Original Papers

Polish Psychological Bulletin
2016, vol. 47(1) 92–102
DOI - 10.1515/ppb-2016-0010

Marta Białecka-Pikul[*]
Magdalena Kosno[*]
Karolina Byczewska-Konieczny[*]

Where was it? Working memory as a predictor of passive vocabulary development in the third year of life

Abstract: *The objective of the presented research was to test whether working memory, measured using the Spin the Pots task, is an important factor in passive vocabulary development in 2- and 3-year-old children. Two longitudinal studies were conducted. In the first, 135 children participated in the first study. At 18 months their responding to joint attention was measured, and then at 24 months their working memory and passive vocabulary was tested. It was demonstrated that responding to joint attention predicts the level of development of working memory, which in turn influences the extent of the passive vocabulary. In the second study, 113 children participated – at 30 months their working memory was measured, and at 24 months and then 36 months their passive vocabulary was tested. It was observed that at the age of 3 working memory is still a significant predictor of passive vocabulary. The usefulness of the Spin the Pots task for measuring the working memory of young children was shown and discussed in conclusions.*

Key words: *working memory development, passive vocabulary, joint attention*

Introduction

A large body of evidence shows that vocabulary size, that is how many words a preschool child knows, is a significant predictor of later academic achievement (e.g. Alloway, Gathercole, Adams, & Willis, 2005; Biemiller & Boote, 2006; Gathercole, Lamont & Alloway, 2006; Kastner, May, & Hildman, 2001; Ouellette, 2006, Tannebaum, Torgesen, & Wagner, 2006). Looking for the causes if this relationship, we can point to the fact that the passive vocabulary is without doubt a good measure of intelligence (Hornowska, 2005; Wechsler, 2004), as well as argue that having a substantial vocabulary is conducive to the development of the ability to read. It is therefore very important to look for early – or even very early – determinants of vocabulary development, i.e. to ask which factors affect development of passive vocabulary up to the age of 3. However, the objective of the research presented in this paper is not to provide a broad analysis of the factors influencing vocabulary development described to date, but rather to examine what role working memory plays among these factors. Defining working memory as a construct describing not only concurrent maintenance but also manipulation (i.e. processing or updating) of information, we assume that it refers to a mental workspace, determined by the individual's capacity to temporarily store, and more importantly manipulate information (Baddeley, 2007; 2012; Orzechowski, Piotrowski, Balas, & Stettner, 2009; Orzechowski, 2012). We therefore emphasise that Baddeley's central executive (2012) responsible for this process of manipulation is the most important component of working memory, which probably develops later than the visuospatial sketchpad and phonological loop (Carlson, 2005; Gathercole, Pickering, Ambridge, & Wearing, 2004).

In this paper we aim to answer two questions. Firstly, what are the developmental relations between working memory and other predictors of development of the passive vocabulary, more precisely joint attention, and how do these two factors – joint attention and working memory – affect vocabulary development in children of 2 years of age? Secondly, at the age of 3 is working memory still an important factor affecting vocabulary development and the rate at which the vocabulary evolves?

Studies on the significance of vocabulary for later achievements at school stress the importance of conducting research on the determinants of vocabulary development (e.g. Tannebaum, Torgesen, & Wagner, 2006). Many studies show that socio-economic status has an effect on the

[*] **Institute of Psychology, Jagiellonian University**

Presented research was financially supported by a grant from the National Science Centre (no. DEC-2011/01/B/HS6/00453) to Marta Białecka-Pikul.

vocabulary (Hoff, 2003; Fernald, Marchman, & Weisleder, 2013; Pungello, Iruka, Dotterer, Mills-Koonce, & Reznick, 2009; Stokes & Klee, 2009), as does the way mothers speak to their children (e.g. the length of their utterances: Barrett, Harris, & Chasin, 1991; Hoff & Naigles, 2002; Pungello et al., 2009). Among these factors, known as environmental, particularly important is the role of so-called joint attention in the first and second years for a child's linguistic development. Carpenter and colleagues (1998) as well as Tomasello (1988; 1995; Tomasello & Farrar, 1986) argue that longer episodes of joint attention and mothers' tendency to follow their child's attention are factors with a direct effect on the growth of a child's lexicon.

Joint attention, defined as the ability to coordinate attention with a social partner in order to share experience (Rheingold, Hey, & West, 1976), has been studied intensively in infants and toddlers (Bakeman & Adamson, 1984, Mundy, Delgado, Block, Venezia, Hogan, & Seibert, 2003; Seibert, Hogan & Mundy, 1982; Tomasello, 1999). Two different kinds of joint attention are distinguished at behavioural as well as neuronal level (Mundy, 2013), and it has been proved that especially responding to joint attention (meaning the ability to perceive, process and react to external social information about the attention of other people, that is their direction of gaze, head movements, gestures, vocalisations) is related to learning, especially learning new words. Many authors (Baldwin, 1995; Mundy & Brunette, 2005; Scofield & Behrend, 2011; Tomasello, 1995) emphasise that much of early vocabulary acquisition in the 2 year takes place in social learning situations when parents are referring to new objects and events and children need to sort through the number of stimuli to focus on the correct object and acquire an appropriate new word association. Moreover, correlations have been observed between the frequency of responding to joint attention trials during the end of the first year and second year and subsequent vocabulary development in both typically and atypically developing children (Brooks & Meltzoff, 2008; Morales et al., 1998; Mundy et al., 2007; Sigman & McGovern, 2005). Responding to joint attention as the ability that develops during early social interactions and as a kind of social attention seems to be an important factor in vocabulary development. The question is how this ability is related to the cognitive abilities of a preverbal child, such as working memory, and especially the central executive.

Despite the emphasis on the link between attention and working memory (Awh, Vogel, & Oh, 2006; Cowan, 2011; Fougnie, 2008), as yet there has been no research on the connection between joint attention and working memory. Yet it is worth citing those works whose results indirectly prove that such a connection exists. The research of Cuevas and Bell (2014), for instance, demonstrated that 5-month-old infants who look at objects for a shorter time and switch attention between them more quickly (short lookers) subsequently – at 24, 36 and 48 months – attain higher results in tasks measuring their executive functions (including working memory) than children who look at objects longer and are slower to switch attention between them (long lookers). Miller and Marcovitch (2015), meanwhile, show that the symbolic representational skills that develop as a result of joint attention are important predictors of the level of development of the executive function in children aged 2. Van Hecke, Mundy, Block, Delgado, Parlade, Pomares and Hobson (2012) claim that the development of the ability to respond to joint attention of children aged 12 months is linked to later – tested at 36 months – ability in the area of self-regulation measured in the paradigm of delay of gratification. In other words, the cognitive control functions of children aged 3 definitely develop on the basis of earlier abilities of children in such skills as focusing attention, but also on joint attention, the essence of which is focusing attention while interacting with an adult. It seems that the perspective of neo-constructivist theories of cognitive development (cf. Newcombe, 2011) as well as the sociocultural approach to this development (Gauvain, 2013; Rogoff, 2003) provide a suitable theoretical framework allowing us to state that the developmental order of acquisition of skills involves initially mastering them in situations of interaction (e.g. sharing fields of attention with an adult), in order for them to gradually become abilities of an individual operating independently and without adult support. The above arguments incline us to accept the premise that in looking for early predictors of vocabulary development in 3-year-old children it is legitimate to test – consecutively – first joint attention, and then the working memory that may develop on its basis.

The first thing that must be stressed with reference to the connection between development of working memory and vocabulary is its mutual – or bi-directional – nature. Wolfe and Bell (2007), in their study of the influence of the vocabulary on working memory, demonstrated that language and temperament – and specifically effortful control – are good predictors of working memory and explain even 39% of variance of working memory measured in 4-year-old children. The correlation between the measurements of passive vocabulary and effortful control was between .33 and .48, but more importantly the link between vocabulary and working memory was not only strong, but its strength increased with age (from the group of 2-year-olds $r = .51$, $p = .02$; for the group of 4-year-olds: $r = .55$; $p = .01$; for the group of 4.5-year-olds: $r = .78$, $p < .001$). We should note that the measurements of working memory in these studies were go-no/go-type tasks, which, although they required participants to remember a rule, were more concerned with measuring the aspect of hindering than manipulation of information. Other studies on preschool children also show that the developing vocabulary affects the working memory, especially through its influence on changes in the phonological loop. For example, an increase in processing speed permits fast verbal rehearsal, leading to more efficient retaining of information in the verbal working memory (Fry & Hale, 2000). Barrouillet, Bernardin and Camos (2004) argue that faster processing speed can also result in better use of the executive processes of attention, thus release resources that can be allocated to updating or refreshing representations in working memory.

It appears, however, that a larger number of studies point to the reverse relationship – i.e. the influence of working memory on vocabulary development. We should stress that this is usually research involving preschool and older children (Baddeley, Gathercole, & Papagno, 1998; Gathercole, 2006; Gathercole, Willis, Emslie, & Baddeley, 1992). Gathercole and Baddeley (1989) showed that verbal working memory of children aged 4 is a predictor of vocabulary development a year later (even when the level of vocabulary development is controlled at age 4). They also revealed that the vocabulary level at age 4 is not a significant predictor of working memory at age 5 (Gathercole et al., 1992). Savage, Cornish, Manly and Hollis (2006), meanwhile, who studied children aged between 6 and 11, proved that the phonological loop and "central processing" measures are predictors of reading ability, even when age and intelligence level are controlled. Pham and Hasson (2014) also demonstrated that in children aged 9–12, verbal working memory was a stronger predictor in reading fluency and comprehension, and visuospatial working memory also significantly predicted reading skills. Gathercole and Baddeley (1993) emphasise that development of the phonological loop and central executive supports the growth of skills in vocabulary, comprehension, reading, and speech production.

Research on younger – aged 2 to 3 – children also reveals the influence of working memory on linguistic development, especially when measured through such indicators as length of utterance or active vocabulary. For example, Blake, Austin, Cannon, Lisus and Vaughan (1994) demonstrated that phonological working memory capacity is a better predictor of mean length of utterance in 2- and 3-year-olds than chronological and mental age. Adams and Gathercole (1995) proved that phonological short term memory (PSTM) predicts quantity and quality of spontaneous speech in 3-year-old children. Children with a higher PSTM level produced longer utterances containing a greater range of syntactic structures and lexical diversity compared to children with a lower PSTM level. Furthermore, in the third and fourth year children with a good phonological working memory also have a higher level of verbal fluency than children with a lower level of this memory (Adams & Gathercole, 1995). Stokes and Klee's (1995) research on the determinants of language development in 24–30-month-old children, meanwhile, showed that among such factors as economic status, nonverbal cognitive development, processing skill (fast mapping), phonological working memory (PWM), gender and age, it was PWM that was the best predictor of vocabulary development in children (explaining some 36% of variance). In summary, the above results of research essentially concern PWM and its effect on language development. The research presented in this paper aimed to test the influence of the executive and non-verbal component of working memory on the development of vocabulary in children in early childhood.

The next point in favour of the argument that working memory is a factor in vocabulary development is the results of research involving children with impaired language development. Montgomery and Evans (2009) demonstrated that children in the age range from 6 to 12 years with Specific Language Impairment (SLI) perform worse on measures of verbal working memory than their matched peers do, and are characterised by a lower level of complex sentence comprehension. In other research, Hick, Botting and Conti-Ramsden (2005) showed that 4-year-old children with SLI have a lower level of verbal working memory than a control group selected on the basis of age and non-verbal level of intelligence. Swanson's (2003; 2006) research on people with dyslexia (aged from 5 to adult) proved that children with reading disabilities possesses impairments not only in their phonological STM, but also in the central executive. Referring to research involving very young children, we ought also to cite the work of Fernald, Marchman and Weisleder (2013), whose research on two groups of children – those developing normally and so-called late takers – at 18 and 30 months indicated that it is the executive aspect of working memory, and specifically processing efficiency in word recognition evident in infancy, that have cascading consequences for later word learning.

The main reason for the fact that relatively few studies tackle the issue of the link between working memory and language development in children younger than preschool age would appear to be the limited possibility of measuring the central executive in early childhood. In children in early childhood, search tasks are usually employed: in 1-year-old children this is an A-not-B task (Diamond, 1985; 2002), in 2–3-year-olds a multilocation search task, an example of which is the Spin the Pots task (Hughes & Ensor, 2005). Interestingly, the construction of the Spin the Pots task is very similar to the Spatial Working Memory task from the CANTAB test battery (Conklin, Luciana, Hooper, & Yarger, 2007) used in study of older children from 4 upwards and adults. In this task, the subjects must find blue tokens hidden in boxes of various colours. In each trial in several boxes on the screen only one blue token is hidden, and in a given location on the screen a token is only hidden once. The participant must therefore remember where he/she found the token. The Spatial Working Memory task requires that participants generate a strategy, update information with each response selection and monitor performance across selections. Thus, this task is generally conceptualised as placing a heavier demand on the working memory central executive or being higher in processing demands than SPAN-type tasks (e.g. D'Esposito, Aguirre, Zarahn, Ballard, Shin, & Lease, 1998; Luciana, Conklin, Hooper, & Yarger, 2005).

As a result of these characteristics, in our research we selected the Spin the Pots task (Hughes and Ensor, 2005) as a measurement of the executive aspect of working memory and as a task measuring non-verbal, spatial working memory. We should begin with a brief description of this task in order to show its other characteristics that make it ecologically suitable in studying children aged 2 and 3. Firstly, it has a "play" character – the tester sits opposite the child, at a table with a turning tray on it, on which coloured boxes are placed. In this task the children look for real stickers hidden in the boxes. They must remember in which boxes the stickers were placed at the beginning, because in subsequent trials they look for the stickers and win them upon finding them. When looking for the stickers, a child must therefore remember which boxes the stickers were hidden in, and which were empty at the start or became empty (temporary store of information), i.e. after every sticker find the child must update information. This construction of the task therefore means that it is the central executive, not just the short-term memory, that is measured. The prize element acts as a motivation to the child, which is extremely important when testing 2- and 3-year old children. Most important, however, is the fact that the measurement is taken in a situation of an interaction with an adult, when they first hide the stickers together, and then the child points to the box and receives feedback from the adult. To conclude, in Spin the Pots task as also in described earlier Spatial Working Memory task the default question which a child could instantly ask her/himself "in mind" is "Where it was?" The right answer for this question could be used as an expression of the child's ability to store and update the information.

In summary of these opening remarks, we must again stress that in developmental psychology both the passive vocabulary and the working memory, especially verbal working memory measured by SPAN-type tasks, and the mutual relations between them, are most frequently studied in preschool children (review: Gathercole et al., 1992; Jarrold, Thorn, & Stephens, 2009; Kirkham, Cruess, & Diamond, 2003; Müller, Jacques, Brocki, & Zelazo, 2009). Our research therefore constitutes an important supplement to the previous knowledge on the subject. In it, we first check how, together and independently from each other, joint attention and working memory make it possible to predict the level of vocabulary development in 2-year-old children. This age is when, following the single word stage, children enter a period of using their two word sentences. Moreover it is also the first important moment when it is not only with the help of parental report, but also using the standardised tool of Polish version of Peabody Test, naming Picture Vocabulary Test – Comprehension (OTSR; Haman & Fronczyk, 2012) we can precisely measure children's passive vocabulary. Secondly, we test whether in the third year of life an important role continues to be played by the working memory, and therefore whether at the age of 3 it is a predictor independent of the level of vocabulary development both of the extent of vocabulary and of the rate of its change over the course of the third year. The age of 3, when children are already able to use sentences (Kurcz, 2005), is regarded as a significant moment in language development. Describing the role played by working memory in language development – and specifically in development of the passive vocabulary in early childhood – is the fundamental objective of our research.

Study 1

In the first study we tested the assumption on the role of working memory as a factor mediating in language development in the second year. The model employed assumed that this variable would be linked both to early social competences (responding to joint attention, measured at 18 months) and to vocabulary in children at 24 months. We checked whether it is possible to observe the following developmental system: responding to joint attention as a predictor of working memory, constituting the next important factor of vocabulary development. By way of comparison, we also tested two other models in which responding to joint attention and working memory are treated as independent or interacting predictors of vocabulary at age 2.

Method

Subjects

A total of 135 children aged around 18 months participated in the research (mean age 80.34 weeks, standard deviation 1.73 weeks, range 76.71–87.23 weeks) – 65 girls and 70 boys. The children were mostly from a large-city environment (76% of the group), and their parents were generally educated to degree level (57% of the group). The parents indicated their interest in taking part in the study after receiving an invitation via regular mail or e-mail. First the children were studied between September and December 2012, and then again the same children were tested aged 24 months (mean age 104.24 weeks, standard deviation 1.82 weeks, range 101.14–112.00 weeks) from March to June 2013.

Research procedure

The study was carried out in the Child Development Psychology Lab at the Institute of Psychology of the Jagiellonian University in Krakow. The children participated in two meetings (aged 18 months and 24 months) together with their parents. Both meetings were preceded by free play during which each child had the opportunity to get to know the new place and the tester. The study lasted about 60 minutes and took the form of structured play, during which the tester proposed various activities and objects to the child among which those involving responding to joint attention (at 18 months) and working memory and passive vocabulary (at 24 months) were carried out. The meetings with the child were filmed using two cameras placed in opposite corners of the room in which the research was taking place. From the point of view of the child's position in the room, one camera was in the left corner in front of the child, and the other was in the right corner behind the child, filming the behaviour of the tester.

Measures

Responding to Joint Attention measured with Early Social Communication Scales. Time 1

A set of objects and toys was used to measure the children's early nonverbal communication competencies. The tester and the child sat opposite each other at a table (the child sat on his/her parent's lap), and to the right of the tester were toys that were visible to the child but out of his/her reach. On the walls of the room were four posters – one to the left and one to the right of the child (90°) as well as two behind the child's back (165°). The tasks used to measure Responding to Joint Attention was performed with these posters. The tester pointed to the poster calling child's name and waited if a child looked to the poster. All examples of tasks used and the full coding procedure based on video recordings are described by the authors of the Early Social Communication Scale (Mundy et al., 2003), and also in the study on Polish version of this tool (Białek, Białecka-Pikul & Stępień-Nycz, 2014). Kappa coefficient between two independent coders assessed for 25% of obtained data was satisfactory (.72, $p<.001$)

Working Memory Task. Time 2

Working memory was measured with a modified version of the Spin the Pots task (Hughes & Ensor, 2005). In this task the child has to find the stickers hidden in boxes. At first the tester shows the child five different stickers and five boxes differing in colour and size. The child and the tester together hide stickers in the boxes (only one sticker could be in each box). Then all boxes are put on a large rolling tray and covered with a scarf. The tester spins the tray (during this time the boxes are covered so the child can not see them), and then the tester removes the scarf. The child sees the same set of boxes, but after spinning the tray they have a different location than before. The child is asked to find a sticker by pointing at the correct box. Then the procedure is repeated until the child has found all the stickers (or up to ten trials). The subsequent trials are more difficult, because the child has to remember which boxes are still full, and involve updating information about the contents of the boxes. The scores were calculated as following: 10 (according to the maximum number of trials that the child could perform) minus the total number of mistakes made by the child. It is worth mentioning that in the original task (Hughes & Ensor, 2005) there were more boxes than stickers at the beginning of the task, but we decided to make the task easier for 2-year-olds and start with the same number of stickers and boxes. This meant that the task easier during the first trial, when the child can always win a sticker as all boxes contain one, but does not change the idea of the task, that the child still has to update information during subsequent trials.

Vocabulary Task. Time 2

Haman and Fronczyk's Picture Vocabulary Test – Comprehension (OTSR) (2012) comprises 88 four-picture cards (51 nouns, 25 verbs and 12 adjectives). The cards feature pictures corresponding to the key word (about which the child is asked), as well as a phonetically similar word, semantically similar word and thematically similar word. The task has two equivalent versions (A and B).

The child's task upon seeing the card is to point to one of the four pictures in reaction to the question about the key word. For example, the child, looking at four pictures (sun, bun, star, beach), is asked: Where is the sun? The correctness of the answers given, as well as the number of errors of a phonetic, semantic and thematic nature are all assessed in this task (the last two indicators were not considered in the analyses presented below).

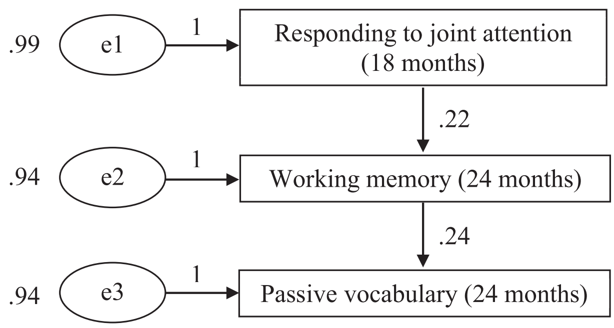
Results

Descriptive statistics of all variables – responding to joint attention (measured at 18 months), working memory and passive vocabulary (both measured at 24 months) – are presented in Table 1.

Three models of relations between the variables included in the study were tested. In the first one the following developmental relation was tested: responding to joint attention → working memory → passive vocabulary. In the second, working memory was treated as independent from responding to the joint attention predictor of passive vocabulary. In the third model, the interaction between working memory and responding to joint attention was included as a predictor of passive vocabulary. To make interpretation easier all analyses were conducted on standardised data.

The results of testing the first model are presented in Figure 1.

Figure 1. Model of following relations: responding to joint attention → working memory → passive vocabulary at 24 months



In this model both paths are significant: from responding to joint attention to working memory ($p<.01$) and from working memory to passive vocabulary ($p<.01$). The whole model fits the data well (chi^2=1.39; p=.24; *chi2/df*=1.39; *CFI*=.97; *RMSEA*=.05).

The second model is presented in Figure 2.

Table 1. Descriptive statistics of variables measured in Study 1

	Range	*M*	95% *CI*	*SD*	Median
Responding to joint attention (18 months)	0.00–200.00	169.44	163.02–175.87	37.72	175.00
Working memory (24 months)	2.00–10.00	8.01	7.67–8.36	2.05	8.00
Passive vocabulary (24 months)	0.00–40.00	9.86	8.23–10.89	6.05	9.00

Figure 2. Model of working memory and responding to joint attention as independent predictors of passive vocabulary at 24 months

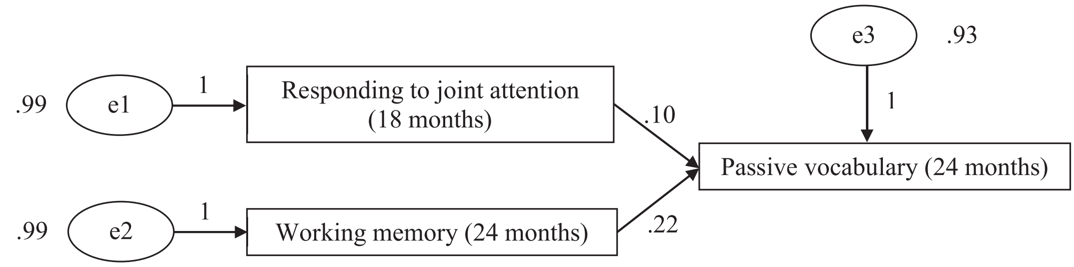
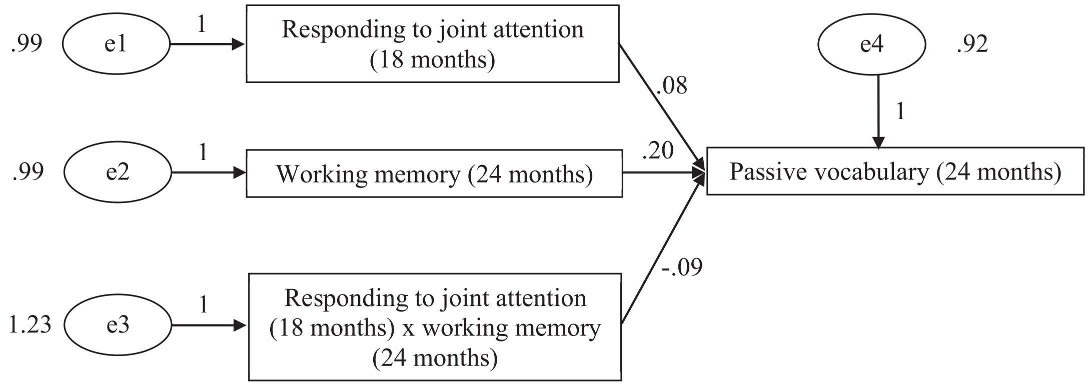


Figure 3. Model of working memory, responding to joint attention and interaction between them as predictors of passive vocabulary at 24 months



In this model only the path between working memory and passive vocabulary is significant (p<.01). The relationship between responding to joint attention and passive vocabulary is weak and not significant (p=.23). The whole model does not fit the data well (chi^2=6.90; p=.01; *chi2/df*=6.90; *CFI*=.55; *RMSEA*=.21).

In the third model, the interaction between responding to joint attention and working memory as a predictor of passive vocabulary was added. The results are presented in Figure 3.

As previously, only the path between working memory and passive vocabulary is significant (p<.05). The role of responding to joint attention (p=.33) and interaction (p=.21) is small (both paths are not significant). The whole model does not fit the data well (chi^2=15.53; p<.01; *chi2/df*=5.18; *CFI*=.38; *RMSEA*=.18).

Discussion

Of the three models of the relationship between the variables tested – responding to joint attention (measured at 18 months) as well as working memory and vocabulary (both measured at 24 months), only one proved to be a good fit to the data. It presents a relationship in which working memory is a statistically significant predictor of language development of 2-year-olds, and its efficiency is conditioned by the child's earlier competences in joint attention. The two other models, in which responding to joint attention and working memory were treated as two independent predictors of vocabulary, were not confirmed. In each of them, however, a significant role of working memory for vocabulary development in 2-year-olds was confirmed.

The results that we obtained provided confirmation for our hypothesis about the significance of working memory for early language development. As in the research of Stokes and Klee (2009), it was observed that working memory is a good predictor of a children's vocabulary. This regularity is also observed in older children. As Gathercole and Baddeley (1989) showed, working memory measured at the age of 4 is a significant predictor of vocabulary measured in the same children a year later, but vocabulary at age 4 is not a significant predictor of working memory at age 5.

The importance of early ability of joint attention for vocabulary development was also partially confirmed. In the models in which this variable was considered as an independent predictor of the vocabulary of 2-year-olds, the resulting relationships were not statistically significant, although the direction was in accordance with the trend observed in other studies (Brooks & Meltzoff, 2008; Morales et al., 1998; Mundy et al., 2007; Sigman & McGovern, 2005) – the higher the level of ability to respond to joint attention at 18 months, the larger the passive vocabulary at 24 months. It turned out, however, that for language learning to be effective, not only is the child's engagement in social situations necessary (specifically: participating in episodes of joint attention) (Baldwin, 1995; Mundy & Brunette, 2005; Tomasello, 1995), but also possession of early cognitive resources.

Study 2

In Study 1, the importance of working memory for the linguistic competences that emerge in the second year was confirmed, as an independent predictor of them. In the subsequent study, we wished to establish whether working memory continues to be a significant factor in development of the passive vocabulary in the third year, when the child already has an extensive number of words and begins to use them to construct sentences. We therefore performed a study which considered three variables: the extent of the passive vocabulary, measured at 24 months and 36 months, and the working memory, measured at 30 months. We checked whether, apart from vocabulary at age 2, working memory is a significant predictor of vocabulary development at age 3. The analyses took into account the importance of the working memory for the rate of change, i.e. the growth of the passive vocabulary in the third year – between the ages of 2 and 3.

Method

Subjects

A total of 113 children participated in the research – 48 girls and 65 boys. The children were mostly from a large-city environment (72% of the group), and their parents were generally educated to degree level (59% of the group). The parents indicated their interest in taking part in the study after receiving an invitation via regular mail or e-mail. On the first occasion, the children were studied between March and June 2013, aged 24 months (mean age 104.01 weeks, standard deviation 1.73 weeks, range 101.43–112.00 weeks). The second time, the same group was tested between September and December 2013, when the children were 30 months old (mean age 129.15 weeks, standard deviation 1.42 weeks, range 125.14–133.14 weeks). The third meetings were held between March and June 2014, at 36 months (mean age 154.21 weeks, standard deviation 1.48 weeks, range 150.10–160.00 weeks). The procedure and venue of the study were exactly the same as in Study 1.

Working Memory Task. Time 1

Again, the Spin the Pots task (Hughes & Ensor, 2005) was used, but this time a small modification was made. Eight boxes were presented to the children. Stickers were placed inside six of them, and two remained empty, as in the original procedure used in the research of Hughes & Ensor (2005). The children were asked to find stickers in 10 trials. The result was calculated by subtracting from 10 the number of incorrectly identified empty boxes.

Vocabulary Task. Time 2

To measure vocabulary at 36 months, Haman and Fronczyk's Picture Vocabulary Test – Comprehension (OTSR) (2012) was again used.

Results

The descriptive statistics of all variables: passive vocabulary (measured at 24 and 36 months) and working memory (measured at 30 months) are presented in Table 2.

At first the regression model with two variables (passive vocabulary at 24 months and working memory at 30 months) as independent predictors of passive vocabulary at 3 years was tested. The results are presented in Table 3. The model with two predictors explains about 23% of variance ($F_{(2.110)}$=15.58; p<0.001). Both predictors are significant.

When we added to this model the interaction between passive vocabulary (at 24 months) and working memory (at 30 months), R^2 increased by .01. This change was not significant ($F_{(1.111)}$=1.79; p=.18).

The variable referring to the rate of change in passive vocabulary between 24 and 36 months was then introduced into the analysis. It was calculated as the following subtraction: points in OTSR at 36 months minus points in OTSR at 24 months. The descriptive statistics of this variable were as follows: range=<-6.00; 39.00>; *M*=12.62; *95% CI*=<10.67; 14.57>; *SD*=10.50; median=11.00. The model with working memory (measured at 30 months) as a single predictor of rate of change in passive vocabulary between 24 and 36 months

Table 2. Descriptive statistics of variables measured in Study 2

	Range	*M*	95% *CI*	*SD*	Median
Passive vocabulary (24 months)	0.00–29.00	10.47	9.47–11.47	5.44	9.00
Working memory (30 months)	2.00–10.00	7.44	7.10–7.79	1.89	8.00
Passive vocabulary (36 months)	1.00–61.00	23.09	20.95–25.23	11.63	21.50

Table 3. Results of regression analysis (stepwise method)

Dependent variable	Predictors	*Beta*	ΔR^2	*t*	*p*
Passive vocabulary (36 months)	Passive vocabulary (24 months)	.42	.19	4.94	<.001
	Working memory (30 months)	.19	.04	2.25	.03

was tested. The relation obtained was on the border of significance ($F_{(1,111)}$=3.45; *p*=.066; *Beta*=0.17). The model explained 3% of variance.

Discussion

In Study 2, we tested whether at age 3 working memory continues to be a significant predictor of vocabulary. One would have to assume this based on the results of research conducted on groups of children of preschool age and older, which show that this variable is an important factor in vocabulary development (e.g. Baddeley, Gathercole, & Papagno, 1998; Gathercole et al., 1992; Gathercole, 2006). The developmental importance of early working memory resources for the language resources of 3-year-old children was confirmed. Although this factor was less significant than a child's vocabulary at the age of 2, incorporating it into the regression model raised the percentage of explained variance, and this was a statistically significant change. The interaction between the working memory and vocabulary at age 2, meanwhile, was shown to be insignificant for vocabulary development at 36 months. When the rate of developmental changes occurring in this area in the third year was also considered in the analyses, the importance of the working memory was smaller, although the tested model was on the border of statistical significance.

General discussion

The model of working memory proposed by Baddeley and Hitch (1974) and later modifications (Baddeley, 2000; 2007; 2012) was an important inspiration for further research, including in developmental psychology (Courage & Cowan, 2009). These studies have tested such questions as whether the identified elements are also observed in children (Alloway et al., 2004; Gathercole et al., 2004; Henry, 2012), how not only the scope of memory, but also its important control or executive dimension changes over the years (Frye, Zelazo & Palfai, 1995; Zelazo, Frye, & Rapus, 1996), and also how the link between working memory and language evolves (e.g. Gathercole & Baddeley, 1989; 1993; Gathercole et al., 1992; Stokes & Klee, 2009; Wolfe & Bell, 2007). It has therefore been described how in children who speak competently – i.e. from age 4 onwards – the phonological loop and visuospatial sketchpad change, or even, employing tasks such as the Complex Digit Span or Backward Digit Recall (e.g. Alloway et al., 2004), what form is taken by changes in the central executive. Currently, researchers (e.g. Reznick, 2009) believe that research on working memory can and should also be conducted on very young children – aged up to 3 – in order to discover the developmental foundations of later changes. Our studies belong to this type of research, as in searching for very early determinants of vocabulary development in children we tested whether working memory measured with the Spin the Pots task is an important predictor of this development. The results we obtained allow us to answer to this question in the affirmative.

Firstly, we observed that working memory is an important factor determining the level of development of the passive vocabulary in children aged 2. The model best suited to our data was one in which the development of working memory at age 2 has an effect on vocabulary development, and at the same time the development of working memory is conditioned by the influence of joint attention, a competence that forms earlier in development.

From the point of view of research on cognitive development, the result showing that there is a connection between joint attention and working memory should be viewed as an important and new result. Previously, such a link has been demonstrated only by indirect data. Van Hecke and colleagues (2012) showed that joint attention of 12-month-old children is a significant predictor of the level of self-regulation of 3-year-olds, while Miller and Marcovitch (2015) proved that, through its influence on symbolic representation, it can aid the development of executive functions. Referring to Miller and Marcovitch's (2015) research, our studies also confirmed that the source of manipulation of information and representations is in joint interaction with an adult, when the child can engage joint attention. Responding to joint attention proved to be a significant predictor of working memory, which is itself an important predictor of development of the ability to understand symbols, i.e. passive vocabulary in children at 24 months. Our results support the idea that the ability to "keep in mind" (Olson, 1993) important information develops in 12- and 18-month-old children when an adult and a child together, in a triadic interaction (child-object-adult), pay attention to a given element of reality. By exercising his/her social attention with an adult – i.e. responding to the adult's attention – the child develops the ability to focus attention. These are the later control functions of attention which are the essence of the central executive of working memory. Our research shows that joint attention helps the development of working memory in children even in the second year. Although on the basis of one set of studies it is hard to identify a direct application of the results, it does allow us to state that in the practice of caring for a young child it is important to stress appreciation and support of any activities demanding joint attention during interaction with an adult, in order to stimulate the child's cognitive development.

Secondly, we also demonstrated that if working memory and joint attention are to be treated as either independent or also interacting predictors of vocabulary development at age 2, although such models are not a good fit for the data, working memory is always the predictor that allows the extent of passive vocabulary to be predicted. In the age of 2, therefore, working memory is an important factor affecting vocabulary formation. The efficiency of language acquisition is influenced by joint attention (Baldwin, 1995; Mundy and Brunette, 2005; Tomasello, 1995) – not indirectly, however, but through working memory, which illustrates the role of a child's early cognitive resources for his/her later development. This result should be emphasized as it adds new knowledge into area of child development: responding to joint attention influences vocabulary development via child's cognitive resources, namely working memory capacity. Especially interesting is that it was for passive – not only for active vocabulary development – that executive, non-verbal aspect of working memory turned to be significant factor. So even language understanding as a base of whole cognitive development may be triggered by working memory, especially its active component.

The research cited earlier showed the importance of verbal working memory and the central executive for language development in preschool and older children (Adams & Gathercole, 1995; Blake et al., 1994; Gathercole & Baddeley, 1993; Savage et al., 2006). SPAN tasks were most often employed to measure these elements of working memory, meaning that this measurement is possible only in children at preschool age (e.g. Alloway et. al., 2004; Müller et al., 2009). However, at an earlier stage – in the second and third years – important changes are observed in language development, also concerning increase in vocabulary (Kurcz, 2005). The importance of the phonological component of working memory for the vocabulary of 24–30-month-old children was demonstrated by Stokes and Klee (2009). They used a nonword-repetition task, but their research showed that this task was solved by only 77% of mostly older – 2.5-year-old – children. This reveals the difficulties in testing the verbal working memory of children younger than preschool age. In our research, in order to test the significance of working memory for passive vocabulary development we employed tasks measuring the executive and spatial aspect of working memory. Pham and Hasson (2014) showed the importance of the visual-spatial component of working memory for language skills, albeit in later childhood, in this case in reading ability. Both studies presented in the article demonstrated something more: that working memory, measured by a non-verbal, spatial task, is a significant predictor of vocabulary development in early childhood. Our research therefore provides further information on the significance of working memory for language development in young children, revealing that the spatial, non-verbal aspect of working memory is also important in passive vocabulary development in the second and third years, as well as proving that it is possible to test this working memory in young children effectively. Although Henry (2012) emphasized that components of working memory are separate at age 6 we managed to provide initial proof of the role of its active, executive component in language development.

Thirdly, in the next study we were able to confirm that in the third year too working memory still affected the developing passive vocabulary. It was observed that the very extent of a child's vocabulary at age 2 determines what the extent will be at age 3, but working memory measured at age 2.5 continued to be an important variable, which explained an additional 4% of the variance in the child's vocabulary at age 3.

Working memory also remains an important predictor of passive vocabulary development in the third year. An appropriate level of vocabulary permits a child to proceed to the next stage of language development, in which children begin to join words together and construct two-word clusters and sentences (Kurcz, 2005). Working memory can also be of significance for the rate of developmental changes in the passive vocabulary over the course of the second and third years. The results of our research show that working memory is a significant factor in language development starting in early childhood, when language is only beginning to emerge and working memory is visual-spatial in nature, and throughout childhood, when the child starts to build sentences consecutively or to learn to read. Language development affects development of the executive and verbal aspect of working memory, which in turn influences the subsequent stages of language development, including reading. Research suggest that this can decide on a child's success at school (e.g. Alloway et al., 2005; Biemiller & Boote, 2006; Tannebaum et al., 2006).

Finally, it is worth looking at the methodological aspect of our research. An undoubted asset was the fact that a large group of children was studied using a longitudinal approach. As Reznick (2009) argues, only microgenetic and longitudinal studies can bring important discoveries on the early manifestations and mechanisms of development of working memory. The difficulty with studying the youngest children results from the importance of motivation for completing a task, which in older children can be supported by the very fact of conscious participation in research, and in the youngest children might be assured by good contact with the adult-tester, a friendly atmosphere of play or a reward, e.g. winning stickers. The Spin the Pots task has an additional feature making it an attractive method to be used again, which also confirms our suspicion that if we were to ask a 2-year-old to repeat numbers or words backwards the "floor result" would have to be viewed as an artefact and not a real measurement of working memory. The Spin the Pots task allows not only short term memory to be measured, but also the executive component of working memory. It could be even called „Where it was" as these expressed the idea that updating of information is the most import skilled measured by this task. A further important feature of the Spin the Pots task was its interactive character. Together with the adult, the child focused his/her attention on hiding the stickers in the boxes, after each trial receiving feedback on his/her behaviour from the adult.

In future research, important supplementary information on the relationship between working memory and language in early childhood would be provided by testing the significance of working memory for development of the active vocabulary and even other linguistic competences, grammatical as well as phonological and pragmatic. Seeing cognitive development as the process of active construction (Newcombe, 2011) we found – using Spin in the Pots paradigm – that executive aspect of working memory may play important role in language development. Showing the link between responding to joint attention and working memory leads us to plan research that aim to determine also the role of initiating joint attention, as well as other communicative behaviours, for the development of working memory. Moreover we are now more convinced that generally working memory should and can be studied in young children and it is an important factor of their cognitive development.

References

Adams, A. M., & Gathercole, S. E. (1995). Phonological working memory and speech production in preschool children. *Journal of Speech, Language, and Hearing Research*, *38*(2), 403–414. DOI:10.1044/jshr.3802.403

Alloway, T. P., Gathercole, S. E., Adams, A. M., & Willis, C. (2005). Working memory abilities in children with special educational needs. *Educational and Child Psychology, 22*, 56–67.

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*(2), 85–106. DOI:10.1016/j.jecp.2003.10.002

Awh, E., Vogel, E. K., & Oh, S. H. (2006). Interactions between attention and working memory. *Neuroscience*, *139*(1), 201–208. DOI:10.1016/j.neuroscience.2005.08.023

Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences, 4*(11), 417–423. DOI:10.1016/S1364-6613(00)01538-2

Baddeley, A. D. (2007). *Working memory, thought, and action*. Oxford: Oxford University Press.

Baddeley, A. D. (2012). Working memory: theories, models, and controversies. *Annual Review of Psychology*, *63*, 1–29. DOI: 10.1146/annurev-psych-120710-100422

Baddeley, A. D., & Hitch, G. J. (1974). Working memory. In: G. A. Bower (Ed.) *The psychology of learning and motivation*, Vol. 8. (pp. 47–89). New York: Academic Press.

Baddeley, A., Gathercole, S., & Papagno, C. (1998). The phonological loop as a language learning device. *Psychological Review*, *105*(1), 158–173. http://dx.doi.org/10.1037

Bakeman, R. & Adamson, L. B. (1984). Coordinating attention to people and objects in mother-infant and peer-infant interaction. *Child Development*, *55* (4), 1278–1289.

Baldwin, D. A. (1995). Understanding the link between joint attention and language. In: Ch. Moore, P. J. Dunham (Eds.) *Joint attention: Its origins and role in development*, 131–158. Hillsdale, NJ: Erlbaum.

Barrett, M., Harris, M., & Chasin, J. (1991). Early lexical development and maternal speech: A comparison of children's initial and subsequent uses of words. *Journal of Child Language*, *18*(01), 21–40. DOI: 10.1017/S0305000900013271

Barrouillet, P., Bernardin, S., & Camos, V. (2004). Time constraints and resource sharing in adults' working memory spans. *Journal of Experimental Psychology: General*, *133*(1), 83–100. DOI: 10.1037/0096-3445.133.1.83

Białek, A., Białecka-Pikul, M., & Stępień-Nycz, M. (2014). The Nature of Child-Adult Interaction. From Turn-Taking to Understanding Pointing and Use of Pointing Gestures. *Psychology of Language and Communication*, *18*(2), 87–105. DOI: 10.2478/plc-2014-0008

Biemiller, A., & Boote, C. (2006). An effective method for building meaning vocabulary in primary grades. *Journal of Educational Psychology*, *98*(1), 44–62. DOI: 10.1037/0022-0663.98.1.44

Blake, J., Austin, W., Cannon, M., Lisus, A., & Vaughan, A. (1994). The relationship between memory span and measures of imitative and spontaneous language complexity in preschool children. *International Journal of Behavioral Development*, *17*(1), 91–107. DOI: 10.1177/016502549401700106

Brooks, R., & Meltzoff, A. N. (2008). Infant gaze following and pointing predict accelerated vocabulary growth through two years of age: A longitudinal, growth curve modeling study. *Journal of Child Language*, *35*(01), 207–220. DOI: 10.1017/S030500090700829X

Carlson, S., M. (2005). Developmentally sensitive measures of executive function in preschool children, *Developmental Neuropsychology,* 28, 2, 595–616. DOI:10.1207/s15326942dn2802_3

Carpenter, M., Nagell, K., Tomasello, M., Butterworth, G., & Moore, C. (1998). Social cognition, joint attention, and communicative competence from 9 to 15 months of age. *Monographs of the Society for Research in Child Development*, 63(4), i–174. DOI: 10.2307/1166214

Conklin, H. M., Luciana, M., Hooper, C. J., & Yarger, R. S. (2007). Working memory performance in typically developing children and adolescents: Behavioral evidence of protracted frontal lobe development. *Developmental Neuropsychology*, *31*(1), 103–128. DOI: 10.1080/87565640709336889

Courage, M. L., & Cowan, N. (Eds.). (2009). *The development of memory in infancy and childhood*. Hove, UK: Psychology Press.

Cowan, N. (2011). The focus of attention as observed in visual working memory tasks: making sense of competing claims. *Neuropsychologia*, *49*(6), 1401–1406. DOI:10.1016/j.neuropsychologia.2011.01.035

Cuevas, K., & Bell, M. A. (2014). Infant attention and early childhood executive function. *Child Development*, *85*(2), 397–404. DOI: 10.1111/cdev.12126

D'Esposito, M., Aguirre, G. K., Zarahn, E., Ballard, D., Shin, R. K., & Lease, J. (1998). Functional MRI studies of spatial and nonspatial working memory. *Cognitive Brain Research*, *7*(1), 1–13. DOI:10.1016/S0926-6410(98)00004-4

Diamond, A. (1985). Development of the ability to use recall to guide action, as indicated by infants' performance on AB. *Child Development*, *56*(4), 868–883. DOI: 10.2307/1130099

Diamond, A. (2002). Normal development of prefrontal cortex from birth to young adulthood: Cognitive functions, anatomy, and biochemistry. In D. Stuss, R. Knight (Eds.), *Principles of frontal lobe function* (pp. 466–503). London, UK: Oxford University Press.

Fernald, A., Marchman, V. A., & Weisleder, A. (2013). SES differences in language processing skill and vocabulary are evident at 18 months. *Developmental Science*, *16*(2), 234–248. DOI: 10.1111/desc.12019

Fougnie, D. (2008). The relationship between attention and working memory. In N. B. Johansen (Ed.), *New research on short-term memory*, (pp 1–45). Nova Science Publishers.

Fry, A. F., & Hale, S. (2000). Relationships among processing speed, working memory, and fluid intelligence in children. *Biological Psychology*, *54*(1), 1–34. DOI:10.1016/S0301-0511(00)00051-X

Frye, D., Zelazo, P. D., & Palfai, T. (1995). Theory of mind and rule-based reasoning. *Cognitive Development*, *10*(4), 483–527. DOI:10.1016/0885-2014(95)90024-1

Gathercole, S. E. (2006). Nonword repetition and word learning: The nature of the relationship. *Applied Psycholinguistics*, *27*(04), 513–543. DOI: 10.1017/S0142716406060383

Gathercole, S. E., & Baddeley, A. D. (1989). Evaluation of the role of phonological STM in the development of vocabulary in children: A longitudinal study. *Journal of Memory and Language*, *28*(2), 200–213. DOI:10.1016/0749-596X(89)90044-2

Gathercole, S. E., & Baddeley, A. D. (1993). Phonological working memory: A critical building block for reading development and vocabulary acquisition?. *European Journal of Psychology of Education*, *8*(3), 259–272. DOI: 10.1007/BF03174081

Gathercole, S. E., Lamont, E. M. I. L. Y., & Alloway, T. P. (2006). Working memory in the classroom. In: S. J. Pickering (Ed.) *Working memory and education* (pp. 219–240), Oxford: Elsevier.

Gathercole, S. E., Pickering, S. J., Ambridge, B., & Wearing, H. (2004). The structure of working memory from 4 to 15 years of age. *Developmental Psychology*, *40*(2), 177–190. DOI: 10.1037/0012-1649.40.2.177

Gathercole, S. E., Willis, C. S., Emslie, H., & Baddeley, A. D. (1992). Phonological memory and vocabulary development during the early school years: A longitudinal study. *Developmental Psychology*, *28*(5), 887–898. DOI: 10.1037/0012-1649.28.5.887

Gauvain, M. (2013). Sociocultural context of development. In P. D. Zelazo (Ed.), *The oxford handbook of developmental psychology* (pp. 425–451). Oxford: Oxford University Press.

Haman, E., Fronczyk, K. (2012). *Obrazkowy Test Słownikowy – Rozumienie*. Gdańsk: Pracownia Testów Psychologicznych i Pedagogicznych.

Henry, L. (2012). *The Development of Working Memory in Children*, London: SAGE Publications Ltd.

Hick, R. F., Botting, N., & Conti-Ramsden, G. (2005). Short-term memory and vocabulary development in children with Down syndrome and children with specific language impairment. *Developmental Medicine & Child Neurology*, *47*(8), 532–538. DOI: 10.1111/j.1469-8749.2005.tb01187.x

Hoff, E. (2003). The specificity of environmental influence: Socioeconomic status affects early vocabulary development via maternal speech. *Child Development*, *74*(5), 1368–1378. DOI: 10.1111/1467-8624.00612

Hoff, E., & Naigles, L. (2002). How children use input to acquire a lexicon. *Child Development*, *73*(2), 418–433. DOI: 10.1111/1467-8624.00415

Hornowska, E. (2005). *Testy psychologiczne. Teoria i praktyka*. Warszawa: wyd. Scholar.

Hughes, C., & Ensor, R. (2005). Executive function and theory of mind in 2 year olds: A family affair? *Developmental Neuropsychology*, *28*(2), 645-668. DOI:10.1207/s15326942dn2802_5

Jarrold, C., Thorn, A. S., & Stephens, E. (2009). The relationships among verbal short-term memory, phonological awareness, and new word learning: Evidence from typical development and Down syndrome. *Journal of Experimental Child Psychology*, *102*(2), 196–218. DOI:10.1016/j.jecp.2008.07.001

Kastner, J. W., May, W., & Hildman, L. (2001). Relationship between language skills and academic achievement in first grade. *Perceptual and Motor Skills*, *92*(2), 381-390. DOI: 10.2466/pms.2001.92.2.381

Kirkham, N. Z., Cruess, L., & Diamond, A. (2003). Helping children apply their knowledge to their behavior on a dimension-switching task. *Developmental Science*, *6*(5), 449–467. DOI: 10.1111/1467-7687.00300

Kurcz, I. (2005). *Psychologia języka i komunikacji*. Warszawa: Wyd. Scholar.

Lee, J. (2011). Size matters: Early vocabulary as a predictor of language and literacy competence. *Applied Psycholinguistics, 32*(1), 69–92. DOI: 10.1017/S0142716410000299

Luciana, M., Conklin, H. M., Hooper, C. J., & Yarger, R. S. (2005). The development of nonverbal working memory and executive control processes in adolescents. *Child Development*, *76*(3), 697–712. DOI: 10.1111/j.1467-8624.2005.00872.x

Müller, U., Jacques, S., Brocki, K., & Zelazo, P. D. (2009). The executive functions of language in preschool children. In A. Winsler, Ch. Fernyhough, & I. Montero (Eds.). *Private Speech, Executive Functioning, and the Development of Verbal Self-Regulation* (pp. 53–68). Cambridge University Press.

Miller, S. E., & Marcovitch, S. (2015). Examining executive function in the second year of life: Coherence, stability, and relations to joint attention and language. *Developmental Psychology*, *51*(1), 101–114. DOI: 10.1037/a0038359

Montgomery, J. W., & Evans, J. L. (2009). Complex sentence comprehension and working memory in children with specific language impairment. *Journal of Speech, Language, and Hearing Research*, *52*(2), 269–288. DOI: 10.1044/1092-4388

Morales, M., Mundy, P., & Rojas, J. (1998). Following the direction of gaze and language development in 6-month-olds. *Infant Behavior and Development, 21*, 373–377. DOI:10.1016/S0163-6383(98)90014-5

Mundy, P., & Brunette, C. (2005). Joint attention and neurodevelopment. In: E. Volkmar, A. Klin, & R. Paul (Eds.). *Handbook of autism and persvasive developmental disorders* (3rd ed., pp. 650–681). Hoboken, NJ: John Wiley.

Mundy, P. (2013). A neural networks, information-processing model of joint attention and social-cognitive development. In P. D. Zelazo (Ed.), *The Oxford Handbook of Developmental Psychology* (pp. 217–241). Oxford: Oxford University Press.

Mundy, P., Block, J., Delgado, C., Pomares, Y., Van Hecke, A. V., & Parlade, M. V. (2007). Individual differences and the development of infant joint attention. *Child Development*, *78* (3), 938–954. DOI: 10.1111/j.1467-8624.2007.01042.x

Mundy, P., Delgado, C., Block, J., Venezia, M., Hogan, A., & Seibert, J. (2003). *Early Social Communication Scales (ESCS)*. Coral Gables, FL: University of Miami.

Newcombe, N. S. (2011). What Is Neoconstructivism? *Child Development Perspectives, 5*, 157–160. DOI: 10.1111/j.1750-8606.2011.00180.x

Olson, D. R. (1993). The development of representations. The origins of mental life. *Canadian Psychology*, 34, 293–306. http://dx.doi.org/10.1037/h0078834

Orzechowski, J. (2012). *Magiczna liczba jeden, czyli co jeszcze zmieści się w pamięci roboczej*. Kraków: WUJ.

Orzechowski, J., Piotrowski, K. T., Balas, R., Stettner, Z. (red.) (2009). *Pamięć robocza*. Warszawa: Academica.

Ouellette, G. P. (2006). What's meaning got to do with it: The role of vocabulary in word reading and reading comprehension. *Journal of Educational Psychology*, *98*(3), 554–566. DOI: 10.1037/0022-0663.98.3.554

Pham, A. V., & Hasson, R. M. (2014). Verbal and visuospatial working memory as predictors of children's reading ability. *Archives of Clinical Neuropsychology*, DOI:10.1093/arclin/acu024

Pungello, E. P., Iruka, I. U., Dotterer, A. M., Mills-Koonce, R., & Reznick, J. S. (2009). The effects of socioeconomic status, race, and parenting on language development in early childhood. *Developmental Psychology*, *45*(2), 544–557. http://dx.doi.org/10.1037/a0013917

Reznick, J. S. (2009). Working memory in infant and toddlers. In M. L. Courage & Cowan (Eds.). *The development of memory in infancy and childhood* (pp. 343–365). Hove: Psychology Press.

Rheingold, H., Hey, D., & West, M. (1976). Sharing in the second year of life. *Child Development*, *47* (4), 1148–1158. DOI: 10.2307/1128454

Rogoff, B. (2003). *The cultural nature of human development*. Oxford University Press.

Savage, R., Cornish, K., Manly, T., & Hollis, C. (2006). Cognitive processes in children's reading and attention: The role of working memory, divided attention, and response inhibition. *British Journal of Psychology*, *97*(3), 365–385. DOI: 10.1348/000712605X81370

Scofield, J., & Behrend, D. A. (2011). Clarifying the role of joint attention in early word learning. *First Language*, *31*, 326–341, DOI: 10.1177/0142723710395423

Seibert, J. M., Hogan, A. E., & Mundy, P. C. (1982). Assessing interactional competencies: The early social-communication scales. *Infant Mental Health Journal*, *3* (4), 244–258. DOI: 10.1002/1097-0355(198224)3:4<244::AID-IMHJ2280030406>3.0.CO;2-R

Sigman, M., & McGovern, C. W. (2005). Improvement in cognitive and language skills from preschool to adolescence in autism. *Journal of Autism and Developmental Disorders*, *35*(1), 15–23. DOI: 10.1007/s10803-004-1027-5

Stokes, S. F., & Klee, T. (2009). Factors that influence vocabulary development in two-year-old children. *Journal of Child Psychology and Psychiatry*, *50*(4), 498–505. DOI: 10.1111/j.1469-7610.2008.01991.x

Swanson, H. L. (2003). Age-related differences in learning disabled and skilled readers' working memory. *Journal of Experimental Child Psychology*, *85*(1), 1–31. DOI:10.1016/S0022-0965(03)00043-2

Swanson, H. L. (2006). Working memory and reading disabilities: Both phonological and executive processing deficits are important. In: T. P. Alloway & S. E. Gathercole (Eds.), *Working memory and neurodevelopmental disorders* (pp. 59–88). Hove: Psychology Press.

Tannenbaum, K. R., Torgesen, J. K., & Wagner, R. K. (2006). Relationships between word knowledge and reading comprehension in third-grade children. *Scientific Studies of Reading*, *10*(4), 381–398. DOI: 10.1207/s1532799xssr1004_3

Tomasello, M. (1988). The role of joint attentional processes in early language development. *Language Sciences*, *10*(1), 69–88. DOI:10.1016/0388-0001(88)90006-X

Tomasello, M. (1995). Joint attention as social cognition. In: Ch. Moore, P. J. Dunham (Eds.) *Joint attention: Its origins and role in development*, (pp. 103–130). Hillsdale, NJ: Erlbaum.

Tomasello, M. (1999). *The Cultural Origins of Human Cognition*. Cambridge, MA: Harvard University Press.

Tomasello, M., & Farrar, M. J. (1986). Joint attention and early language. *Child Development*, *57*(6), 1454–1463. DOI: 10.2307/1130423

Van Hecke, A. V., Mundy, P., Block, J. J., Delgado, C. E., Parlade, M. V., Pomares, Y. B., & Hobson, J. A. (2012). Infant responding to joint attention, executive processes, and self-regulation in preschool children. *Infant Behavior and Development*, *35*(2), 303–311. DOI:10.1016/j.infbeh.2011.12.001

Wechsler, D. (2004). *Wechsler Intelligence Scale for Children* IV^{UK}. London; Psychological Corporation

Wolfe, C. D., & Bell, M. A. (2007). Sources of variability in working memory in early childhood: A consideration of age, temperament, language, and brain electrical activity. *Cognitive Development*, *22*(4), 431–455. DOI:10.1016/j.cogdev.2007.08.007

Zelazo, P. D., Frye, D., & Rapus, T. (1996). An age-related dissociation between knowing rules and using them. *Cognitive Development*, *11*(1), 37–63. DOI:10.1016/S0885-2014(96)90027-1