

The sorting rule was alternately color and shape. Each phase was 12 sorts. A phase was considered achieved if a minimum of 8 out of 12 cards were sorted correctly. The test was discontinued if the criterion of 8/12 correct responses was not met. This is because each phase functions as the preswitch for the next phase.

Procedure

The task is introduced by saying, "Now we will sort some cards. We will play the color game."

1 Pre-switch (Colour game)

The experimenter opens the target booklet to the first page and says, "Look! Here is a gray bear." She opens the other target booklet and says, "And here is a pink boat. Now we will play the colour game. In the colour game the pink ones go here and the gray ones go there. Here's a pink bear. It goes here." The experimenter places the bear in the correct tray, face down, and says; "Now you try it. Here's a gray one. Where does it go?"

The experimenter labels each card by the relevant dimension only and lets the child place the cards in the tray, face down, making sure that the same card is not selected more than twice in a row. If a child places a card face up, the experimenter turns the card over but does not otherwise give feedback on the placement of the cards. After 12 trials, the next section is introduced by saying, “Now we’re not going to play the colour game, we’re going to play the shape game”.

2 Total (Shape game)

The experimenter turns the page immediately and says, “Look! Here is a yellow bird.” She turns the page in the other booklet and says, “And here is a purple house. Now we are not going to play the colour game. We are going to play the shape game. In the shape game all the birds go here and all the houses go there. Here is a house. Where does it go?” The rest of the game is as in phase 1. There is no overlap between the stimuli in the previous phase and stimuli in the current phase.

3 Partial (Colour game)

The game and rules are introduced as in phase 1. The stimuli are orange and green houses and birds, to be sorted by colour. There is overlap between the previously relevant stimuli (birds and houses) and the currently irrelevant stimuli. The previously irrelevant stimuli have been replaced with new, relevant stimuli. This is also a switch back to a previously relevant dimension, and it is reasonable to expect that there may therefore be a negative priming effect on the level of the rule.

The British Picture Vocabulary Scale Second Edition

The BPVS-II (Dunn, Dunn, Whetton, & Burley, 1997) is a standardized test of English receptive vocabulary that is derived from the third edition of the Peabody Picture Vocabulary Test (PPVT)(Dunn, & Dunn, 1981). The BPVS-II has recently been translated to Norwegian and standardized on Norwegian age-reference groups at the University of Oslo (S. v. Tetzchner, personal communication, March, 2008). The test does not require the subject to give verbal responses. The children are required to choose the picture out of four that correctly illustrates the word that the experimenter has spoken. The words get more difficult as the test progresses. At the time of our initial testing, the translation was available but the means and standard deviations were not.

We used the test for the purposes of comparing the groups and for examining a relationship between language and other functions. All the children completed up to and including the third set of the test, which corresponds to the age of 6-7 years. However, using the first three sets may have resulted in a ceiling effect, which limits the usefulness of this test for comparing the groups. We have therefore tested the children a second time with the rest of the BPVS-II. The children completed the last three items from the third set as practice, before going on to the next set, until reaching a set with 8/12 incorrect responses. We did not adjust the scores on the first three sets. Means and standard deviations from age four years are available at the time of writing, enabling us to convert the raw scores to t-scores based on the child's age at the time of the second testing. Using t-scores allows us to compare the performance of each child with age-norms, as well as to compare the groups.

For two children (one monolingual and one bilingual) who were 3 years 11 months at the time of the second testing, we have used the norms for four years. All the children but two performed within two standard deviations of the means for their age. One bilingual child performed over 2 standard deviations below the mean for her age (t=24.40) and one monolingual boy performed over two standard deviations above the mean for his age (78.60). But it is worth mentioning that these means are not based on a bilingual population and should therefore be applied with caution to the performance of bilingual children. The British edition has supplementary data and norms for children with English as an additional language (Dunn, Dunn, Whetton, & Burley, 1997).

The relationship between scores on the first three sets of the BPVS-II, raw scores on the whole test and t-scores on the whole test was investigated using Pearson product-moment correlation coefficient. There were large positive correlation between scores on the first three sets and raw scores on the whole BPVS-II [r=.739, n=38, p<.0.01] and between the raw scores and t-scores on the whole BPVS [r=754, n=38, p<.0.01]. There was a moderate correlation [r=.424, n=38, p<.0.01] between the first three sets and T-scores on the whole test. These correlations are not high enough to justify using the first three sets to compare the groups, so comparisons between the groups are conducted using the T-scores of the whole BPVS II. However, scores from the first three sets still provide valuable information about children's knowledge of simple words, so the scores are retained and used in the analysis of the inter-relatedness of the tasks. The first three sets of the BPVS-II will be referred to as BPVS1-3.

Columbia Mental Maturity Scale

The CMMS is a test of general reasoning ability suitable for children as young as 3 ½ years (Burgemeister, Blum, & Lorge, 1955). The test consists of a series of 100 large cards with pictures. The child is instructed to look at all the pictures and point to the one that doesn’t belong with the others. The instruction remains the same throughout the entire test but the stimulus material and level of abstraction become increasingly complex. The child completes the entire level that corresponds to her age, to receive a raw score, which is converted into an IQ score. This test was used to ensure that the groups were functioning at a similar intellectual level. Performance on the CMMS was found to correlate .74 with the full scale IQ of the Wechsler Intelligence Scale for Children in a bilingual population (Cooper, 1958) and .71with the McCarthy Scales of Children's Abilities (MSCA) in 60 preschool children (Phillips, Pasewark, Tindall,1978). Prewitt Diaz, and Rivera (1989) confirm the concurrent validity of the Spanish versions of WISC-R with CMMS in 30 Puerto Rican 1st-grade pupils

Picture Span

This test is similar to the Knox Cube Test (Arthur, 1947), which measures visuospatial attention span with the addition of a sequencing component (Lezak, 2004) and was used as a rough measure of working memory or attentional capacity. The present test consists of a 28 × 11 cm laminated card with four drawings depicting a green bunny, a grey bear, a yellow house and a red boat. The examiner says, “I am going to point to a picture and I want you to point to the same picture”. After two trials, the examiner says, “Now I will point to more pictures, and you will point to them just like me”. The examiner taps the pictures in prearranged sequences of increasing length and complexity, and the child must try to imitate the tapping pattern exactly. The test is discontinued when the child has made 3 errors in a row. The score is the number of correct trials, with a maximum score of ten.

Statistical Procedures

Variables important for the comparison of the groups, such as age, intelligence and vocabulary were controlled for by conducting independent-samples t-tests on age in months as well as on scores on the Columbia Mental Maturity Scale and the British Picture Vocabulary Scale to determine if there were differences between the groups.

The hypothesis was tested by conducting independent-samples t-tests on scores on the Dimensional Change Card Sort- Alternating Games.

Differences between the groups related to response inhibition or visual working memory span were examined by conducting independent-samples t-tests on scores on NEPSY Hand Game, NEPSY Eyes Closed, and Picture Span.

The impact of gender on the neuropsychological tests was investigated by conducting independent-samples t-tests on scores on DCCS-AG, NEPSY Hand Game, NEPSY Eyes Closed, and Picture Span.

The relationship between age and the neuropsychological tests was investigated using Pearson product-moment correlation coefficient.

Differences between the language groups for children older and younger than 4 ½ years were examined by splitting the sample and conducting t-tests on scores on the neuropsychological tests.

The interrelatedness of the tasks was investigated using Pearson product-moment correlation coefficient.

Results

Do the bilingual children have an advantage with regard to cognitive flexibility?

The hypothesis, that the bilinguals would have an advantage related to cognitive flexibility, was tested by conducting independent-samples t-tests on scores on the Dimensional Change Card Sort- Alternating Games. There were no significant differences in mean scores for monolinguals (M=33.7, SD=1.4) and bilinguals (M=28.9, SD=9.9, p=.072). This establishes that our hypothesis does not receive support. The bilingual children did not have higher scores on the DCCS-AG, which places demands on cognitive flexibility.

Are there differences in the sample that can mask an eventual bilingual advantage?

First, it is important to establish that the monolinguals and bilinguals were similar with regard to variables that may have impacted performance on a task requiring cognitive flexibility. Variables important for the comparison of the groups, such as age, intelligence and vocabulary were controlled by conducting independent-samples t-tests on age in months, and on scores on the Columbia Mental Maturity Scale and the British Picture Vocabulary Scale to determine if there were differences between the groups.

Are the language groups similar with regard to age, intellectual level and vocabulary?

The monolingual group had a mean age 56.5 months (SD=8.1) the bilingual group had a mean age of 57 months (SD=8.5). This establishes that the groups were of similar age. There was no significant difference in scores on the CMMS for monolinguals (M=120.6, SD=17.6) and bilinguals (M=126.4, SD=13.7). The magnitude of the difference, which was in favor of the bilinguals, was small/moderate (eta squared=.034). This indicates that the groups were functioning at a similar intellectual level.

There was no significant difference in scores on the BPVS II for monolinguals (M=53.97, SD=11.17) and bilinguals (M=49.87, SD=11.24588). The magnitude of the difference was small/moderate (eta squared=.034). This indicates that the groups had similar Norwegian receptive vocabulary.

Are the language groups similar with regard to gender?

The monolingual group consisted of 12 boys and 7 girls and the bilingual group consisted of 7 boys and 12 girls. This establishes that the groups were dissimilar with regard to gender. This indicates that the language groups were similar with regard to age, intellectual level, and Norwegian receptive vocabulary but there was a different number of boys and girls in the language groups.

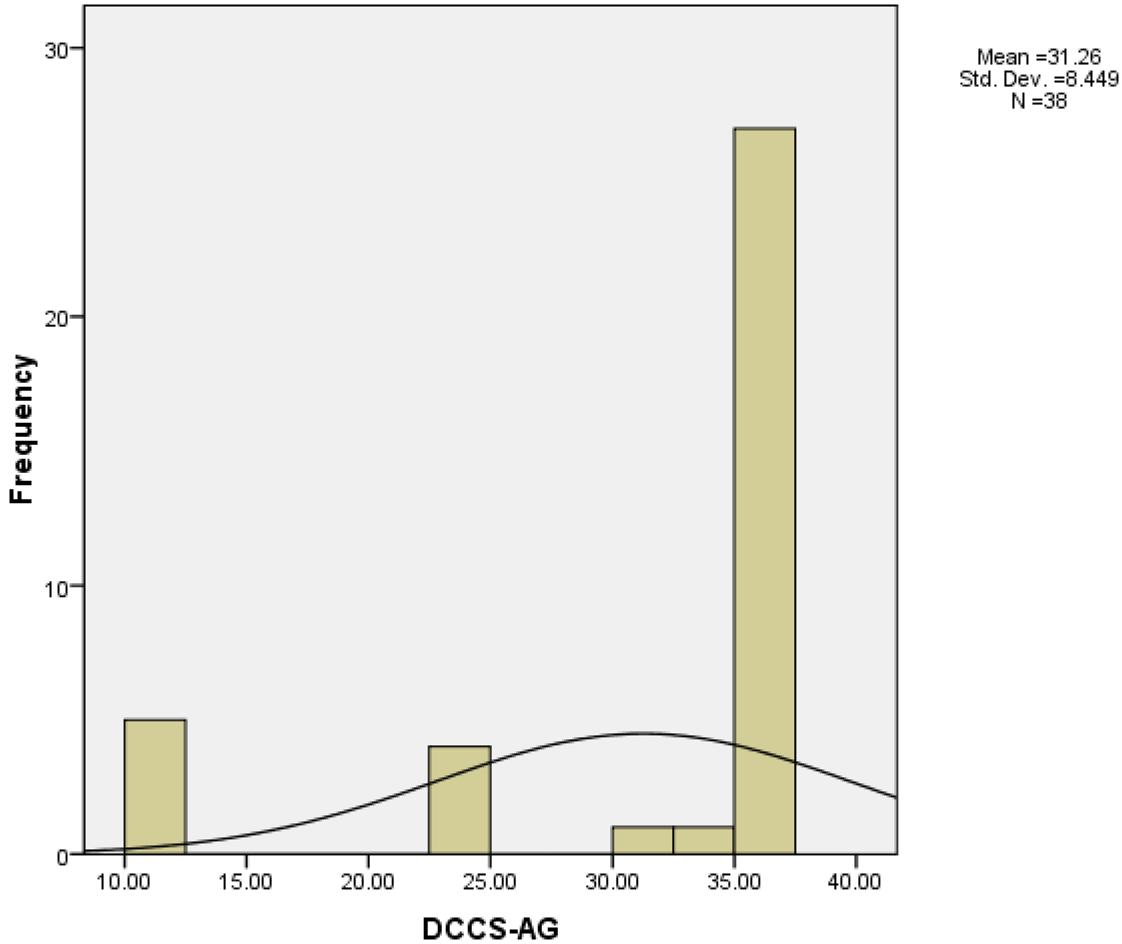
Is there an impact of gender on the neuropsychological tasks?

T-tests were conducted to determine if there was any difference between boys and the girls on any of the tests. There were no significant differences between the groups on any of the tests.

Is there a ceiling effect on the DCCS-AG?

We were interested in the distribution of scores on the DCCS-AG because we wanted to know if there was a ceiling effect. As can be seen on the histogram (figure 1), most of the scores cluster towards the upper end of possible scores. In addition, we can see that the scores are not gradual; instead they jump from 12 to 24 to 36, reflecting the tendency of children to either sort all cards within a phase correctly, or no cards correctly. The scores for monolinguals (M=33.7, SD=1.4) are high and the variation around the mean is small. The scores for bilinguals (M=28.9, SD=9.9, p=.072) are somewhat lower and the standard deviation larger. In addition, the advantage of the monolinguals approaches significance. This indicates that the ceiling effect is mostly affecting scores in the monolingual group.

Figure 1



Are there differences in the language groups with regard to the other tests?

We were interested in other differences between the groups for the purpose of identifying the component responsible for a bilingual advantage. If a ceiling effect hid an eventual bilingual advantage, there may still be evidence of such an advantage in other tests. Differences between the groups related to response inhibition or visual working memory span were examined by conducting independent-samples t-tests on scores on NEPSY Hand Game, NEPSY Eyes Closed, and Picture Span. There were no significant differences in mean scores between the language groups. This establishes that there are no differences in the language groups with regard to performance on any of the tests.

Is there an impact of age on the neuropsychological tests?

The age range investigated (3 ½ - 6 years) is a time of rapid changes in the functions of interest for the study. We would therefore expect to see that the neuropsychological tests correlate with age. We would also expect that were there differences between groups, these differences may appear at certain ages but not at others.

The relationship between age and the neuropsychological tests was investigated using Pearson product-moment correlation coefficient. As can be seen in table 1, there were strong, positive correlations between age and Picture Span [r = .606, n = 38, p < .001], between age and BPVS 1-3 [r=540, n=38, p <.01] and between age and CMMS [r=658, n=38, p<.01]. The medium correlation between age and NEPSY Eyes Closed approached significance [r=.313, n=38, p= .056]. There was no significant correlation between age and the DCCS, but in one of its phases, Partial there was a medium correlation with age that approached significance [r=.340, n=33, p=.053]. There was not a significant correlation between age and NEPSY Hand Game.

Table 1

		Hand Game	Eyes Closed	CMMS	Picture Span	DCCS Total	DCCS Partial	DCCS-AG	BPVS 1-3
age in months	Pearson Correlation	.243	.313	.658(**)	.606(**)	.019	.340	.142	.540(**)
	Sig. (2-tailed)	.142	.056	.000	.000	.911	.053	.394	.000
	N	38	38	38	38	38	33	38	38

* Correlation is significant at the 0.05 level (2-tailed)

.** Correlation is significant at the 0.01 level (2-tailed)

N=38. BPVS1-3=British Picture Vocabulary Scale, sets 1-3; CMMS=Columbia Mental Maturity Scale; PICTURE=Picture Span; Hand=NEPSY Hand Game; Eyes=NEPSY Eyes Closed; Total=DCCS-AG Total Change Phase; Partial=DCCS-AG Partial Change Phase; DCCS-AG=Dimensional Change Card Sort-Alternating Games

Were there differences between the language groups at certain ages?

We split the sample between children older and younger than 4 ½ years and we conducted t-tests to determine if there was any difference between the language groups. Among the youngest children, there was a difference in scores on Picture Span between monolinguals (M=4.3750, SD=1.06, n=8) and bilinguals (M=5.8571, SD=.89974, n=7). This difference was in favor of the bilinguals. The magnitude of the difference was large (eta squared=0.39). Among the children over 4 ½ years, there was a difference in scores on DCCS-AG between monolinguals (M=35.8182, SD=.40452, n=11) and bilinguals (M=29.0, SD=10.80404, n=12). The difference was in favor of the monolinguals. The magnitude of the difference was small (eta squared=.013).

There was also a difference on the BPVS1-3 for monolinguals (M=35, SD=1.0, n=11) and bilinguals (M=33.4167, SD=2.27470, n=12). This difference favoured the monolinguals and had a large magnitude (eta squared=0.22).

In which ways was performance on the tasks interrelated?

We were interested to see to what degree the DCCS-AG, correlated with BPVSII, BPVS1-3, Picture Span and NEPSY, in order to investigate the role of respectively language, working memory and inhibition in the development of cognitive flexibility. The intertask correlations were investigated using Pearson product-moment correlation coefficient. DCCS Partial correlated with BPVS1-3 and NEPSY Hand Game but not with Picture Span. None of the tasks correlated with t-scores on the BPVS-II.

Intertask Correlations for the overall sample are presented in table 2.

Interrelatedness of the tasks, controlling for age

Although not all tasks correlated significantly with age, some of the shared variance may still have reflected the effects of age. We therefore conducted Pearson product-moment partial correlation, controlling for the effects of age. BPVS1-3 correlates with both DCCS1-3 and with DCCS Partial. Intertask correlations controlling for age are presented in table 3.

Table 2

	1	2	3	4	5	6	7	8
Hand (1)								
Eyes (2)								
CMMS (3)								
Picture (4)	.379(*)		.566(**)					
Total (5)	.347(*)							
Partial (6)								
DCCS-AG (7)	.411(*)				.893(**)	.990(**)		
BPVS1-3 (8)			.488(**)	.363(*)	.335(*)	.544(**)	.486(**)	

Table 3

Control variable		1	2	3	4	5	6	7	8
age in months	Hand (1)								
	Eyes (2)								
	CMMS (3)								
	Picture (4)								
	Total (5)								
	Partial (6)								
	DCCS-AG (7)						.989(**)		
	BPVS1-3 (8)						.454(**)	.475(**)	

* Correlation is significant at the 0.05 level (2-tailed)
.** Correlation is significant at the 0.01 level (2-tailed)
N=38. BPVS=British Picture Vocabulary Scale; CMMS=Columbia Mental Maturity Scale; PICTURE=Picture Span; Hand=NEPSY Hand Game; Eyes=NEPSY Eyes Closed; Total=DCCS-AG Total Change Phase; Partial=DCCS-AG Partial Change Phase; DCCS-AG=Dimensional Change Card Sort-Alternating Games

Summary

The monolinguals and bilinguals were similar with regard to age, intelligence and vocabulary but the combination of boys and girls differed between the language groups.

The hypothesis, that the bilinguals would have an advantage with regard to cognitive flexibility, was not supported.

There were no differences between the language groups related to response inhibition or visual working memory span.

There was no impact of gender on scores on the neuropsychological tests.

There were strong, positive correlations between age and Picture Span, between age and BPVS 1-3 and between age and CMMS . There were no significant correlations between age and DCCS-AG, NEPSY Eyes Closed or NEPSY Hand Game.

Among the children younger than 4 ½ years, there was an advantage on Picture Span for bilinguals.
Among the children over 4 ½ years, there was an advantage on the DCCS-AG for monolinguals. There was also an advantage on the BPVS1-3 for monolinguals.

The interrelatedness of the tasks was as follows: DCCS Partial correlated with BPVS1-3 and NEPSY Hand Game but not with Picture Span. When we controlled for the effects of age, BPVS1-3 correlated with both DCCS1-3 and with DCCS Partial.

Discussion

Hypothesis

The bilingual children will have an advantage with regard to cognitive flexibility as measured by DCCS-AG.

The main hypothesis, that the bilingual children would have an advantage on a task related to cognitive flexibility, did not receive support. Not only did the bilingual children not outperform the monolingual children, they did a little worse, although this result did not reach significance in the overall sample.

Why did we not find an advantage?

There are a number of possible explanations for the fact that the present study did not find an advantage for bilinguals related to cognitive flexibility. It is possible that an advantage exists for bilinguals related to flexibility, but our study failed to demonstrate this advantage due to characteristics of our sample or procedures. On the other hand there may be no advantage related to bilingualism for cognitive flexibility. If this is the case, then the advantage on tasks related to flexibility that was found in four previous studies (e.g. Bialystok, 1999; Bialystok, & Martin, 2004) may reflect some other characteristic(s) of the samples studied.

Bilinguals have an advantage which we did not find

We will examine the sample and procedures of the present study with the objective of finding characteristics of the participants or procedures that may have masked an advantage for bilinguals related to cognitive flexibility.

Participants

Are there differences between the groups that may have masked an eventual advantage for bilinguals? The monolingual and bilingual groups were of similar age, geographic area and intelligence and vocabulary.

There was a difference in the groups with regard to gender: the monolingual group had 12 boys and 7 girls, while for the bilinguals the inverse was true. However there is no significant difference between the performance of girls and boys on this task, so the different ratio of boys and girls is not relevant for the lack of support for our hypothesis.

Was there anything about the monolingual children in our study that could have masked an eventual advantage for bilinguals related to the flexible control of attention and behaviour? It was difficult to recruit monolinguals for the study even though most of the preschools had more monolingual children than bilingual children. Was there a difference between parents of bilinguals, who had an intrinsic interest in the study; and parents of monolinguals, for whom the study was not as immediately relevant, but who all the same responded to the study? Perhaps these parents were more interested in research or had more time to respond to questionnaires, differences that could be related to intelligence or socioeconomic status. However the groups did not differ in IQ and both groups came from the same area. The groups were therefore similar in measurements that we expect to be relevant to comparing performance on the flexibility task.

Procedures

Were there validity problems related to the procedures used to control for intellectual level and language proficiency? Perhaps the groups were dissimilar with regard to intelligence despite performing similarly in the CMMS. However the CMMS has been found to be valid for testing intelligence in preschool children (Phillips, Pasewark, Tindall,1978) and bilingual children (Prewitt Diaz, & Rivera,1989).

Perhaps the groups were dissimilar as regards language proficiency despite performing similarly on a task related to Norwegian receptive vocabulary. Language proficiency is more than vocabulary and language assessment of bilinguals is a more complicated affair than it is for monolinguals (Goldstein, 2006). This is a limitation that the present study shares with other studies of bilingual children (e.g. Bialystok, 1999; Bialystok and Martin, 2004; Yang and Lust, 2005).

Language of testing

The performance of the bilingual children may misrepresent their ability because the language of testing was Norwegian, which may not be the strongest language for some of the children (although many of the bilingual children were exposed to Norwegian from birth). In addition, the task used as a measure of cognitive flexibility (DCCS-AG) may have a verbal component because the task exposes children to a misleading situation and requires them to alter their behaviour to a verbal instruction.

Perhaps the bilingual children were not proficient enough in Norwegian, which was the language of testing, to follow the instructions. However, if this were the case, then we would expect the children to have difficulty understanding the instructions on other tasks as well, which they did not have; the children were able to perform all the tasks. Perhaps the instruction for the flexibility task is more complex than for the other tasks. If this were the case, however, we would expect to see difficulties already in the first phase of the DCCS-AG, because the instructions within this task do not change in complexity. But we do not see any difficulty in the first phase of the DCCS-AG; all the children were able to complete this phase. But perhaps language proficiency affects performance on the DCCS-AG simply because a child more proficient in the language of testing is more likely to listen to instructions when they conflict with what the child would otherwise do.

However, other studies concerning bilingualism and cognitive flexibility tested children in English, which was presumably the weaker of the bilinguals' languages; English was first encountered in day-care or preschool (Bialystok, 1999; Bialystok, & Martin, 2004; Yang, & Lust, 2005).

The DCCS-AG

The DCCS-AG, which is the test used in the present study, differs from the standard version in that there are two switches and the cards and targets are changed between games, with different levels of overlap. The purpose of this is to make it easier to interpret errors. However, this may result in a learning effect. The first switch is relatively simple, because it involves no overlap of stimuli, and may facilitate the next switch (Kloo, & Perner, 2003). There may a ceiling effect with this task. However scores in the monolingual group (M=33.7, SD=1.4) are high and the variation around the mean is small. The scores for bilinguals (M=28.9, SD=9.9, p=.072) are somewhat lower and the standard deviation is larger. This may indicate that a ceiling effect primarily is affecting scores in the monolingual group; it is not likely that this effect is masking a bilingual advantage.

Interestingly, a ceiling effect characterizes the standard version of the DCCS in two previous studies of this phenomenon. This includes the second study in Bialystok and Martin (2004), (but not the first and third) and Yang and Lust (2005).

One can speculate that using a verbal rule to shift attention and behaviour has a social element. The verbal rule is not just verbal in an abstract sense, it is a spoken rule, and the rule is spoken by a person, about whom the child may have feelings. It is therefore likely that the degree to which the children trusted, or respected the experimenter may have influenced performance. Again, this is a characteristic of previous studies.

Summary

In summary, the monolinguals and the bilinguals were matched with regard to age, intelligence, receptive vocabulary and socioeconomic status. The different ratio of boys to girls in the groups did not have a bearing on the lack of support for the hypothesis. Although one would ideally test language proficiency more thoroughly, previous studies with a similar objective have also controlled for language proficiency with a test related to receptive vocabulary (e.g. Bialystok, 1999; Bialystok, & Martin, 2004; Yang, & Lust, 2005).

A problem with our procedures is that testing occurred in Norwegian, which may not have been the strongest language for some (but not all) of the bilinguals in our study. However, this is a problem that characterizes the present study less than it does previous studies concerning bilingualism and cognitive flexibility, where testing occurred in the weaker language for all of the bilinguals. The task used to test the hypothesis has a verbal or social component. In addition, the task may have had a ceiling effect. However these are also features of previous investigations of bilingualism and flexibility.

It would appear that the present study has controlled adequately for differences between the samples and used appropriate procedures to test the groups. Perhaps the fact that we did not find support for our hypothesis means that there is not actually an advantage for bilinguals related to cognitive flexibility.

Bilingual children do not have an advantage

Perhaps the hypothesis was not supported because there is no advantage for bilinguals related to cognitive flexibility, or the advantage only appears under some conditions. If this is the case, then there may be some other reason that bilinguals in Bialystok (1999); and Bialystok and Martin (2004) outperformed monolinguals in flexibility tasks. We will consider these studies in terms of differences between the groups that may have masqueraded as an advantage for bilinguals. As Bialystok (2001) points out, it is very difficult to find children who are alike in all respects except that one knows two languages and the other knows one.

The bilinguals may have been more intelligent. The following tests were used to control for intelligence: Peabody Picture Vocabulary Test (PPVT)(Bialystok, 1999); Raven Colored Progressive Matrices (Raven, Court, & Raven, 1986); and Digit Span (Bialystok, & Martin, 2004). The PPVT and Digit Span, being verbal tasks performed in English, may represent more of a challenge for the bilingual children, so it is possible that the bilingual children were more intelligent. Similarly, these researchers also controlled for language proficiency with a test related to receptive vocabulary (PPVT))(Dunn, & Dunn, 1981), which may not give a full picture of the children's language proficiency. Especially for bilingual children, assessment of language is a complicated endeavor (Goldstein, 2006); the bilingual children in these studies may have had superior verbal abilities, had both languages been taken into account.

Perhaps the children had an advantage not because they knew two languages, but because their parents came from China. Three of the four studies tested children who were bilingual in Mandarin and English or Cantonese and English. Sabbagh, Xu, Carlson, Moses, and Lee (2006) found advantages for preschoolers in mainland China related to executive functions that these authors attribute to socio-cultural and genetic factors.

Another possibility is that an advantage may exist for bilinguals related to flexibility but only for some combinations of languages or under some circumstances. Contradictory findings may reflect differences or difficulties in the acquisition process of certain pairs of languages (Yang, & Lust, 2005). In addition, the children's competence in the two languages may be crucial for advantages to appear. Perhaps the children have to be balanced bilinguals, or have achieved a high level of competence in both languages in order for advantages to appear (e.g. Bialystok, 2001). This is in accordance with Cummins' thresholds theory (1978), that the level of proficiency in each of the languages may affect cognitive outcomes; with benefits occurring only where there are high levels in both languages (referred to as balanced bilinguals). However, if this is true, than it is difficult to determine which came first, the proficiency in two languages in early childhood, itself an achievement, or an advantage related to cognitive flexibility.

Other differences between the groups

There were no differences between the groups in the sample as a whole. There were, however, differences between the groups at particular ages that were not apparent in the sample as a whole. When we examined the results separately for children younger or older than 4 ½ years, we found a number of differences between the performance of monolinguals and the bilinguals.

Picture Span

Among children younger than 4 ½, we found that the bilingual children had a significant advantage on Picture Span, even though this advantage did not reach significance in the overall sample. The advantage that the youngest bilinguals showed on the task may be related to the advantage that is sometimes found for bilinguals related to control of attention (Yang, & Lust, 2005).

If the storage capacity of attention is a critical component in executive attention, as is claimed by Cowen and colleagues (2004), then under the right circumstances, we might expect to see an advantage for bilinguals related to cognitive flexibility. If Cowen and colleagues are right, then we expect to see a significant correlation between the DCCS-AG and Picture Span.

DCCS-AG and BPVS1-3

Among children over 4 ½ years, the bilinguals had a significant disadvantage on the DCCS-AG, relative to the monolinguals. The bilingual children also had a disadvantage on the first three sets of the vocabulary test (BPVS1-3). This finding may support the idea that the DCCS-AG task has a verbal component.

It is difficult to understand why the oldest bilingual children had a significant disadvantage on the first three sets of the vocabulary test but did not differ from the monolinguals in T-scores on the whole vocabulary test. Is there a difference in the nature of the words early in this test and later in this test? The first three sets of the vocabulary test includes words that are fairly common, such as *run*, *peal* and *measure* -words familiar to young children in Norwegian. Later in the test, the words are more formal, and possibly more international, such as *arctic* and *parallel* – words of Greek origin that may be similar in different languages; knowing these words may indicate more than language proficiency. This observation leads to the speculation that perhaps some of the older children in the bilingual group may have had more trouble with understanding Norwegian than the results of the whole BPVS-II would indicate.

The interrelatedness of the tasks

Although the number of children in the study is too few for us to use factor analysis, we were interested in the interrelatedness of the tasks, i.e. to what degree the DCCS-AG correlated with the BPVS-II, Picture Span and NEPSY, in order to investigate the role of respectively language, working memory and inhibition in the development of cognitive flexibility. DCCS-AG correlates with the first three sets of BPVS-II and NEPSY Hand Game but not with Picture Span, and interestingly not with the whole BPVS-II.

Although not all tasks correlated significantly with age, some of the shared variance may still reflect the effects of age. We therefore conducted Pearson product-moment partial correlation, controlling for the effects of age. BPVS1-3 correlates with both DCCS1-3 and with one of the phases DCCS Partial (the phase that places the most demands on attentional inhibition).

The DCCS-AG did not correlate significantly with Picture Span. A significant correlation between the DCCS-AG and Picture Span would have provided support for accounts that place the emphasis on working memory (Morten, & Munakata, 2002) or the storage capacity of attention (Cowen et al., 2004) in explaining the development of cognitive flexibility. The fact that there is not a correlation between Picture Span and the DCCS-AG weakens the idea that the advantage we found for the younger bilinguals related to working memory span is a rudimentary form of the elusive bilingual advantage related to cognitive flexibility. Picture span correlates with Hand Game, which may support the idea of a single factor underlying tasks related to response inhibition and working memory (Rueda, Posnes, & Rothbert, 2005). However this correlation could also reflect the fact that both these tasks require the children to use their hands accurately. In addition, Picture Span may have a strong component related to inhibition of response; it seemed to be difficult for the children to resist pointing before the experimenter was finished demonstrating the sequence.

The DCCS-AG correlated with impulse control, which supports accounts that emphasize the ability to inhibit a prepotent response (Diamond, Kirkham, & Amso, 2002) in the development of cognitive flexibility. The DCCS-AG also correlates with vocabulary, which provides support for an emphasis on the role of language in the regulation of behaviour and attention such as Cognitive Complexity and Control-Revised theory (Zelazo et al., 2003) or accounts emphasizing the ability to redescribe a stimulus from two different perspectives (Perner, & Lang, 2002). Our idea that a child with less verbal ability is less likely to choose to listen to verbal instructions that are incongruent with experience is also supported by the interrelatedness of the tasks.

It is interesting to note that it is the score on the first three sets in the BPVS II that correlates significantly with the DCCS-AG. Why should this be? Perhaps verbal ability up to a point is crucial for the development of the ability to switch flexibly, but this is enough. More ability than that does not make a difference. Alternatively, this may reflect qualities of this BPVS-II.

Summary

Our hypothesis, that bilingual children would have an advantage related to cognitive flexibility, was not supported. We have three explanations for this finding. The first explanation for the lack of support for our hypothesis is that the advantage may exist, but the present study failed to reveal it due to problems with our sample or procedures. Candidates for flaws in our sample and procedures include the idea that the bilinguals in our study were not as proficient in Norwegian despite performing similarly in a task of receptive vocabulary, combined with the idea that performance on the task related to cognitive flexibility may have a strong verbal component. However these are problems that the current study shares with studies that have found a connection between flexibility and bilingualism (Bialystok, 1999; Bialystok, & Martin, 2004).

Alternatively, there may be no advantage related to cognitive flexibility for bilinguals. The advantage described by previous researchers may reflect other qualities of the children studied, such as intelligence, language proficiency or culture. A third possibility is that an advantage may exist for bilinguals related to flexibility but only for some combinations of languages or under some circumstances. Contradictory findings may reflect differences or difficulties in the acquisition process of certain pairs of languages (Yang, & Lust, 2005). In addition, the children’s competence in the two languages may be crucial for advantages to appear. However, if this is true, than it is difficult to determine which came first, the proficiency in two languages in early childhood, itself an achievement, or advantages related to executive functions.

The only trace of a processing advantage for bilinguals related to executive functions was an advantage among the children younger 4 ½ years related to visual working memory span, or attentional capacity (Picture Span). The fact that this advantage did not reach significance in the overall sample may indicate that the monolingual children caught up. Among the older children, the bilinguals had significant disadvantages related to vocabulary and cognitive flexibility. A disadvantage related to Norwegian proficiency may have diminished performance due to the verbal demands of the flexibility task.

Cognitive flexibility correlated with vocabulary and impulse control, but not with working memory span. This interrelatedness supports accounts that emphasize the inhibition of response and the use of language to guide behaviour in the development of executive functions. This interrelatedness also supports the idea that verbal ability helps a child to choose to follow a verbal instruction when it conflicts with experience. When we controlled for the effects of age on performance, only vocabulary correlated with DCCS-AG. This result may mean that verbal ability is more important for cognitive flexibility than the ability to inhibit a prepotent response, i.e. that the connection between inhibition and flexibility is maturational. Alternately, the correlation with vocabulary that remains after we have controlled for age may be an artefact of the DCCS-AG and its reliance on the use of a spoken rule. The fact that Picture Span did not correlate with the DCCS-AG weakens the idea that the advantage demonstrated for the younger bilinguals is an indication of a processing advantage that may, under the right conditions, reveal itself as an advantage related to cognitive flexibility.

General discussion

A theme that emerges is language, which seems to have significance both as a source of error in the comparison of the groups and as an explanatory factor. Verbal ability may support cognitive flexibility through the ability to use a rule to guide behaviour (Zelazo et al., 2003) or to redescribe a stimulus from several perspectives (Perner et al). Alternatively, the correlation with verbal ability may reflect the fact that both the standard form of the DCCS and the DCCS-AG require the child to change attention and behaviour in response to a verbal rule that conflicts with experience. It is possible that some children will be more inclined to use a verbal rule to override a prepotent response than others. Whether the child switches in response to a spoken rule may be influenced by the child’s verbal ability. This may not mean that the child who doesn't switch in response *cannot* switch attention or behaviour when she sees reason to do so.

A related idea is that the DCCS paradigm may have a strong social element. Such an idea is supported by the robust finding that performance on the DCCS standard version is correlated with tasks assessing theory of mind (ToM), even when controlling for age and vocabulary (e.g. Zelazo et al., 2003). An additional factor that may influence whether or not the child switches may involve the quality of the child's relationship to the speaker.

Choosing to override an established pattern of response and attention in response to a spoken rule requires that the child have confidence in the speaker of this rule-change. Of course, such confidence or trust is important for all aspects of the testing, but the need may be stronger in a situation where a rule changes. Confidence in the experimenter would be affected by the attitude of adults to whom the child is attached, a factor that varied in this study. Such an idea is supported by the following experience: there was one preschool where the teachers were exceptionally cooperative. In this preschool all the children in the relevant age group participated, and all the children succeeded in switching.

The fact that we did not find support for the hypothesis emphasizes the idea that the development of executive function in early childhood is a complex phenomenon, into which researchers are just now delving and about which much remains to be understood. Similarly, it reminds us that childhood bilingualism is a many-faceted experience and that bilingualis represents many languages, situations and people.

Future research

The indication that language ability may be related to the development of executive function in the preschool period should be investigated in a future project where language is tested more thoroughly. Such a study should have a larger sample so that factor analysis is possible. It is also necessary to further improve the DCCS-AG so that it is possible to test switching under different amounts of distraction in the same child. It would be interesting to create a version of the DCCS that does not rely on a verbal instruction to signal a change of rule.

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