Executive and phonological processes in second language acquisition

Pascale M. J. Engel de Abreu[1] & Susan E. Gathercole[2]

[1] Educational Measurement and Applied Cognitive Science Research Unit, University of Luxembourg/Luxembourg
[2] MRC Cognition and Brain Sciences Unit/UK

Abstract

This paper reports a latent variable study exploring the specific links between executive processes of working memory, phonological short-term memory, phonological awareness, and proficiency in first (L1), second (L2), and third (L3) languages in 8- to 9-year-olds experiencing multilingual education. Children completed multiple L1-measures of complex span, verbal short-term storage, and phonological awareness, and tests of proficiency in a range of linguistic domains (vocabulary, grammar, and literacy) in Luxembourgish (L1), German (familiar L2) and French (unfamiliar L3). Results indicate that executive processing abilities, phonological short-term memory, and phonological awareness operate as distinct but related constructs that manifest differential associations with native and second language proficiency in multilingual children: Phonological short-term memory was uniquely linked to vocabulary in L1 and the structurally similar L2; executive processes were related to grammar across languages, reading comprehension, and spelling; and phonological awareness made specific contributions to word decoding, spelling, and language proficiency in the structurally dissimilar L3. Phonological processing abilities appear to be critical for acquiring the sound structure of a new language, whereas executive processes share more general links with higher-order linguistic abilities in second language learners.

Keywords: working memory; executive processes; phonological short-term memory; phonological awareness; second language acquisition; multilingual education

Executive and phonological processing has been proposed to play a key role in children's native language learning. If and how these processes account for individual variability in second language acquisition is at present unclear. In an increasingly globalized world with growing international immigration and vigorous debates on foreign language education, an understanding of the cognitive underpinnings of second language learning is of considerable practical as well as theoretical importance. The aim of the present study was to identify the underlying factor structure of executive and phonological processing abilities in young second language learners and to explore the relationship between the identified factors with proficiency in several domains of first (L1), second (L2), and third (L3) languages.

Second language acquisition refers to the process of learning subsequent languages in addition to one's native language. It is distinguishable from 'foreign language learning' (Chrystal, 2003) in that the second language plays a major functional role in the particular country or region of the L1-speaker (e.g. immigration, education, government). Much less is known about the cognitive underpinnings of second language acquisition than native language learning. Second language learners constitute a heterogeneous group and it is crucial to distinguish between individuals who belong to a minority-language group versus a majority-language group, and between those who learn several languages from infancy versus those who have acquired a single first language and are learning subsequent languages later in life. The focus of the current research is on the latter group: young majority-language children who learn second languages (L2 and L3) at a relatively young age in the context of formal instruction in a multilingual educational system.

The cognitive mechanisms that have received a great deal of attention in the L1-literature are working memory and phonological awareness; both have been linked to native language development (Cain, Oakhill, & Bryant, 2004; Hu & Schuele, 2005; Majerus, Poncelet, Greffe, & van der Linden, 2006). Working memory is a cognitive system that temporarily holds and manipulates information over brief periods of time in the course of ongoing cognitive activities. It is thought to consist of domain-general executive processes that coordinate activity within the entire working memory system and of domain-specific mecha-

nisms of short-term storage (Baddeley, 2000; Cowan, et al., 2005; Engle, Tuholski, Laughlin, & Conway, 1999). Working memory capacity is commonly assessed by complex span tasks that require to process and store information simultaneously (Daneman & Carpenter, 1980; Turner & Engle, 1989). An example of such a task is counting span, in which participants are asked to count a particular class of items in successive arrays and to store at the same time the number of target items in each array (Case, Kurland, & Goldberg, 1982). Mechanisms of short-term storage are generally assessed by simple span tasks that require maintaining information over a short period of time with no interpolated distraction. It has been argued that complex and simple span tasks are similar in that both require temporary storage but they differ in that complex span task recruit additional executive processes. Support for this position comes from latent variable studies showing that complex span tasks predict performance on measures of fluid intelligence even after controlling for the common variance associated with simple span (Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Engel de Abreu, Conway, & Gathercole, 2010, Engle et al., 1999).

Executive processing has been identified as the crucial factor that links the working memory system to higher-order language abilities such as language comprehension (Cain et al.,2004; Seigneuric, Ehrlich, Oakhill, & Yuill, 2000) and reading (Bayliss, Jarrold, Gunn, & Baddeley, 2003; Gathercole, Alloway, Willis, & Adams, 2006). Most complex language tasks require remembering some task elements and suppressing others (Gernsbacher, 1993; Zacks & Hasher, 1994). Executive processes might thus be used to maintain task-relevant information in an active state and to regulate controlling processes. There is accumulating evidence that multilingual individuals rely on executive processes in order to manage several language systems. Learning a second language requires focusing on the relevant aspects of the new language, ignoring distractions, and suppressing interference from the non-target language (see Bialystok, 2001 for a review). Furthermore, speech is a perceptually complex stimulus that contains rapidly changing acoustic information; executive processes might be used to determine which of the overwhelming amount of sensory information needs to be processed in greater detail (Astheimer & Sanders, 2009). Children with better executive processes may therefore present an advantage in second language learning. At present little is known about how or even if, children rely on executive processes to acquire second languages.

The working memory component that has received greater interest with reference to second language learning is phonological short-term memory. It has been suggested that phonological short-term memory provides essential temporary storage of novel phonological forms, from which more stable lexical phonological representations are abstracted (Baddeley, Gathercole, & Papagno, 1998). Several studies have identified a link between verbal short-term storage and foreign vocabulary learning; most studies, focused, however on one single measure of short-term memory, namely nonword repetition of L2-like nonwords (Cheung, 1996; Masoura & Gathercole, 2005; Service, 1992). Two particular findings are relevant for the discussion at hand: First, phonological short-term memory has been specifically linked to vocabulary acquisition rather than to other aspects of foreign language learning (Service, 1992). Second, phonological short-term memory and long-term lexical knowledge share a highly interactive relationship with vocabulary learning (Jones, Gobet, & Dine, 2008). In a key study Cheung (1996) found that phonological short-term memory predicted L2-vocabulary learning in a group of second language learners with low but not with high foreign language proficiency (see also Massoura & Gathercole 2005). On this basis it has been argued that phonological short-term memory plays a crucial role in the initial stages of vocabulary learning but as familiarity with a language develops new word learning is increasingly mediated by existing long-term lexical knowledge rather than by mechanisms of short-term storage per se.

A concept closely related to phonological short-term memory is phonological awareness, described as the ability to make explicit judgements about the sounds of spoken words independent of their meanings (Ziegler & Goswami, 2005). Examples of standard phonological awareness tasks include rhyme recognition (Bradley & Bryant, 1983), sound blending (Mann & Liberman, 1984), and Spoonerism tasks (Walton & Brooks, 1995). Studies on native language learning have identified strong links between phonological awareness and early literacy abilities (see Goswami & Bryant, 1990 for reviews) and some have claimed a contribution of phonological awareness to vocabulary acquisition (Bowey, 2006; Hu & Schuele, 2005). In a recent study on minority-language children, Swanson and colleagues (Swanson, Orosco, Lussier, Gerber, Guzman-Orth, 2011) found that when controlling for working memory, L1-phonological awareness made unique contributions to L2-reading and L2-language acquisition.

Considerable debates exist on whether phonological short-term memory and phonological awareness should be regarded as distinguishable processes. According to one account both are alternative surface manifestations of an underlying phonological processing ability (Bowey, 2006; Metsala, 1999; Wagner & Torgesen, 1987). Others claim that, although phonological short-term memory and awareness clearly rely on an indi-

vidual's phonological system, both abilities are separable: Whereas phonological awareness tasks predominantly reflect conscious metalinguistic knowledge of the phonological structure of words (Boada & Pennington, 2006; Windfuhr & Snowling, 2001), assessments of phonological short-term memory primarily tap into the ability to encode and retrieve the serial order of phonological sequences (Gupta, Lipinski, Abbs, & Lin, 2005; Majerus et al., 2006). Empirical evidence for the dissociation account exists. Clinical studies have shown that phonological short-term memory can be selectively impaired in patients while phonological processing abilities are maintained (Vallar & Baddeley, 1989). Furthermore, measures of phonological short-term memory and awareness have been found emerged as separate but related factors in structural equation models (Alloway, Gathercole, Willis, & Adams, 2004) and share dissociable links with learning (Chiappe, Glaeser, & Ferko, 2007; Gathercole, Tiffany, Briscoe, Thorn, & the ALSPAC team, 2005).

The present study

The main goal of this study is to provide a detailed examination of the relationship between executive and phonological processes and L1-, L2-, and L3-proficiency in a relatively homogeneous group of second language learners who follow the same multilingual curriculum. The study took place in the Grand-Duchy of Luxembourg, a trilingual country in which Luxembourgish, German, and French are recognized as official languages but only Luxembourgish bears the status of national language. Luxembourg's multilingualism is closely connected to its geographical location, which places it on the linguistic border between a Germanic and a Romance area (Fehlen, 2002). Due to their common Germanic origin, Luxembourgish and German are structurally similar (e.g. word order rules, phonology) and differ considerably from the romance language French (Gilles & Moulin, 2003). Despite the strong presence of German (mainly through the written press and television), Luxembourg is not considered a German-speaking country; Luxembourgish is the main language spoken throughout the Grand-Duchy and is the native language for the vast majority of the Luxembourgish population. Luxembourgers use spoken French and German exclusively in the exchange with foreigners (see Kirps & Reitz, 2001 for a description of the use of languages in Luxembourg). Luxembourg's education system is trilingual: In kindergarten (compulsory for ages 4-6) the language of instruction is Luxembourgish; no second languages are taught or used by the teachers. In first grade (age 6-7) children start to learn their first second language, German (8 hours/week). Together with Luxembourgish, German is used as media of instruction and children learn to read and write in German not in Luxembourgish. Oral French is introduced as subject of study in the second half of the second grade (age 7-8, 3 hours/week). In the present study children were assessed at the end of second grade on a range of tasks tapping into L1-executive and L1-phonological processing abilities as well as different linguistic domains in L1 (Luxembourgish), L2 (German), and L3 (French). Notably, the second languages under study differ by their degree of familiarity with the children's L1 (German being more familiar than French). The study controlled for a range of covariates known to affect second language learning such as chronological age, lengths of formal language instruction, language exposure in the home, motivation, and socio-economical status (SES).

The relationship between executive processes, phonological short-term memory, and phonological awareness was explored at the level of latent variables rather than at the level of individual tasks. Latent variables reflect the shared variance among multiple tasks and are relatively independent of task-specific factors or measurement error. For each construct of interest two tasks were administered. The selected measures are widely used in research with children, form part of many standardized test batteries (e.g. AWMA, Alloway, 2007; PhAB, Frederickson, Frith, & Reason, 1997; CNRep, Gathercole & Baddeley, 1996), and have been found to provide reliable and valid measures of cognitive ability in Luxembourgish children (Engel de Abreu, Gathercole, & Martin, 2011). Phonological short-term memory was assessed with simple storage-oriented span tasks involving the maintenance of lexical and sublexical information but with no concurrent processing requirement. Children also completed two complex span tasks involving storage-plus-processing of verbal information. Following Engle and colleagues (Conway et al., 2002; Engel de Abreu et al., 2010; Engle et al. 1999) executive processing was operationalized as the remaining variance in complex span after controlling for simple span performance. Phonological awareness was assessed with tasks requiring the analyses and the manipulation of phonemes.

The study had two major objectives: (a) to investigate the underlying factor structure of executive and phonological processing abilities in young multilingual children and (b) to explore the cross-sectional links between the identified factors with proficiency in vocabulary, grammar, and literacy across different languages (L1, L2, and L3). In relation to the first objective clear hypotheses could be formulated: If measures of phonological short-term memory and phonological awareness tap into distinguishable underlying processes, they should emerge as separate constructs in confirmatory factor analyses and share dissociable links with language learning (Alloway et al., 2004; Chiappe

et al., 2007; Gathercole et al., 2005). If instead phonological processing is similarly involved in both phonological short-term memory and awareness tasks (Bowey, 2006; Metsala, 1999) the two constructs might essentially be indistinguishable. Furthermore, the hypothesis was tested that complex span tasks of working memory measure something significantly more (i.e. executive processes) than verbal simple span tasks which makes these two constructs separable (Baddeley & Logie, 1999; Engle et al., 1999). Given the lack of an overarching theory of second language acquisition coupled with the sparse research on basic cognitive processing in multilingual children it would be premature to directly test competing hypotheses related to the second objective of the study. As such, the second part of the study is exploratory, with predictions largely formulated within the framework of cognitive-linguistic processing in monolingual children. It is anticipated that executive processes of working memory make domain-general contributions to language learning (Engel de Abreu, et al., 2011; Engle, et al., 1999) whereas phonological short-term memory and phonological awareness were expected to be specifically linked to vocabulary and reading respectively (de Jong & van der Leij, 1999; Service & Kohonen, 1995; Swanson et al., 2011). Following previous research showing that the contribution of phonological short-term memory to language learning is strongest if the language is unfamiliar but subsequently diminishes as familiarity with the language develops (Cheung, 1998, Masoura & Gathercole, 2005) it was expected that there would be a strong relationship of phonological short-term memory with French and a weaker link with German. Finally, the study explored the links between L1-, L2-, and L3-proficiency in order to determine whether additional factors to L1-long-term lexical knowledge are involved in second language acquisition.

Method

Participants

The initial sample consisted of 119 Luxembourgish-speaking children from 34 primary classes of 16 state schools across the Grand-Duchy of Luxembourg. Children were recruited on the basis of a language background questionnaire that was completed by the main caregiver. The data of 21 children was excluded because one of the caregivers was bilingual. The remaining 98 children had Luxembourgish as their L1, Luxembourgish-speaking parents, and no foreign language was actively spoken in the home environment or wider family. The sample was composed of 43 girls and 55 boys with a mean chronological age of 8 years; 3 months (*SD* = 3.6 months, range = 7;8 - 8;10). All children scored between the 50th and the 95th percentile on the Raven Progressive Coloured Matrices test of nonverbal reasoning (Raven, Court, & Raven, 1986). None of the children presented learning difficulties or frank neurological deficits as indicated by parent and teacher reports. Ethnic representation of the sample was 100 per cent Caucasian. The socioeconomic status (SES) of the population was primarily middle class: On average parents had completed 14 years of schooling (*SD* = 2.0 years, range = 10 - 17) and most households possessed over 100 books (the highest educational level of either parent was used; OECD, 2009). The average number of children in each family, including the child participating in the study, ranged from 1 to 6 with a mean of 2.3 children per family. Notably 51 per cent of the children had one stay-at-home caregiver, a practice that is encouraged by the Luxembourgish government.

Children were recruited to represent a homogeneous group in terms of second language experience and learning context. All participants were born in Luxembourg of Luxembourg-born caregivers and had completed two years of preschool and one year of primary school in Luxembourgish schools. Caregivers indicated watching TV mainly in German (Luxembourg has very few national channels aired for approximately 1.5 hours/day) and reading to their child mostly in Luxembourgish. All caregivers were trilingual in Luxembourgish, German and French. Children were tested in their second year of primary after having formally studied German for 19 months and French for 4 months. All the children had started their L2-German instruction at the beginning of grade 1; there was however some variability in relation to lengths of study of L3-French (mean = 4.4 months; *SD* = .87; range = 3.1 – 5.6); this variable was therefore included in the subsequent analyses as a covariate. All of the children had learned to read and write in German but not yet in Luxembourgish and French. Participating schools followed the same governmental curriculum, all teachers had been trained at the same institute for higher education, and didactical material and educational books were identical across schools.

Procedure

With the exception of one measure, all the tests were individually administered in 3 sessions of 30 to 40 minutes each. Children were tested by the first author, a native Luxembourgish speaker who is also fluent in German and French. Testing took place in a quiet area of the school on different school days. Tests of executive processing, phonological short-term memory, and phonological awareness were administered in children's L1-Luxembourgish. Adapted versions of English originals were used (see Engel de Abreu et al., 2011 for further details on test adaptation). Vocabulary

and grammar was assessed in all three languages using parallel language tests of English originals. A pilot study showed that the French parallel language measures were too difficult for Luxembourgish children at the initial stages of French instruction. Two new measures were therefore designed in which the linguistic demands were suitable for Luxembourgish second language learners (TEVEX and TECOSY described below). As children had not yet learned to read in Luxembourgish and French, tests of literacy could only be administered in children's L2-German. For all the measures, raw scores were used as dependent variables as no data were available regarding measures of standardized norms in a population of Luxembourgish children. Reliability of instruments was established for the scores produced by the measures in this study and are presented in the method and results section (Table 1). Tests were grouped by language and administered in a fixed sequence designed to vary task demands across successive tests. Unless otherwise specified, tests that form part of published batteries were administered according to standard procedures and are not described in detail.

Measures

Complex span tasks

In the *counting recall* task (AWMA, Alloway, 2007) the child is presented with pictures containing circles and triangles and is asked to count and memorize the number of circles in each picture. At the end of each trial the child has to recall the number of circles of each picture in the right order. The reliability coefficient of the test was .89 and the possible maximum score was 42. In the *backwards digit recall* [1] task (AWMA, Alloway, 2007) the child hears a sequence of spoken digits and is required to immediately repeat the list in the reverse order. The reliability coefficient was .80 and the possible maximum score on the test was 36.

Phonological simple span tasks

In the *digit recall* task (AWMA, Alloway, 2007) the child is asked to immediately repeat sequences of spoken digits in the order that they were presented. The internal consistency coefficient was .89 and the possible maximum score was 54. In the *Luxembourgish Nonword Repetition Task* (LuNRep, Engel, 2009; Engel de Abreu et al., 2010) the child has to immediately repeat unfamiliar sound sequences that conform to the phonotactic rules and stress pattern of Luxembourgish (see Appendix 1). The reliability coefficient of the measure was .83 and the inter-rater reliability based on Cohen's Kappa was .72 (Cohen, 1960).

Phonological awareness

Phonological awareness was evaluated with a *Luxembourgish spoonerism* task based on the Phonological Assessment Battery (PhAB, Frederickson, Frith, & Reason, 1997). In the first half of the test the child is required to replace the onset of a spoken word with a new sound. In the following trials onsets from two words have to be exchanged (see Appendix 2). The total maximum score on the task was 30 and the reliability coefficient of the measure was .88. Children also completed a *Luxembourgish odd-one-out* task, adapted from Kirtley and colleagues (Kirtley, Bryant, Maclean, & Bradley, 1989). Sets of three words are orally and visually presented and the child has to point or name the picture that does not match with the two others. Only frequent Luxembourgish words containing three sounds each (CVC) were used. In the first eight trials the words began with the same consonant and the "odd-one" contained a different vowel sound. In the following eight trials the sound that differentiated the two similar words from the "odd-one" was the last consonant (see Appendix 3). Reliability analyses showed that three items presented item-total correlation scores below .1 and were therefore excluded from the analyses. The total maximum score was 13 and the internal consistency coefficient was .62.

Vocabulary

Luxembourgish (L1) and German (L2) vocabulary was assessed with the *Expressive One Word Picture Vocabulary Test* (EOWPVT, Brownell, 2000). In this test the child has to name a picture consisting of a line drawing of an object, action, or concept. Items are arranged in order of increasing difficulty. Each language version was translated from the English original by two independent native speakers. The responses of both translations were used to determine the acceptable answers. No additional acceptable responses were identified after all the data were collected. The correlation of item difficulty to item order was .82 for the Luxembourgish version and .76 for the German version. All the children started at test item one and testing stopped after the failure of eight consecutive items. The internal consistency coefficient was .84 for the Luxembourgish version and .88 for the German version.

Children also completed the French *Test de Vocabulaire Expressif* (TEVEX) designed for the purpose of this study. The test consists of a series of drawings of objects and concepts that require the production of a spoken word in French. The selected vocabulary was based on the curriculum of the second grade French course of primary schools in Luxembourg. The images were selected from the Rossion and Pourtois (2004) databank of coloured line drawings of objects. In addition, the semantic categories "colour"

and "number" were added to the selected picture set. The final test contained 23 items from seven different semantic categories. The dependent measure was the number of correct responses with a possible maximum of 23. The reliability coefficient of the measure was .83.

Grammar

Children completed a Luxembourgish[1] and a German version (Fox, 2006) of the *Test for Reception of Grammar* (TROG, Bishop, 2003) assessing understanding of grammatical contrasts. In this test children have to identify a target picture out of a choice of four to match a spoken sentence. Only half of the items were administered for each language version; in each case two items per block were selected. No starting or stopping criterion was applied and the total possible maximum score on each test was 40. The internal consistency coefficient was .66 for the Luxembourgish version and .65 for the German version.

French syntactic comprehension was assessed with the *Test de Compréhension Syntaxique* (TECOSY) designed for the purpose of this study. Test design and administration was based on the TROG (Bishop, 2003). A restricted simple vocabulary was used to construct the test sentences. Only grammatical constructions that are introduced in the second grade French course of primary schools in Luxembourg and that could be depicted unambiguously were selected for inclusion in the test (see Appendix 4). All of the test pictures were hand drawn and coloured. Lexical and/or grammatical distracters served as foils. Eight different grammatical contrasts were assessed with four items each. The total test consisted of 32 items. Structured teacher interviews revealed that two teachers had not yet introduced the grammatical construction *derrière* (behind); the two test sentences involving this construction were therefore excluded from the final analyses resulting in a total possible maximum score of 30. The reliability coefficient of the measure was .70.

Literacy

In the *single word reading* test the child has one minute to read in a normal pace grade-appropriate German words presented on individual flashcards in a 72-point font (procedure based on CBM, Deno, 1985). The majority of the words were nouns taken from the school material of the second grade curriculum in Luxembourg. If the child sounded out the word accurately it was scored as correct, even if pronunciation was not fast. Mispronunciations due to articulation difficulties were not counted as errors. A word was scored as correct if the child provided a self-correction within the time period allowed. Substitution, deletion, or additions of phonemes were considered as mistakes.

Children completed the text comprehension subtest of the ELFE 1-6 (Ein Leseverständnistest für Elementarschüler; Lenhard & Schneider, 2006) assessing the ability to find information in a text, infer meaning beyond written sentences, and draw conclusions about text. The test consists of 13 short passages of written text in German (2-7 sentences each), provided in a test booklet, each followed by one or several questions regarding the content of the text with four possible answers per question. Children were required to silently read the texts and select the correct answer to each question. Testing stopped after seven minutes or after completion of all the questions with a possible maximum score of 20. The test was group administered with a maximum of six children per group. The internal reliability coefficient of this measure was .83.

The single word spelling subtest from the HSP-2 (Hamburger Schreibprobe für zweite Klasse; May, 2007) was administered. In this test, children are asked to write 15 German words that are individually dictated to them in a natural reading prosody. The number of correctly spelled letters or letter combinations (e.g. sch, ah, ie, ck…) serves as the dependent variable with a total maximum score of 88. The reliability coefficient of the measure was .92.

Motivation

Children were asked to indicate on a four-point likert scale how much they enjoyed learning German and French in the classroom.

Results

Scores on the 15 variables were screened for univariate outliers defined as values more than 3 *SD* above or below the group mean (Kline, 1998). Two cases out of 1470 in the dataset met one of these criteria and were replaced with scores corresponding to plus or minus 3 *SD* as appropriate. The variables manifested reasonable univariate and multivariate normality with standardized kurtosis values below 3 (Kline, 2005). The measures did not present floor or ceiling effects: all means were at least 1 *SD* from the maximum and minimum scores. No multivariate outliers were identified for any of the analyses (Mahalanobis distance D^2; $p < .001$) and reliability coefficients of the scores were in an acceptable range. Descriptive statistics for all the measures are provided in Table 1. Children performed significantly better in the L1-Luxembourgish than the L2-German language measures [EOWPVT, $t(97) = 4.68$, $p < .01$; TROG, $t(97) = 5.78$, $p < .01$] confirming that although German and Luxembourgish are structurally similar, German represents a second language for L1-Luxembourgish-speaking children[2]. The motivation measure showed that children favored learning German over French: $t(97) = 3.13$, $p < .01$.

TABLE 1 - Descriptive Statistics for All Test Scores (N = 98)

Measures		Max.	Mean	*SD*	Range	r_{xx}
Age (in months)		--	98.92	3.58	92-106	--
SES (years of education)		21	14.36	2.02	10-17	--
L2-motivation		4	3.38	.88	1-4	--
L3-motivation		4	2.96	.91	1-4	--
L3-length of study (in months)		--	4.45	.87	3.1-5.6	--
L1-complex span	Counting recall	42	18.46	3.65	8-26	.89[c]
	Backwards digit recall	36	11.47	2.29	6-18	.80[c]
L1-verbal simple span	Digit recall	54	24.77	3.19	18-32	.89[c]
	Nonword repetition	50	39.01	5.23	24-49	.83[c]; .72[e]
L1-phonol. awareness	Spoonerism	30	16.66	6.19	1-29	.88[c]
	Odd-one-out	13	9.30	2.32	3-13	.62[d]
Vocabulary	L1-EOWPVT (Lu)	--	76.40	7.11	53-91	.84[c]
	L2-EOWPVT (D)	--	74.29	8.20	46-91	.88[d]
	L3-TEVEX (Fr)	23	12.66	4.65	2-21	.83[d]
Grammar	L1-TROG (Lu)	40	33.75	2.64	26-39	.66[d]
	L2-TROG (D)	40	32.36	2.75	23-38	.65[d]
	L3-TECOSY (Fr)	30	20.11	3.86	10-30	.70[d]
Literacy	L2-Word decoding (D)	1 min	31.71	9.13	11-58	--
	L2-Reading comprehension[a] (D)	20	6.64	3.43	0-16	.83[d]
	L2-Spelling[b] (D)	88	79.66	5.66	63-88	.92[d]

Note: Max: Maximum possible score; Lu: Luxembourgish; D: German; Fr: French; EOWPVT: Expressive One Word Picture Vocabulary Test; TEVEX: Test de Vocabulaire Expressif; TROG: Test for Reception of Grammar; TECOSY: Test de Compréhension Syntaxique; [a] ELFE: Ein Leseverständnistest für Elementarschüler; [b] HSP-2: Hamburger Schreibprobe für zweite Klasse; [c] reliabilities are coefficient alpha; [d] reliabilities are K-R 20. [e] interrater reliability based on Cohen's Kappa (Cohen, 1960).

Correlational analysis

Zero-order correlation coefficients between the principal measures of interest are represented in Table 2. Partial correlation was used to explore the relationship between the measures while controlling for L1-vocabulary (Table 2, upper triangle). Correlation coefficients are interpreted following Cohen's guidelines of coefficients of .10 as small, .30 as moderate, and .50 as high (Cohen, 1988). The first part of the analyses focused on the covariates: L3-length of study and L3-motivation (Spearman's rho) were not significantly linked to the language outcome measures (length of study: r_s's ranging from .00 to .11; motivation: r_s's ranging from .01 to .05). L2-motivation manifested weak links with word decoding (r_s = .21) and reading comprehension (r_s = .22) but no associations with any other variables (r_s's ranging from .00 to .18). Chronological age was not significantly linked to any measure. In the absence of notable relations those measures were not analyzed further. Importantly, SES (years of parental education) manifested weak to moderate correlations with nonword repetition, vocabulary, grammar, and the reading measures (*r*'s ranging from .21 to .45). SES was therefore retained as a covariate in the hierarchical regression models.

Within each area of cognitive skill measures correlated with each other, with *r*'s of .33 for the complex span measures of working memory; .61 for the verbal simple span tasks; and .67 for the phonological awareness measures. The within-construct coefficients were higher than the between-construct coefficients and remained significant after controlling for L1-vocabulary, suggesting good internal validity of the measures. The data on the language measures showed that L1-vocabulary and L1-grammar manifested strong links with their respective counterparts in L2-German (*r*'s of .84 and .61 respectively) and moderate associations with the L3-French measures (*r*'s of .40 for vocabulary and .37 for grammar). The literacy measures manifested strong associations ranging from .66 to .79.

Across constructs the pattern of results indicates the following: the complex span tasks were not related to vocabulary and word decoding but manifested medium associations with grammar (*r*'s ranging from .14 to .33), reading comprehension (*r*'s of .15 and .23), and spelling (*r*'s of .24 and .28) that were independent of L1-vocabulary.

TABLE 2 - Correlations Between the Main Scores Using Pearson's Correlation Coefficient (N = 98)

Measures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. Age	--	.11	.18	.04	-.03	-.02	.00	-.12	--	-.09	-.07	-.03	-.01	-.00	.09	.06	.01
2. SES	.18	--	.13	.04	.02	.10	.03	-.03	--	.00	.04	.14	.04	.06	.15	.05	.01
L1-complex span																	
3. Counting recall	.19	.16	--	**.32**	.08	.06	.15	.20	--	.13	.13	**.25**	**.23**	**.23**	.17	**.22**	**.23**
4. Back. digit recall	.07	.12	**.33**	--	.13	.08	.17	.16	--	.05	-.06	**.28**	**.26**	.08	.14	.08	**.24**
L1-verbal simple span																	
5. Digit recall	.03	.16	.10	.19	--	**.55**	**.24**	.05	--	.00	-.06	.12	.17	.17	.02	.06	.12
6. Nonword rep.	.06	**.26**	.09	.15	**.61**	--	**.33**	.16	--	.14	.15	.12	**.26**	.09	**.26**	.17	**.27**
L1-phonological awareness																	
7. Spoonerism	.07	.18	.17	**.23**	**.32**	**.42**	--	**.63**	--	.04	**.23**	**.34**	**.24**	**.34**	**.38**	**.23**	**.48**
8. Odd-one-out	-.03	.13	**.21**	**.21**	.16	**.28**	**.67**	--	--	.03	**.22**	**.33**	.19	**.32**	**.34**	**.23**	**.40**
Vocabulary																	
9. L1-EOWPVT (Lu)	.19	**.45**	.08	.19	**.33**	**.39**	**.34**	**.33**	--	--	--	--	--	--	--	--	--
10. L2-EOWPVT (D)	.11	**.39**	.14	.19	**.28**	**.39**	**.30**	**.29**	**.84**	--	.07	.18	**.24**	.05	.18	**.21**	**.33**
11. L3-TEVEX (Fr)	.00	**.21**	.15	.02	.08	**.28**	**.33**	**.34**	**.40**	**.37**	--	.09	.09	**.51**	**.45**	**.35**	**.51**
Grammar																	
12. L1-TROG (Lu)	.06	**.33**	**.26**	**.33**	**.26**	**.28**	**.44**	**.44**	**.48**	**.49**	**.27**	--	**.47**	**.25**	**.20**	**.27**	**.26**
13. L2-TROG (D)	.09	**.28**	**.24**	**.32**	**.32**	**.41**	**.37**	**.33**	**.54**	**.56**	**.29**	**.61**	--	**.22**	**.21**	.19	**.24**
14. L3-TECOSY (Fr)	.06	**.20**	**.24**	.14	**.26**	**.20**	**.42**	**.40**	**.33**	**.30**	**.58**	**.37**	**.35**	--	**.34**	**.30**	**.41**
Literacy																	
15. L2-Word decoding (D)	.14	**.23**	.19	.18	.09	**.32**	**.42**	**.39**	**.23**	**.29**	**.49**	**.29**	**.30**	**.39**	--	**.78**	**.73**
16. L2-R.Comprehension (D)	.13	**.21**	**.23**	.15	.17	**.28**	**.32**	**.33**	**.37**	**.41**	**.45**	**.40**	**.35**	**.38**	**.79**	--	**.63**
17. L2-Spelling (D)	.06	.12	**.24**	**.28**	.19	**.34**	**.52**	**.45**	**.24**	**.38**	**.55**	**.34**	**.33**	**.45**	**.75**	**.66**	--

Note: simple correlation coefficients are shown in the lower triangle, correlation coefficients with L1-vocabulary partialed out are shown in the upper triangle; significant values marked in boldface, $p < .05$; Lu: Luxembourgish; D: German; Fr: French; EOWPVT: Expressive One Word Picture Vocabulary Test; TEVEX: Test de Vocabulaire Expressif; TROG: Test for Reception of Grammar; TECOSY: Test de Compréhension Syntaxique.

The phonological awareness tasks were related to all of the language measures, manifesting medium links with vocabulary (*r*'s ranging from .29 to .34), grammar (*r*'s ranging from .33 to .44), and reading (*r*'s ranging from .32 to .42) and strong associations with spelling (*r*'s of .52 and .45). The verbal simple span tasks were moderately associated with grammar (*r*'s ranging from .20 to .41) and vocabulary in L1 and L2 (*r*'s ranging from .28 to .39). Interestingly, digit recall and nonword repetition, although strongly associated, manifested a differential pattern of results with L3-French-vocabulary and L2-literacy. Whereas nonword repetition was moderately associated with French-vocabulary and German-literacy (*r*'s ranging from .28 to .34), digit span was not. Noteworthy were the strong links between the L3-French-vocabulary and L2-literacy measures (*r*'s ranging from .45 to .55). Finally, partial correlations showed that the associations of the verbal simple span tasks with grammar and L2-German-vocabulary were mediated by L1-vocabulary (*r*'s ranging from .00 to .26).

Confirmatory factor analyses

The purpose of these analyses was to confirm the theoretical position that executive processes, phonological short-term memory, and phonological awareness represent distinguishable constructs in young multilingual children. A three-factor model was tested in which the complex span tasks (counting recall and backward digit recall) defined a common factor; the simple span tasks (digit recall and nonword repetition) loaded on a second factor; and spoonerism and odd-one-out loaded on a third factor. Analyses were performed on the covariance structure with maximum likelihood estimation using *AMOS* 7 (Analysis of Moment Structures, Arbuckle, 2006). Fit indices suggest that this three-factor model provided an excellent account of the data: $\chi^2(6) = 4.06$, $p > .10$; CFI = 1.00; IFI = 1.01; RMSEA = .00 (see Kline, 2005 for a review of the different fit indices). The model solution is summarized in Figure 1.

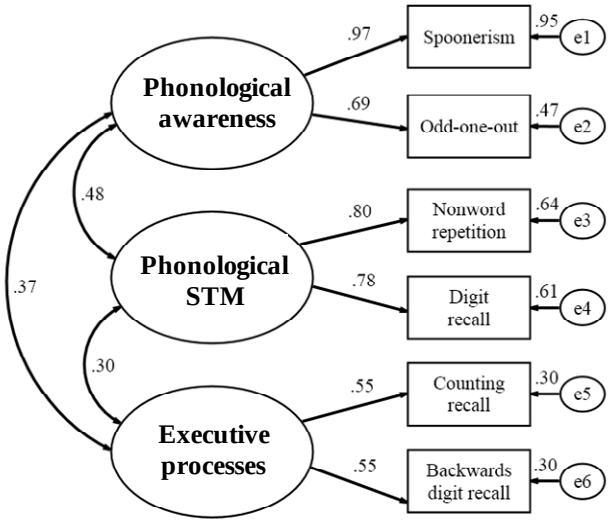

FIGURE 1. Three-factor confirmatory factor analyses model for the complex span, simple span and phonological awareness tasks. Solid lines indicate coefficients significant at the .05 level. Numbers next to the circles are proportions of variance in the observed variables explained by the latent construct. STM: short-term memory.

All of the measures loaded significantly onto their respective constructs and none of the correlation coefficients could be constrained to one without harming model fit confirming that the three-factor solution provides the best account of the data.

Hierarchical regression analyses

In order to explore the specific links between the identified factors with proficiencies in different languages and linguistic domains, latent factor hierarchical regression analyses were performed. The nine criterion variables were: L1-, L2-, and L3-vocabulary and -grammar; and L2-decoding, L2-reading comprehension, and L2-spelling. In each case the latent variables, represented in Figure 1, were entered into the regression equation as predictors in a pre-specified order after SES was controlled. The method adopted was based on an approach by de Jong (1999; see also, Loehlin, 1996) in which a Cholesky factoring is applied to the latent predictors. All the models were specified as second-order factor models. The second-order factors were uncorrelated and their number was identical to the first-order predictor factors. The dependent latent factor (e.g. reading comprehension) was regressed onto the second-order factors. The order in which the latent predictors were entered into the analyses was determined by the specific pattern of loadings of the first-order onto the second-order factors (for more information on this statistical procedure see Engel de Abreu et al., 2010).

In each case phonological short-term memory was entered into the regression before the factor determined by the complex span tasks following the logic that executive processes of working memory are captured by the remaining variance in complex span tasks after performance on simple span tasks is controlled (Engle et al., 1999). Phonological awareness was entered in two different orders – before and after phonological short-term memory – in order to disentangle the general and the specific contributions of phonological short-term memory and phonological awareness to language learning. Separate analyses were conducted for each outcome variable and the standardized estimates are reported in the upper section of Table 3. For all the analyses the total R^2 is provided in italics.

The data showed that phonological short-term memory, but not executive processing abilities, was significantly linked to vocabulary in L1-Luxembourgish and L2-German. These associations were highly specific and remained significant after controlling for phonological awareness. In contrast, links between phonological awareness with L1- and L2-vocabulary were largely mediated by phonological short-term memory. For L1- and L2-grammar the opposite pattern emerged: links with phonological short-term memory were mediated by phonological awareness whereas associations with executive processing abilities were highly specific and remained significant after controlling for phonological processing (short-term memory and awareness).

TABLE 3 - Standardized Regression Coefficients from Hierarchical Regression Analyses (N = 98)

		Vocabulary			Grammar			L2-Literacy		
Step	Construct	L1	L2	L3	L1	L2	L3	Decod.	R. Comp.	Spell.
1	SES	**.45**	**.39**	**.21**	**.33**	**.28**	**.20**	**.23**	**.21**	.12
2	Phonological STM	**.34**	**.34**	.20	**.27**	**.41**	**.24**	**.25**	**.26**	**.33**
3	Executive processes	.04	.12	.09	**.42**	**.37**	**.27**	.20	**.26**	**.39**
4	Phonol. awareness	.16	.09	**.27**	**.26**	.08	**.32**	**.31**	.17	**.35**
2	Phonol. awareness	**.31**	**.27**	**.35**	**.46**	**.36**	**.45**	**.44**	**.33**	**.56**
3	Phonological STM	**.22**	**.24**	.05	.06	.20	.03	.04	.11	.08
4	Executive processes	.01	.09	.00	**.31**	**.33**	.17	.12	**.21**	**.26**
	Total R^2	*.35*	*.29*	*.17*	*.42*	*.39*	*.27*	*.27*	*.21*	*.40*
2	L1 vocabulary	--	**.75**	**.34**	**.37**	**.47**	.27	.14	**.31**	**.21**
3	Phonological STM	--	.06	.07	.13	.20	.14	.20	.15	**.27**
4	Executive processes	--	.09	.07	**.40**	**.34**	**.27**	.23	**.25**	**.39**
5	Phonol. awareness	--	.03	**.24**	.21	.03	**.30**	**.33**	.15	**.36**
3	Phonol. awareness	--	.02	**.25**	**.36**	**.22**	**.39**	**.43**	**.26**	**.53**
4	Phonological STM	--	.06	.03	.00	.17	.01	.04	.06	.07
5	Executive processes	--	.09	.01	**.30**	**.32**	.16	.11	.19	**.25**
	Total R^2	--	*.72*	*.23*	*.47*	*.48*	*.29*	*.28*	*.24*	*.41*

Note: Significant values are marked in boldface, $p < .05$; STM: short-term memory; Decod.: word decoding; R. Comp.: reading comprehension; Spell.: spelling.

Importantly, the data showed that for L3-French-vocabulary and -grammar the pattern of results was different than for L1 and L2: phonological awareness was significantly and highly specifically linked to L3-vocabulary and L3-grammar whereas neither phonological short-term memory nor executive processing accounted for any specific variance over and above phonological awareness. Finally, the results on the L2-literacy measures showed that phonological awareness but not phonological short-term memory was specifically linked to word decoding and spelling; and executive processing accounted for specific variance in reading comprehension and spelling.

A particular interest of the study was to explore the specificity of the links between the cognitive predictors and language proficiency after controlling for L1-oral language. Results are reported in the lower part of Table 3. After controlling for SES (step one) and L1-vocabulary knowledge (step two) the most notable findings are as follows: (1) no specific links between phonological short-term memory and any language measures; (2) executive processing abilities accounted for unique variance in grammar across languages, reading comprehension, and spelling; (3) phonological awareness explained additional variance in word decoding, and spelling, as well as L3-French-vocabulary and L3-French-grammar. Subsequent analyses revealed that the link between phonological awareness and L3-grammar was mediated by L3-vocabulary (accounting for 30% of the variance in L3-grammar). Finally, it is worth highlighting that L1-oral language accounted for 56% of the variance in L2-German-vocabulary versus 12% of the variance in L3-French-vocabulary.

Discussion

The relationship between executive and phonological processing abilities with language learning was explored in young majority-language children acquiring two second languages in the context of multilingual education. Executive processes of working memory, phonological short-term memory, and phonological awareness were found to reflect distinct but related processes differentiated by their associations with different linguistic domains in native and second languages. These findings are inline with the account that phonological short-term memory and awareness repre-

sent separable cognitive domains (Alloway et al., 2004; Gathercole, et al., 2005), and extends it to young multilingual children. The study further showed that executive processing abilities were related to grammar across languages, reading comprehension, and spelling; phonological short-term memory was uniquely linked to vocabulary in L1-Luxembourgish and L2-German; and phonological awareness made specific contributions to word decoding and spelling, and manifested robust links with L3-French.

Importantly, the structurally similar languages Luxembourgish and German shared more than half of their variance and manifested comparable links with the cognitive processing abilities, suggesting a substantial amount of language transfer. L3-French, in contrast, was only moderately related to L1-Luxembourgish and presented a different pattern of associations with the underlying cognitive factors than L2-German. One possibility is that the early acquisition of a second language that shares little structural overlap with children's first language draws on different underlying mechanisms than new word learning in a structurally similar second language. High degrees of phonological overlap between L1 and L2 might favour a word learning strategy in which new L2-words are acquired via a process of bootstrapping onto the secure knowledge base already established for the native language. Learning new words in a phonologically dissimilar second language might not benefit in the same way from existing long-term lexical knowledge. Vocabulary learning might thus be based on lexical and semantic mediation techniques if the second language is familiar whereas new word learning in an unfamiliar second language that does not share many phonological, lexical, and semantic features with the native language might rely on more basic cognitive processes (see Cheung, 1996; Massoura & Gathercole, 2005 for similar findings in different contexts).

An unexpected finding was the absence of a relationship between phonological short-term memory and L3-French-vocabulary which seems to conflict with other studies that identified a link between phonological short-term storage and foreign vocabulary learning (Cheung, 1996; Masoura & Gathercole, 2005; Service, 1992; Service & Kohenen, 1995). Importantly, these studies employed nonword repetition as an index of phonological short-term memory. In the present context, nonword repetition was indeed significantly related to L3-French-vocabulary; however, digit span was not. Measures of phonological awareness, that were clearly distinguishable from nonword repetition (see also Gathercole, 2006), remained significantly related to L3-French even after native vocabulary was controlled. These results indicate that the relationship between nonword repetition and L3-French primarily reflects the processes that phonological short-term memory and phonological awareness have in common. A potential factor that might influence performance on both is the ability to construct well-defined phonological representations from incoming acoustic signals (Boada & Pennington, 2006; Service, Maury, & Luotoniemi, 2007). The capacity to discern the sound system of a language might be particularity important in the early stages of acquiring a second language with an unfamiliar phonology. For Luxembourgish school children, L3-French foreign words are marked by unfamiliar sounds, sound combinations, syllable configurations, and stress assignments. Children thus need to be able to analyse and extract the phonemic details of the foreign L3-French words in order to establish a distinct phonological representation in short-term memory which might then lead to long-term lexical learning. If children merely attend to the primitive characteristics or the salient acoustic shape of the foreign word, phonological representations might be poorly defined and consequently can not be properly encoded in short-term memory. It is important to highlight that the children in this study were assessed after only four months of L3-French instruction and had not been explicitly taught French phonology (which is not part of the Luxembourgish curriculum). It is therefore likely that they had not yet created stable representations of the different sound units in the French language which might have shadowed the contribution of short-term storage to vocabulary learning. Further studies are needed in order to explore whether significant links might emerge at later stages of L3-French learning.

Phonological short-term memory was only indirectly related to other linguistic domains than vocabulary: links with grammar were mediated by vocabulary knowledge and links with literacy were mediated by processes shared with phonological awareness. These results reinforce the position that phonological short-term memory makes specific rather than general contributions to second language learning (Service, 1992; Service & Kohonen, 1995). Phonological awareness was related to word decoding and spelling. These findings are inline with an extensive body of previous research on monolingual children (de Jong & van der Leij, 1999; Goswami, & Bryant, 1990 for a review) and second language learners (Swanson et al., 2011); whether these associations are a cause or a consequence of reading remains open to debate (see Castle & Coltheart, 2004 for a review).

Highly specific links also emerged between executive processing abilities and grammar across languages that were independent of native vocabulary knowledge. To successfully understand syntactically complex sentences various ideas have to be integrated into a coherent and meaningful representation. Executive processes might be needed in order to keep task-

relevant information active while other cognitively demanding activities - such as processing a second language for meaning and transforming a linear sequence of words into a hierarchical structure - are performed. Executive processing was also significantly associated with reading comprehension and spelling but not with word decoding. Understanding written text in German is a cognitively effortful task for young Luxembourgish children in which they have to process the L2 while simultaneously analysing the text for meaning. Similarly, L2-spelling is a complex cognitive activity involving phonological recoding in addition to the manual production of written symbols that is not yet automatic in children of this young age (Bourdin & Fayol, 1994). Decoding single words in German, in contrast, is a highly automatized activity in Luxembourgish school children after 18-months of reading instruction. German is a language with relatively consistent grapheme-phoneme relations, and accuracy of word decoding is obtained quicker than in languages with less transparent orthographies (de Jong & van der Leij, 2002). Indeed, reading accuracy in the present study was 100 per cent and words were read fluently by all children. In this population single word decoding might thus not have been taxing enough to rely on executive processes of working memory. The pattern of findings suggests that the contributions of executive processing abilities to higher-order linguistic activities are inherently linked to the cognitive load of a given task which is likely to change with development. In novice readers word decoding might represent a cognitively demanding activity that relies on executive processes (see Engel de Abreu, et al. 2011). The contributions of executive processes to reading might, however, diminish as proficiency in word decoding develops but remain apparent in more cognitively effortful literacy activities such as reading comprehension or spelling.

Although the study is unique in exploring links between basic cognitive processes and key elements of first and second language acquisition in a large group of multilingual children it is important to highlight the specificity of multilingual education in Luxembourg. Luxembourg's education system is characterized by extensive language teaching, and the use of multiple languages of instruction. A distinctive feature of the system is that children learn to read and write in the second language German but not in Luxembourgish. Whether the presented findings extend to children from other multilingual educational programs (e.g. immersion programs in Canada) remains to be seen. The major limitation of the study was that children had learned L2-German substantially longer than L3-French. Further longitudinal studies are clearly needed in order to confirm that the observed results are related to language typology rather than lengths of instruction.

Conclusion

The presented evidence provides valuable insights into the cognitive underpinnings of second language learning in language-majority children acquiring second languages in the classroom. The study indicates that language familiarity might be an important factor to consider in second language acquisition research: Whereas long-term lexical knowledge in L1 appears to play a crucial role in the acquisition of a familiar L2, native language contributions to L2 learning might diminish and basic cognitive processes gain in importance as familiarity with L1 increases. Most notably basic phonological processing abilities in the native language seem to be an important springboard to success in the learning of a second language with an unfamiliar phonology. Finally, the study showed that executive processes of working memory make general rather than specific contributions to language learning possibly in terms of attentional control mechanisms that actively maintain crucial information and regulate controlling processes during complex and effortful learning activities present in many classroom situations.

Acknowledgements

This project was funded by the National Research Fund of the Grand-Duchy of Luxembourg (FNR) and the Economic and Social Research Council of Great Britain (ESRC). The study is part of a longitudinal research project investigating working memory and learning in childhood. The authors wish to thank the schools, parents, and children who consented to participate in this study; Romain Martin for advice on task design; Christiane Bourg for assistance in scoring; and Lori Astheimer for valuable comments on an earlier version of the manuscript.

Correspondence concerning this article should be addressed to Pascale M. J. Engel de Abreu, EMACS Research Unit, University of Luxembourg, L-7201 Walferdange, G.D. de Luxembourg. Email: Pascale.Engel@uni.lu

References

Alloway, T. P. (2007). *Automated working memory assessment*. London: Pearson Assessment.

Alloway, T. P., Gathercole, S. E., Willis, C., & Adams, A.-M. (2004). A structural analysis of working memory and related cognitive skills in young children. *Journal of Experimental Child Psychology, 87*, 85-106.

Arbuckle, J. L. (2006). *AMOS 7 [Computer software]*. Chicago: SmallWaters.

Astheimer, L., & Sanders, L. D. (2009). Listeners modulate temporally selective attention during natural speech processing. *Biological Psychology, 80*, 23-34.

Baddeley, A. D. (2000). The episodic buffer: a new component of working memory? *Trends in Cognitive Sciences, 4*(11), 417-423.

Baddeley, A. D., & Logie, R. H. (1999). The multiple-component model. In A. Miyake & P. Shah (Eds.), *Models of working memory: Mechanisms of active maintenance and executive control* (pp. 28–61). New York: University Press.

Baddeley, A. D., Gathercole, S. E., & Papagno, C. (1998). The phonological loop as a language learning device. *Psychological Review, 105*(1), 158-173.

Bradley, L., & Bryant, P. E. (1983). Categorizing sounds and learning to read - A causal connection. *Nature, 301*(5899), 419-421.

Bayliss, D. M., Jarrold, C., Gunn, M. D., & Baddeley, A. D. (2003). The complexities of complex span: Explaining individual differences in working memory in children and adults. *Journal of Experimental Psychology: General, 132*(1), 71–92.

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

Bishop, D. (2003). *Test for reception of grammar- 2*. London: Pearson Assessment.

Boada, R., & Pennington, B. F. (2006). Deficient implicit phonological representations in children with dyslexia. *Journal of Experimental Child Psychology, 95*(3), 153-193.

Bourdin, B., & Fayol, M. (1994). Is written language production more difficult than oral language production? A working memory approach. *International Journal of Psychology, 29*(5), 591–620.

Bowey, J. A. (2006). Clarifying the phonological processing account of nonword repetition. *Applied Psycholinguistics, 27*(4), 548-552.

Brownell, R. (2000). *Expressive one word picture vocabulary test*. London: Pearson Assessment.

Cain, K., Oakhill, J., & Bryant, P. (2004). Children's reading comprehension ability: Concurrent prediction by working memory, verbal ability, and component skills. *Journal of Educational Psychology, 96*(1), 31–42.

Case, R., Kurland, D. M., & Goldberg, J. (1982). Operational efficiency and the growth of short-term memory span. *Journal of Experimental Child Psychology, 33*(3), 386–404.

Castles, A., & Coltheart, M. (2004). Is there a causal link from phonological awareness to success in learning to read? *Cognition*, *91*, 77–111.

Cheung, H. (1996). Nonword span as a unique predictor of second-language vocabulary learning. *Developmental Psychology, 32*(5), 867-873.

Chiappe, P., Glaeser, B., & Ferko, D. (2007). Speech perception, vocabulary, and the development of reading skills in English among Korean- and English-speaking children. *Journal of Educational Psychology, 99*(1), 154-166.

Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurement, 20*(1), 37-46.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (second ed.). New York: Academic Press.

Conway, A. R. A., Cowan, N., Bunting, M. F., Therriault, D. J., & Minkoff, S. R. B. (2002). A latent variable analysis of working memory capacity, short-term memory capacity, processing speed, and general fluid intelligence. *Intelligence, 30*(2), 163-183.

Cowan, N., Elliott, E. M., Saults, J. S., Morey, C. C., Mattox, S., Hismjatullina, A., et al. (2005). On the capacity of attention: Its estimation and its role in working memory and cognitive aptitudes. *Cognitive Psychology, 51*(1), 42-100.

Crystal, D. (2003). *A dictionary of linguistics and phonetics* (fifth ed.). London: Blackwell.

Daneman, M., & Carpenter, P. A. (1983). Individual-differences in integrating information between and within sentences. *Journal of Experimental Psychology-Learning Memory and Cognition, 9*(4), 561-584.

de Jong, P. F. (1999). Hierarchical regression analysis in structural equation modeling. *Structural Equation Modeling, 6*(2), 198-211.

de Jong, P. F., & van der Leij, A. (1999). Specific contributions of phonological abilities to early reading acquisition: Results from a Dutch latent variable longitudinal study. *Journal of Educational Psychology and Aging, 91*(3), 450–476.

de Jong, P. F., & van der Leij, A. (2002). Effects of phonological abilities and linguistic comprehension on the development of reading. *Scientific Studies of Reading, 6*(1), 51-77.

Deno, S. L. (1985). Curriculum-based measurement: The emerging alternative. *Exceptional Children, 52*(3), 219-232.

Engel, P. M. J. (2009). *Working memory and learning*. York: University of York.

Engel de Abreu, P. M. J., Conway, A. R. A., & Gathercole, S. E. (2010). Working memory and fluid intelligence in young children. *Intelligence, 38*(6), 552–561.

Engel de Abreu, P. M. J., Gathercole, S. & Martin, R. (2011). Disentangling the relationship between working memory and language: The roles of short-term storage and cognitive control. *Learning and Individual Differences, 21*(5), 569-574.

Engle, R. W., Tuholski, S. W., Laughlin, J. E., & Conway, A. R. A. (1999). Working memory, short-term memory, and general fluid intelligence: A latent-variable approach. *Journal of Experimental Psychology-General, 128*(3), 309-331.

Fehlen, F. (2002). Luxembourg, a Multilingual Society at the Romance/Germanic Language Border. *Journal of Multilingual and Multicultural Development,* 23, 80-97.

Fox, A. V. (2006). *TROG-D: Test zur Überprüfung des Grammatikverständnisses*. Idstein: Schulz-Kirchner.

Frederickson, N., Frith, U., & Reason, R. (1997). *Phonological assessment battery*. London: GL Assessment.

Gathercole, S. E. (2006). Complexities and constraints in nonword repetition and word learning. *Applied Psycholinguistics, 27*(4), 599-613.

Gathercole, S. E., Alloway, T. P., Willis, C., & Adams, A. M. (2006). Working memory in children with reading disabilities. *Journal of Experimental Child Psychology, 93*(3), 265-281.

Gathercole, S. E., & Baddeley, A. D. (1996). *The children's test of nonword repetition*. London: Pearson Assessment.

Gathercole, S. E., Tiffany, C., Briscoe, J., Thorn, A. S. C., & the ALSPAC team. (2005). Developmental consequences of poor phonological short-term memory function in

childhood: A longitudinal study. *Journal of Child Psychology and Psychiatry, 46*(6), 598-611.

Gernsbacher, M. A. (1993). Less skilled readers have less efficient suppression mechanisms. *Psychological Science*, *4*, 294-298.

Gilles, P., & Moulin, C. (2003). Luxembourgish. In A. Deumert & W. Vandenbussche (Eds.), *Germanic Standardizations. Past to Present* (pp. 303-329). Amsterdam: Benjamins.

Goswami, U., & Bryant, P. (1990). *Phonological skills and learning to read*. Hillsdale: Erlbaum.

Gupta, P., Lipinski, J., Abbs, B., & Lin, P. H. (2005). Serial position effects in nonword repetition. *Journal of Memory and Language, 53*(1), 141-162.

Hu, C. F. & Schuele, C. M. (2005). Learning nonnative names: The effect of poor native phonological awareness. *Applied Psycholinguistic, 26*, 343-362.

Jones, G., Gobet, F. & Pine, J. M. (2008). Computer simulations of developmental change: the contributions of working memory capacity and long-term knowledge. *Cognitive Science*, *32*(7), 1148-1176.

Kirps, J., & Reitz, J. (2001). *National report: Grand-Duchy of Luxembourg*. Strasbourg: Council of Europe.

Kirtley, C., Bryant, P., Maclean, M., & Bradley, L. (1989). Rhyme, rime, and the onset of reading. *Journal of Experimental Child Psychology, 48*(2), 224-245.

Kline, R. B. (2005). *Principles and practice of structural equational modeling* (second ed.). New York: The Guilford Press.

Lenhard, W., & Schneider, A. (2006). *ELFE 1-6: Ein Leseverständnistest für Erst bis Sechstklässler*. Göttingen: Hogrefe.

Majerus, S., Poncelet, M., Greffe, C., & van der Linden, M. (2006). Relations between vocabulary development and verbal short-term memory: The relative importance of short-term memory for serial order and item information. *Journal of Experimental Child Psychology, 93*(2), 95-119.

Mann, V. A., & Liberman, I. Y. (1984). Phonological awareness and verbal short-term-memory. *Journal of Learning Disabilities, 17*(10), 592-599.

Masoura, E. V., & Gathercole, S. E. (2005). Contrasting contributions of phonological short-term memory and long-term knowledge to vocabulary learning in a foreign language. *Memory, 13*(3-4), 422-429.

May, P. (2007). *HSP 2: Hamburger Schreibprobe für zweite Klasse*. Hamburg: VPM.

Metsala, J. L. (1999). Young children's phonological awareness and nonword repetition as a function of vocabulary development. *Journal of Educational Psychology, 91*(1), 3-19.

OECD, (2009). *PISA 2006: Technical Report*. Paris: OECD.

Raven, J. C., Court, J. H., & Raven, J. (1986). *Raven's coloured progressive matrices*. London: Pearson Assessment.

Seigneuric, A., Ehrlich, M. F., Oakhill, J. V., & Yuill, N. M. (2000). Working memory resources and children's reading comprehension. *Reading and Writing, 13*(1-2), 81-103.

Service, E. (1992). Phonology, working memory, and foreign-language learning. *Quarterly Journal of Experimental Psychology Section A - Human Experimental Psychology, 45*(1), 21-50.

Service, E. & Kohonen, V. (1995). Is the relation between phonological memory and foreign-language learning accounted for by vocabulary acquisition? *Applied Psycholinguistics, 16,* 155-172.

Service, E., Maury, S., & Luotoniemi, E., (2007). Individual differences in phonological learning and verbal short-term span. *Memory and Cognition, 35*(5), 1122-1135.

Swanson, H. L., Orosco, M. J., Lussier, C. M., Gerber, M. M., & Guzman-Orth, D. A. (2011). The influence of working memory and phonological processing on English language learner children's bilingual reading and language acquisition. *Journal of Educational Psychology, 103*(4), 838-856.

Turner, M. L. & Engle, R. W. (1989). Is working memory capacity task dependent? *Journal of Memory and Language*, *28*, 127-154.

Vallar, G., & Baddeley, A. D. (1989). Developmental disorders of verbal short-term memory and their relation to sentence comprehension - A reply to Howard and Butterworth. *Cognitive Neuropsychology, 6*(5), 465-473.

Wagner, R. K., & Torgesen, J. K. (1987). The nature of phonological processing and its causal role in the acquisition of reading-skills. *Psychological Bulletin, 101*(2), 192-212.

Walton, D., & Brooks, P. (1995). The Spoonerism test. *Educational and Child Psychology, 12*(1), 50-52.

Windfuhr, K. L., & Snowling, M. J. (2001). The relationship between paired associate learning and phonological skills in normally developing readers. *Experimental Child Psychology, 80*(2), 160–173.

Zacks, R. T., & Hasher, L. (1994). Directed ignoring: Inhibitory regulation of working memory. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 241–264). San Diego, CA: Academic Press.

Ziegler, J. C., & Goswami, U. C. (2005). Reading acquisition, developmental dyslexia and skilled reading across languages: A psycholinguistic grain size theory. *Psychological Bulletin, 131*(1), 3-29.