The Importance of Rapid Automatized Naming Skills as a Predictor of Reading Acquisition: A Theoretical Overview

Kadi Lukanenok [1*]
1 Tallinn University, Estonia

Journal Article is reproduced from :
Asia Pacific Journal of Developmental Differences, Vol. 1, No. 2, July 2014, pp 202—223
DOI: 10.3850/S2345734114000056

www.das.org.sg/publications/research-journal/volume-1-no-2-july-2014

This article presents a theoretical overview of the concept of rapid naming skills as one of the critical sub-skills of reading acquisition. Rapid automatized naming is recognized as a relevant marker in early reading in addition to phonological awareness and verbal working memory. This paper describes how the relationship between rapid automatized naming and reading skills affects specific reading difficulties within the framework of existing developmental and cognitive research. Finally, future implications for research and applications in the educational field are provided.

Keywords: naming skills, rapid automatized naming skills, reading acquisition, specific reading difficulties

INTRODUCTION

The purpose of the current paper is to give a theoretical overview on the concepts of naming and rapid automatized naming (RAN). It is also important to show the connections between naming skills, reading skills and reading difficulties (RD). The aim is to emphasise the value of knowledge about the concept and development of naming skills, and possible developmental difficulties as crucial factors from both a scientific and practical perspectives.

These are important for the identification and assessment of reading progress and to potentially identify RD in children. It is proposed that rapid automatized naming is a useful method to include in both cognitive reading research and diagnostic tests. This overview is based on the neuro-cognitive, psycholinguistic and developmental research in the field.

Reading is a fundamental skill for successful performance in modern society and it is therefore hard to over emphasize its value. Considerable emphasis and efforts are focused on teaching and learning to read in educational institutions and society in general. Developed reading skills are the basis of further learning skills and academic success.

Reading includes the functions of both decoding and comprehension. For the purposes of this paper, the reading process is defined as decoding and RD as difficulties in decoding and does not consider the highly significant element of reading comprehension.

RD caused by biological, psychological and cognitive factors, despite adequate pedagogical environment, are considered as specific reading difficulties (SRD) / dyslexia. Cognitive and linguistic processes and reading predictors can be noticed in the pre-reading period and have significant predictive value in later reading performance. Reading ability, risks and difficulties are visible in the pre-reading period and can be efficiently predicted by the level of language skills (naming, rapid naming, phonological processing and awareness), working memory, visual and auditory perception, kinaesthetic perception and rhythm (Georgiou, Parrila, Manolitsis & Kirby, 2011; Furnes & Samuelsson, 2011; Holopainen, Ahonen, Lyytinen, 2001; Lervåg & Hulme, 2009; Norton & Wolf, 2012; Nation, 2005; Pastarus, 1999; Shaywitz, 2003; Van der Leij, Lyytinen & Zwarts, 2001; Wolf, 1999).

NAMING

Naming, which is one of the basic linguistic processes, is defined as the attribution of a linguistic equivalent (symbol) to an object, characteristic, action, and the use of it (Luria, 1962). Different terms express various aspects of the Naming skill concept. *Word finding* and *word retrieval* refer to the ability to retrieve the word from memory capacity and to use it properly. *Lexical retrieval* and *lexical access* refer to lexical and semantic aspects, i.e. aspects of meaning (Salmi, 2008; Tuovinen, 2003).

From the neuropsychological point of view, naming ability, including rapid naming, is a multiple-phased cognitive phenomenon guaranteed by the human

neurobiological structure. The Naming process is provided by cooperation between different areas of the brain. Readiness of the visual area of both hemispheres is crucial for the perception of objects. Subsequently, the language areas of the posterior part of the frontal and temporal lobes of the left hemisphere are activated. In these areas of the brain phonemes and the meanings of words are analysed. The motor areas of the frontal lobe guarantee the activation, i.e. they generate the motor program for oral performing (Laine, 1995; Lehtonen, 1993; Luria, 1962; Wolf, 1982, 2008; Wolf & Bowers, 1999). Automatization of cognitive processes, including speech and language processes is provided by the function of the cerebellum (Nicolson & Fawcett, 1999, 2008).

Several researchers have demonstrated that word finding is guaranteed by different neurological structures within the brain and activation of the specific brain areas depends on the type of stimuli presented (serial or discrete presentation). These researchers have ascertained that naming discrete stimuli is related to occipital and frontal lobes and naming serially presented stimulus is linked to the pre- and anterior parts of the frontal lobe (Messer & Dockrell, 2006; Wiig, Zureich & Chan, 2000).

It has been established that naming different stimuli activates brain regions at different levels of activation. Naming letters has been observed to cause more activation in the angular gyrus, parietal and occipital lobe than naming pictures. Naming pictures activates the frontal lobe more strongly. This pattern of activation pattern suggests that there are stronger links between reading and letter naming than between reading and picture naming (Misra, Katzir, Wolf & Poldrack, 2004). Wolf (1986, 2008) has explained the phenomenon in terms of the automatization processes. Wolf`s research shows that naming pictures can be automatized less than naming letters (alphanumerical stimuli generally), and the latter requires greater activation of brain.

According to Luria (1962), the difficulties in naming are caused by damage or dysfunction of different parts of the brain: pre-motor area of the frontal lobe (efferent motor aphasia), superior and medium part of the temporal lobe (acoustic-amnestic aphasia) and posterior part of the temporal lobe (semantic aphasia).

Damasio and her teams (Damasio, Grabowski, Tranel, Hichwa & Damasio, 1996; Damasio, Tranel, Grabowski, Adolphs & Damasio, 2004) have extended knowledge about the neuropsychological basis for the Naming process. They have proven that word retrieval in naming faces, animals and tools is correlated with separable neural sites within different higher-cortices of the temporal

regions in left hemisphere outside classic language areas and are correlated with noting objects. Additionally, strong activation was found to be visible in other parts of the brain: motor region, orbital frontal lobe, occipital lobe, anterior temporal lobe and supra marginal gyrus. These researchers showed that recognition of the naming task was evenly distributed across the two hemispheres. The researchers' claim is that impaired retrieval of words denoting actions is related to damage of the left prefrontal and/or premotor regions. This confirmed the partial segregation of naming for different word categories. The usage of these brain parts depends on the task performed (to name or to recognize) and the conceptual category of the item (unique, common or familiar). Impaired word retrieval was not visible in the right hemisphere.

All naming tasks investigated related to temporal regions showed significant blood increase for naming tasks relative to the control no-naming tasks. They summarised that for optimal retrieval of words from different categories, different anatomically separable regions are involved and there are dissociations relative to the type of words and anatomical locus. In short, as language is both a left and right hemisphere function, this assumption should be extended to the rapid naming concept as well, and regarded as underpinned by the cooperation of both hemispheres.

Adult brain imaging studies show that the relevant regions of the brain, that underpin reading and naming, involve very closely related neural circuits. It is logical to assume then that (especially single word) reading and naming processes are performed in the same way. Common neural mechanisms and the integrity of left hemisphere circuits sub-serve the development of rapid automatized naming and reading thereby underpinning the relationship between early rapid naming skills and reading skills. However, the relationship between rapid automatized naming and reading seems to be unidirectional in its development. Difficulties in efficiency with the naming circuits constrain development of reading skills, but increased reading skills do not correlate as increased naming skills per se. Development of naming skills is mainly considered as a function of age and cognitive ability (Karlep, 2003; Laine, 1995; Lervåg & Hulme, 2009; Luria, 1962; Messer & Dockrell, 2006).

Rapid automatized naming could be affected by the magnocellular system. Clarke et al. (2005) demonstrated that good readers paused less than poor readers in rapid naming tasks and that their pauses resembled strategic pauses specific to reading. The authors associated the phenomenon to eye fixations, that occur in the reading process. The magnocellular deficit hypothesis states that SRD readers present difficulties with precision of visual perception and eye moving control (Misra et al., 2004). This is questioned by Hutzler, Kronbichler,

Jacobs and Wimmer (2006) who did not notice any differences in eye movements between SRD and normal readers in letter perception and therefore did not associate difficulties in reading with magnocellular deficit.

Moreover, RAN difficulties could be partially caused by inherited genes. Berninger, Abbott, Billingsley and Nagy (2001) found in their study (n > 100 SRD students and their parents) that 83.3% of children and 56% of parents presented rapid naming difficulties. Two longitudinal researches (Jyvaskyla Longitudinal Study and Dutch Study) have shown that children with RD and/or familial dyslexia risk lower achievement in naming tasks than children without any dyslexia risk (van Bergen, de Jong, Regtvoort, Oort, van Otterloo & van der Leij, 2011; Lyytinen, Ahonen, Eklund, Guttorm, Laakso, Leinonen, Leppänen, Lyytinen, Richardson & Viholainen, 2001; Torppa, Lyytinen, Erskine, Eklund & Lyytinen, 2010). Many researchers have evaluated the relationship between RAN and heredity and have found it to be medium to strong (r = 0.40...0.60). These findings suggest that because reading ability in the primary school is affected by genes that rapid naming may also be affected by genes (Byrne, Olson, Samuelsson, Wadsworth, Corely, DeFries & Willcut, 2006; Deutsch & Davis, 2010; König, Schumacher, Hoffmann, Kleensang, Ludwig, Grimm, Neuhoff, Preis, Roeske, Warnke, Propping, Remschidt, Nöthen, Ziegler, Müller-Myhsok & Schulte-Körne, 2010; Grigorenko, 2004; Samuelsson, Byrne, Quain, Wadsworth, Corley, DeFries, Willcutt & Olson, 2005).

Various sets of instruments have been developed in order to explore naming skills. Naming tests are designed to assess the time taken, based on age-related norms, for word finding, semantic and phonological precision and articulation of the named words, assuming the child does not have any speech or language pathology or mental retardation. There are two basic types of naming tests: tests with serially presented stimuli and discrete stimuli.

As mentioned above, naming and reading are underpinned by the same psychological basis. By exploring a person's naming skills one can easily then draw conclusions about his or her reading skills, therefore naming tasks are often included in reading tests.

1. RAPID AUTOMATIZED NAMING (RAN)

Rapid Automatized Naming occurs in everyday life when reading where the correspondence between phonemes and graphemes is a form of rapid naming. During the reading process the rapidly changing grapheme sequence (visual stimuli, letters) has to be decoded into the form of phoneme sequence (sounds).

At the cognitive level, RAN assumes cooperation between many processes: perceptual, attention, memory, reasoning, lexical-semantic and articulatory. Visual, auditory and verbal processes are involved in RAN skills in the context of timing and sequencing. Difficulties in one or more of the aforementioned aspects could cause rapid automatized naming difficulties (RND). RAN and reading skills are found to be correlated at the medium level (n = 1550, r = .45) and Rapid naming deficits are associated with Specific Reading Difficulties (Ahonen, Tuovinen & Leppäsaari, 2003; Denckla & Rudel, 1976a, 1976b; Swanson, Trainin, Necochea & Hammill, 2003; Norton & Wolf, 2012; Waber, Wolff, Forbes & Weiler, 2000; Wolf, 1982, 1991, 1999; Wolf, Bally & Morris, 1986).

Research has shown that RAN has an especially high predictive value for reading results of marginal readers, i.e. those readers who remain under the 10th percentile for reading and above the 90th percentile for slowness of naming (Araujo, Pacheco, Faisca, Petersson & Reis, 2010; Frijters, Lovett, Steinbach, Wolf, Sevcik & Morris 2011; Lervåg, Bråten, & Hulme, 2009; Meyer, Wood, Hart & Felton 1998). According to numerous studies, Rapid Naming predicts reading results up to Grade 4 (Badian, Duffy, Als & McAnulty 1991; Frijters et al., 2011) or even to Grade 6 (Vaessen & Blomert, 2010).

When measuring RAN, the most relevant criteria are naming speed and accuracy/precision. Research suggests that slow naming speed and/or the amount of mistakes in naming tasks predict RD in both regular and irregular orthographies. However, the relation between RAN and reading is considered stronger in regular orthographies than irregular ones (Araujo et al., 2010; Badian et al., 1991; Denckla & Rudel, 1974; Furnes & Samuelsson, 2011; Korhonen, 1995; Salmi, 2008; Wolf, 1986). This is because it is easier to learn to read in a language which is transparent, and therefore speed of reading is the key to diagnosis, by contrast with accuracy in irregular languages. RAN speed has more diagnostic value than accuracy in regular orthographies (Aro, 2004, Holopainen et al., 2001; Lervåg, Bråten, & Hulme, 2009; Misra et al., 2004; Wolf, 1986; Wolf & Bowers, 1999). Studies on Chinese language have shown a strong correlation between RAN and reading in Chinese, i.e. in uniquely different logographic systems of reading.

RAN is identified as a significant and stable predictor of reading in Chinese up to Grade 5 and presents the most dominant type of cognitive deficit in Chinese-speaking children with dyslexia (Ho, Chan, Lee, Tsang & Luan, 2004; Kang, 2004; Yeung, Ho, Chik, Lo, Chan & Chung, 2011). A few studies have examined the predictive power of RAN in Arab and Persian languages. These studies found, that despite having different orthographies in comparison with English, RAN could predict reading skills in these languages as well (Sadeghi, Everatt, McNeill & Elbeheri, 2009; Taibah & Haynes, 2011). Although the lowest in range, RAN

increased steadily and was strongly fixed by Grade 3 (when basic decoding skills become automated) and even exceeded the predictive power of phonological awareness in Arabic (Taibah & Haynes, 2011). A Malay language screening test has also identified RAN as a contributory predictor to reading, in addition to phonological deficits (Lee, 2008).

The most well known RAN tests are the *Rapid Automatized Naming Test*, (Denckla & Rudel, 1974; Wolf & Denckla, 2005), *Rapid Serial Naming Test* (Wolf and Denckla, 1986) and *Rapid Automatized Naming Subtest* (Wiig et al., 2000). Speed, as the most valuable and distinctive characteristic of the process, is assured by changing the stimuli in a RAS serial presentation to make the task more challenging. The number of errors are a secondary consideration in RAN tasks. The aim of naming tasks is to name presented stimulus (alphanumerical, non-alphanumerical or mixed versions) as fast as possible and move ahead to the next stimulus.

The most widely used stimuli are numbers, letters (alphanumerical), pictures, colours, geometrical shapes (non-alphanumerical) and mixed versions. The traditional naming test consists of 4-8 subtests, each subtest contains 5 and 10 randomly presented stimuli repeated over the page (Ahonen et al., 2003; Clarke, Hulme & Snowling, 2005; Denckla & Rudel, 1974, 1976a, 1976b; Wolf, 1982, 1991, 1999; Wolf, Bowers & Biddle, 2000).

A list and summary of selected research using RAN/RAS tests is presented by Wolf and Denckla (2005). This summary, intended for researchers, highlights samples, ages/grades and results gathered between 1972–1995. Most of these investigations have involved children (primary school) and teenagers (basic school); a few studies engaged preschoolers or adults. Two studies explored RAN skills in kindergarten children. Regular readers completed samples as controls, and the experimental groups were described as dyslexic readers, slow learners, ADD students and impaired readers. Two of the studies listed were conducted in German. These studies elaborated on normative data for RAN measurement, investigated RAN and reading relationship and compared RAN results in controls with experimental groups.

The normative data findings from these studies have allowed subsequent years of RAN investigations to delve more deeply into this field of study. The most challenging research questions concerned the neuro-cognitive and genetic relationship between RAN and reading, the role of RAN in the reading process and the connection between Rapid Naming Deficits and Specific Reading Difficulties. Educational and practical implications are very relevant issues in the context of assessment and remedial instruction for struggling readers.

Most of the researchers suggest that there is a stronger and more specific correlation between alphanumerical stimuli and reading than non-alphanumerical stimuli and reading (Misra et al., 2004; Pham, Fine & Semrud-Clikeman, 2011; Wolf, 1991; Wolf, 1999, 2008; Wolf et al., 1986). Savage and Fredricson (2005) and Compton (2003) discovered that the naming of alphanumerical stimuli has predictive value in relation to decoding, reading precision and speed.

In accordance with this body of research, picture naming does not present a predictive value to reading. Savage and Fredricson (2005) have discussed the following: picture naming requires semantic access, which is not inevitable for the naming of non-alphanumerical stimuli. The automatization process in naming alphanumerical stimuli depends on age, cognitive capacity and reading instructions. The decrease in predictive value of picture naming, as an age-related function, is explained by the non-automatization processes of picture naming (Arnell, Joanisse, Klein, Busseri & Tannock 2009; Luria, 1962; Misra et al., 2004; Wolf, 2008; Wolf et al., 1986). Contrary to these notions, some research has demonstrated that picture and colour naming are stronger and more persistent (up to age 18), in relation to reading speed and comprehension, than naming alphanumerical stimuli (Arnell et al., 2009; Cronin, 2011; Denckla & Rudel, 1974; Lervåg & Hulme 2009).

The results of numerous studies have shown that RAN contributes substantially to reading fluency across all six primary school grades. Indeed, the relationship between RAN and word reading fluency increases gradually as a function of reading experience (Breznitz, 2006; Vaessen & Blomert, 2010).

The relationship between RAN and reading comprehension has not been explained unambiguously and the need for further research is articulated (Arnell et al., 2009; Compton, 2003; Denckla & Rudel, 1974; Li, Kirby & Georgiou, 2011). Some research confirms that RAN also predicts reading comprehension. It has been claimed that reading comprehension and number and letter naming might be related to the articulation pause time rather than pure articulation time. The latter relationship is found in Grade 6, but not in Grades 2 or 4 (Li, Cutting, Ryan, Zilioli, Dencla & Mahone 2009; Li, Kirby & Georgiou 2011). Chinese reading comprehension has been found to show a statistically significant (albeit small) contribution from RAN (letters and numbers) (Leong, Tse, Loh & Hau, 2008).

Briefly, research has confirmed that RAN predicts reading performance. The speed of alphanumerical RAN performs as an especially strong predictor in transparent orthographies.

There are clear developmental changes in the speed of RAN, based on the

mean and standard deviations for the RAN/RAS Tests at 14. Age intervals and correlations with age are represented in the RAN/RAS Examiner Manual (Wolf & Denckla, 2005). The data presented show evenly decreasing testing time from age 5 to 18. The mean time recorded at age 18 is two to three times less than the mean time at age 5, accordingly: objects 74 sec and 35 sec, colors 73 sec and 34 sec, numbers 74 sec and 27 sec, letters 83 sec and 28, 2-set letters and numbers 97 sec and 31 sec, 3-set letters, numbers and colors 94 sec and 32 sec. Variability, as expressed in Standard deviations decreased between age 5 to 12 (mean variability 30.5 and 10.6), but persisted to age 15 and increased somewhat between age 16—17 (mean 9.1) and showed the smallest deviations by age 18 (mean 8.8).

RAN mean times were moderately correlated with age, with correlation coefficients between .48 and .64, significant at $p < .0001$ level. Similar developmentally determined findings were reported by Li et al. (2011) who measured RAN articulation and pause times in both English and Chinese and noticed both decreased by age, but the pause time decreased faster than articulation time. These developmental changes in articulation and pause times show that pause time is the more sensitive indicator of language proficiency.

These results confirm that RAN time decreases as function of age. These results are in line with theoretical knowledge about improving reading acquisition in preschool and primary school and stating that reading acquisition to be mainly completed by ages 12-13.

2. NAMING DIFFICULTIES

Several terms are used to refer to naming difficulties: naming deficit, word finding disorder, lexical look-up problems, dysnomia and anomia.

It is justified to consider Naming Difficulties as a persistent problem (reflecting low- or non-automated processes) in word selection, retrieving and producing processes. Naming Difficulties reflect the inability to name a real or imagined object or to find the word necessary to continue a conversation as well as incorrect or improper usage of a word, slow retrieval of words from memory or emerging secondary markers (e.g., extra words, gestures etc.). Naming Difficulty does not implicitly include word comprehension difficulties But rather retrieval diffculties (Constable, 2007; German & Newman, 2007; Luria, 1962; Tuovinen, 2003; Messer & Dockrell, 2006).

Naming Difficulties can be combined with other developmental disabilities. Children with Naming Difficulties are noticably linked with specific language impairment, dysphasia, dyslexia, learning difficulties (LD) and stuttering (Araujo,

Pacheco, Faisca, Petersson & Reis, 2010; German & Newman, 2007; Tuovinen, 2003; Messer & Dockrell, 2006; Rapin & Allen, 1983). There is adult Naming Difficulties have been related to aphasia, dementia, Alzheimer syndrome and Parkinson disease (Luria, 1962; Taler & Phillips, 2008), but these are usually acquired rather than developmental. Naming Difficulties have been observed to be very persistent and can be transmitted from childhood to early adulthood (Ahonen et al., 2003; Arnell et al., 2009; Constable, 2007; Holopainen et al., 2001; Korhonen, 1995; Meyer et al., 1998; Salmi, 2008; Wolf, 1999). The type of Naming difficulty most frequently observed in children with Specific learning difficulties includes word retrieval problems coupled with circumlocution.

2.1. RAPID NAMING DIFFICULTIES

Rapid Naming Difficulties, described as inconsistent and slow or delayed development and abundance of mistakes, are characteristic of specific language impairment (SLI) and other developmental disorders. Rapid Naming Difficulties are usually assessed based on the standard deviation 1, 5 or 2 depending on the naming speed and amount of mistakes (Ahonen et al., 2003; Denckla & Rudel, 1976a; Wolf et al., 1986).

Rapid Naming Difficulties can be observed at both developmental and behavioural levels. At the developmental level, difficulties appear as inconsistencies, i.e. noticeable relapses and nonlinear growth curves. Difficulties at the behavioural level are demonstrated by slow naming speed and an abundance of mistakes. In the following section, the problems with RAN will be explored in greater depth, presenting a range of comparative data.

Ahonen et al. (2003) have explored and described the characteristics of Rapid Naming Difficulties in three independent groups of children aged 6-12. The research included a control group (normal development, no special teaching), part-time special teaching of students in mainstream schools (mild reading difficulties, $n = 235$) and full-time special teaching of students (severe speech and reading difficulties, $n = 85$). RAN development in both of the special groups is characterised as inconsistent and dependent on specialist support in the learning process.

Students in special groups showed delay, achieving approximately similar results to the control group in naming speed (especially with colours and objects) one to three years later. For example, the colors-letters-numbers subtest naming speed in the age 8 control group (51,0 sec) was obtained by students in the part -time special teaching group at 9 years (46,7 sec) and by students in the full-time special teaching group at 10-11 years (48,2 sec).

Moreover instability and relapses were noticed in the development of naming skills for the students in special groups. For example, the special group students' numbers-letters and colors-numbers-letters RAS naming speeds at 10 years were measured respectively at 41,8 sec and 44,6 sec, while at 11 years they were respectively 44,2 sec and 51,7 sec. This seems to indicate that they were becoming slower and more variable with age.

One noteworthy finding is described by Ahonen et al. (2003), namely that special group students passed the objects subtest faster at 8 years than normal development students. These results confirm those previous results demonstrating RAN development peculiarities in children with aberrational speech development.

The amount of mistakes in RAN tests are connected to age and cognitive development. A decreasing number of mistakes and an increasing number of self-corrected mistakes are considered age-related functions, as with naming speed. The aforementioned research by Ahonen et al. (2003) revealed nonlinearity between age and correction of mistakes and dependence on special teaching. The authors found that special group students tended to self-correct their naming mistakes less often than normal group students. Both part-time special group students and control group students tended to correct their mistakes, approximately 60-87%. The range of corrected mistakes of full-time special teaching group students stayed at 44-82, 1%.

Similarly, in a comparative study by Araujo et al. (2010) about dyslexic and normal readers, RAN tests with different results were found. They measured significant differences between dyslexic and normal readers in RAN speed, accordingly – 1.2 ± 1.3 and 0.7 ± 0.87, $p < 0{,}001$.

A Dutch investigation by van Bergen et al., (2011) reported additional different results in RAN tests comparing at-risk dyslexics, at-risk non-dyslexics and controls. Comparisons revealed that in Grade 1, the at-risk non-dyslexics were significantly slower than the controls, but surprisingly, significantly faster than the at-risk dyslexics. The phenomenon is worth further exploration. After half a year of reading instruction, at-risk dyslexics were slower in the naming of letters compared with the at-risk non-dyslexics, who were slower than the controls, and scored accordingly, 0.82, 0.96 and 1.18, $p < 0.001$. By the end of the first school year, at-risk non-dyslexics had reached the same level as the controls, scores for at-risk dyslexics were 1.24, at-risk non-dyslexics and controls 1.01, $p < 0.001$.

Ho, Chan, Tsang & Lee (2002), research showed that 50% of dyslexic Chinese children had difficulties in rapid naming, which is a major problem for orthographic and visual processing (36,7%) (cited by Kang, 2004).

In conclusion, the features of Rapid Naming Deficit are inconsistent development; slow naming speed and large amount of mistakes. Rapid Naming Difficulty is a characteristic problem for SRD/dyslexia and those at risk for it.

2.2. DOUBLE DEFICIT HYPOTHESIS (DDH)

Based on findings drawn from connections between RAN skills, phonological awareness and reading skills, Wolf, (1986) developed the Double Deficit Hypothesis (DDH) which combines a single or combined RAN speed deficit and a phonological deficit in children with SRD. According to this theory readers may be divided into four subgroups. The first subgroup is composed of children with a naming speed deficit but intact phonological awareness. They read slowly but without phonological mistakes. The second group has a phonological awareness deficit but intact naming speed. These children read fast but with many phonological mistakes. Both groups show mild to moderately impaired reading skills and comprehension which is not persistent, especially where they are supported by relevant treatment and special reading instructions. The third group of readers has both naming speed and phonological awareness deficits, i.e. double deficit. These children have severely impaired reading skills and a reading comprehension deficit in combination with a slow verbal ability and they would be classified as classic dyslexics. The fourth group has no problems in naming speed, phonological awareness and reading or reading comprehension. Single deficit occurs among ~ 15-20% and double deficit for ~ 60% of children with SRD. Wolf and Bowers have suggested that RAN difficulties are characteristic of children with SRD but not children with mental retardation (Wolf, 1986; Wolf, 1999; Wolf & Bowers, 1999; Wolf et al., 2000).

Consistent with the aforementioned double-deficit hypothesis, similar subtypes of dyslexic readers were found in Araujo et al. (2010) research in a Portuguese sample: 18.2% showed a single deficit in either RAN or phonological tasks and 50% co-occurrence of both. Based on their research results Araujo and colleagues stated that a RAN deficit seems to be more persistent in impaired readers with intact phonological skills. Papadopoulos, Georgiou and Kendeou (2009) have noted that the single phonological-deficit subtype, showed reading results consistent with their age group by Grade 2, but not the single naming-deficit group. Inter alia, these findings seem to confirm the role of RAN to be more important in regular orthographies (Araujo et al., 2010).

This double-deficit theory was replicated in Cronin's (2011) longitudinal study from preschool up to Grade 5 in order to verify the hypothesis and RAN (besides PA) as a reading predictor. The results showed that the RAN object scores of preschool and kindergarten children predicted reading at every age level and offered support for the double-deficit hypothesis and Lervåg's and

Hulme's (2009) neuro-developmental theory. It was concluded that both RAN and PA predict reading disabilities in English, throughout the elementary school years, and that the early assessments of these variables were more diagnostic than measures used at later ages. Kang's (2004) study in Chinese proved that RAN speed was the most significant predictor of good readers for Grade 1 and Grade 3. Additionally, RAN speed was the most significant predictor for reading failure for Grade 5.

Contrary to Double Deficit Theory, some critics have controlled for the double deficit statistically. They have argued that RAN and phonological awareness are sequenced sub processes from a larger phonological representation and cannot be observed separately (Ramus, 2003).

3. RAPID AUTOMATIZED NAMING, COGNITIVE PROCESSES AND READING

The naming process is a verbal-cognitive complex consisting of cognitive, perceptual and linguistic sub processes all underpinning the reading process. The research stresses that these common processes characterize both naming and reading: retrieving and utilising a linguistic equivalent in accordance to presented stimuli as quickly and precisely as possible. Naming skills are considered important in reading acquisition, especially in alphabetic-phonetic orthographies (Denckla & Rudel, 1976a; Furnes & Samuelsson, 2011; Goswami, 2000; Georgiou et al., 2011; Wolf, 1991, 1999). Incorrectness and slow naming speed refer to SRD, and are characteristics of both SRD and general learning difficulties (Messer & Dockrell, 2006; Heikkilä, Närhi, Aro & Ahonen, 2008; Waber et al., 2000).

The following overview of the cognitive processes, underpinning naming and reading processes, is based on Salmi (2008) and supplemented by the author of this paper. This review reflects published concepts and discussions on this field.

Although the relationship between RAN and phonological skills has been researched and explored, there is no consensus on explanations of the precise mechanism behind it. Some researchers claim that RAN and phonological skills are independent processes measuring different aspects of reading (Närhi, Ahonen, Aro, Leppäsaari, Korhonen, Tolvanen & Lyytinen, 2005; Savage & Fredricson, 2005; Wolf, 1999; Wolf & Bowers, 1999; Wolf et al., 2000). These views were confirmed by Araujo et al. (2010) who identified a group of dyslexic children with intact phonological processing but poor in RAN skills. Other researchers have defined RAN as efficiency of phonological code retrieval and a component in large-scale phonological and memory processing. These researchers e.g. Ramus claim that slow naming speed is related to slow phonological processing and they consider the decreased naming speed to be

a part of the phonological representation (Ramus, 2003; Vellutino, Fletcher, Snowling & Scanlon, 2004; Swanson et al., 2003; Vukovic & Siegel, 2006; Wagner & Torgesen, 1987).

Naming skills are based on speed of information processing. However, it is still not clear whether naming skills are related only to verbal information processing speed or could be related to general information processing speed. According to the verbal information processing theory, naming speed is related only to language processing speed. A connection has been found between slow naming speed and unusual language processing deficiency, associated especially with decreased timing and orthography (Li, Kirby & Georgiou, 2011; Lervåg & Hulme, 2009; Messer & Dockrell, 2006; Neuhaus, Foorman, Francis & Carlsson, 2001; Wimmer, Mayringer & Landerl, 1998).

According to general information processing theory, decreased naming speed reflects general information processing deviation independently of age and reading experience. The special difficulties of dyslexic readers in managing rapidly changing or presented stimuli, in both visual and auditory tasks, have supported this theory (Catts, Gillespie, Leonard, Kail & Miller, 2002; Denckla & Rudel, 1976b; Kail, Hall & Caskey, 1999; Kleine & Verwey, 2009; Nicolson & Fawcett, 2008; Wolf, 1991; Wolf & Bowers, 1999; Wolf et al., 2000). In 1976, Denckla and Rudel had already described the difficulties experienced by dyslexic readers in timing when performing both linguistic and non-linguistic tasks. Some authors presume that there is a strong correlation between general information processing speed and RAN (Logan, Schnatschneider & Wagner, 2009).

Automatization theory stresses that learned skills accumulate through the process of repeated practice and become more and more fluent until intentional thinking about skill performance is no longer needed. Both naming and reading automatization are defined by fast and short reaction times. Automatization of naming skills is considered to be a fast and effortless level of processing, that provides access into phonological, semantic, lexical and syntactical components and requires some or no awareness at all (Catts et al., 2002; Logan, 1997; Logan et al., 2009; Meyer et al., 1998; Nicolson & Fawcett, 2008; Neuhaus & Swank, 2002; Norton & Wolf, 2012; Wolf et al., 1986; Wolf et al., 2000). Tests consisting of serially presented pictures are treated as a relevant tool for measuring the automatization aspect of RAN skills (Meyer et al., 1998).

It has been claimed that automatization deficits affect skills more widely than just those involved in language and literacy, and that all skills that demand expert performance will be compromised (Nicolson and Fawcett, 2008). Children with RD have been found to present automatization difficulties in timing

and sequencing tasks, gross motor and balance tasks (Kleine & Verwey, 2009; Nicolson & Fawcett, 2008).

Contrary to the automatization theory, some studies have shown that general automatization difficulties do not cause SRD. The results that dyslexic children achieved in motor and balance tasks and other non-verbal tasks differed very little from the results of control children of appropriate age (Wimmer et al., 1998; Kasselimis, Margarity & Vlachos, 2007; Ramus, 2003).

There are also contradictory results and explanations about RAN and working memory: some authors confirm the connection between RAN and working memory, others show the instability and/or weakness of the connection, while a third contingent relates a connection with orthography. The need for further research is widely expressed by all (Ackerman, Dykman & Gardener, 1990; Georgiou, Das & Hayward, 2008; Närhi et al., 2005; Salmi, 2008).

There is now a limited number of recent studies that have investigated articulation as an underlying factor for RAN. The research evaluated explicit articulation time and pausing between two stimuli as two distinct processes. The process more relevant to RAN and the reading relationship is pausing time as it refers to language-specific associations between visual and verbal codes, speed of lexical access and progress forward speed (Araujo, Inacio, Francisc, Faisca, Petersson & Reis, 2011; Georgiou, Parrila & Kirby, 2006; Lervåg & Hulme, 2009; Li, Cutting, Ryan, Zilioli, Dencla & Mahone 2009; Li, Kirby & Georgiou, 2011; Salmi, 2008, Wolf, 1999 Wolf & Bowers 1999). Li et al., (2009, 2011) has figured out that colour and letter naming pause time and number naming articulation time were significant predictors of reading fluency. In contrast, the same investigation showed that number and letter pause variability were predictors of reading comprehension. In summary, RAN pause time and total naming time were related to reading comprehension by Grade 6, but not in earlier grades.

Naming skills are related to lexical-semantic processes (Salmi, 2008). However, researchers have found that naming skills and semantic skills are weakly connected statistically and that semantic problems do not include naming difficulties implicitly (Constable, 2007; Swanson et al., 2003). Serially presented stimuli tests investigate RAN sub-skills and discretely presented stimuli tests measure lexical-semantic aspects. Children with SRD tend to have difficulties in RAN tasks rather than unusual deficiencies in vocabulary skills. Consequently, serial RAN could be more strongly related to reading than discrete RAN (de Jong, 2011; Meyer et al., 1998). Wolf (1991) has pointed out that children with SRD have shown difficulties in naming discretely presented stimuli, that relates to the weakness in reading acquisition and in access to the lexical-semantic features.

The differential value of RAN tasks is noteworthy when viewed in the context of developmental disorders. RAN and diverse learning difficulties are probably related in several various ways. The differences in rapid naming RAN, especially in picture naming, have been noticed to discriminate between children with RD and attention deficit hyperactivity disorder (ADHD) (Savage & Fredricson, 2005) and also children with SRD and general learning difficulties (Denckla & Rudel, 1976a, 1976b; Heikkilä et al., 2008; Torppa et al., 2010). Conversely, Waber et al. (2000) found that RAN made a more visible difference in LD, but was inefficient in separating SRD children from LD children. The discussion on RAN as general or language specific phenomena is still an open one, and more research is needed.

EDUCATIONAL AND FUTURE IMPLICATIONS

In summarising materials referenced and analysed on the role of RAN in the reading process, it is possible to propose some implications for future scientific research and educational practice.

By necessity, future research into RAN needs to be accompanied by heterogeneous and relevant knowledge about reading complexity, the underlying processes of reading and reading difficulties. Increased depth of understanding about RAN's role in the reading process assumes the continued incorporation of information from brain imaging and/or genetics. More in depth understanding of the role of RAN in reading processes assumes that the incorporation brain imaging and/or genetics should be continued.

Understanding the relationships and the sequence of cause and result sequences is crucial for effective early identification and remediation arrangements. In the reading research conducted so far, there have been various sets of instruments and variables used. Educators need reliable, easy-to-use and time-efficient approaches and methods to detect reading status, reading difficulties and the risk for it in children at preschool and school age. RAN tests administered in the early years of reading (from preschool up to Grade 3) have been shown to have high diagnostic value and so, the inclusion of RAN tasks into reading assessment instruments is justified by these numerous investigations.

By detecting potential difficulties in reading acquisition, as early as possible, we can prevent further academic, behavioural, emotional and social problems (Byrne et al., 2006; Katzir, 2008; Kim, 2004; Norton & Wolf, 2012; Wolf, 2003).

Struggling readers need access to effective and science-based educational

remediation programs. Understanding the different types of challenges children face in learning to read is important in developing and delivering accommodated instruction practices to children. Children with reading problems benefit from specified remediation programs directed toward their cognitive and language abilities, including naming and fluency problems that underlie reading disabilities. Children with special naming and fluency deficits may not benefit from traditional intervention programs (Byrne et al., 2006; Katzir, 2008; Norton & Wolf, 2012; Wolf, 1999).

It is debated whether RAN presents limited implications in practice to improve reading skills and it has been noted that training for RAN (letter) has little effect on either RAN or reading training. This evidence suggests that RAN taps into a more basic index of cognitive and language processing (Lervåg & Hulme, 2009; Norton & Wolf, 2012).

Wolf (1999), and colleagues have investigated using reading sub-skills to demonstrate methods for improving reading fluency. The essential consequences and implications of the Double Deficit Theory can be demonstrated using the RAVE-O program (retrieval, automaticity, vocabulary-elaboration, and orthography). RAVE-O meets the needs for reading fluency and automaticity at two levels: in reading behaviors (word identification, word attack, and comprehension) and in the underlying component processes, including visual and auditory recognition, orthographic pattern recognition, lexical-retrieval and semantic processes. Tasks in this program have been used to address the need to increase visual scanning speed, orthographic pattern recognition, auditory discrimination and word identification, which share the same cognitive processes with RAN.

The principle concept of the practice is that one retrieves fastest what one knows best. Norton and Wolf (2012), stated that differential treatment studies are critical in determining whether subtypes of children with processing-speed difficulties are benefited by the targeting of specific word recognition skills or by placing more comprehensive emphases on fluency across all the underlying components.

The results of existing studies indicate that remedial training programs need to be specific to a reader's subgroups (by DDT) and the language in which reading improvements are sought (Li et al., 2011; Wolf, 1999; Wolf & Bowers, 1999).

Recent developments in visual media have inspired researchers to consider how reading using new and electronic media affects early reading instructions and reading automaticity and fluency comprehension (Norton & Wolf, 2012).

SUMMARY

Previous research has shown that naming skills provide two basic functions of language – naming and generalisation. It is essential for everyday living to be able to retrieve necessary words from memory and to present them as fast and correctly as possible. Disturbances (slow speed and crucial amounts of mistakes) in these processes suggest Naming Difficulties and are related to SRD (Denckla & Rudel, 1976a, 1976b; German & Newman, 2007; Luria, 1962; Messer & Dockrell, 2006; Tuovinen, 2003; Wolf & Bowers, 1999).

Valuable knowledge has been obtained about RAN, one of the naming sub-skills. RAN is considered a verbal-cognitive skill that is comprised of visual and auditory perception, articulation and lexical processes of language, as well as, sequencing and timing processes. RAN tasks simulate the reading process and they have the same origins. Therefore, results from RAN tests are able to predict later reading performance including both as SRD and the risk of SRD. Researchers have shown that Naming Difficulties have persistent connections to SRD. Naming Difficulties observed before the beginning of formal reading instruction (age 6-9) persisted through adolescence, so that reading was performed more slowly and more mistakes were made in both naming and reading tasks, than by their peers.

Despite the progress that has been made in understanding the phenomenon of RAN and connections to the reading process, future investigations are required. More research is needed to elaborate on causal mechanisms between RAN and reading involving cognitive and executive processes. Furthermore, the relationship between RAN and phonological processing needs further investigation. We look forward to the continued analyses of the two concurrent approaches still under discussion in the field: whether the issue is language specific or a more general deficit. The double deficit hypothesis and the three proposed groups of RD are not clearly established yet. There is a lack of investigations about double deficit hypothesis in different languages and orthographies. The stability of RD groups is still under question and requires more detailed research.

Practical experience in the use of RAN in the diagnostic process is still not fully reflected in published research. There must be lot of essential information for scientific approach and researches in generalisation of practice.
RAN as a treatment has value and merits more attention. Its widely known title of *'easy to measure, hard to improve'* makes it a worthy matter for both theoretical and practical application.

In conclusion, contemporary research into the area of RAN skills are essential for different languages and cultures in focusing on the nature of RAN and its casual relationship to different developmental difficulties regarding further theoretical and practical statements.

REFERENCES

Ackerman, P. T., Dykman, R. A., & Gardener, M. Y. (1990). Counting rate, naming rate, phonological sensitivity and memory span: Major factors in dyslexia. *Journal of Learning Disabilities, 23*, 5, 325-327.

Ahonen, T., Tuovinen, S., & Leppäsaari, T. (2003). *Nopean sarjallinen nimeämisen testi* [Rapid Serial Naming Test]. Lievestuore OY.

Araujo, S., Inacio, F., Francisco, A., Faisca, L., Petersson, K. M., & Reis, A. (2011). Component Processes Subserving Rapid Automatized Naming in dyslexic and Non-Dyslexic Readers. *Dyslexia 17*, 3, 242-255. DOI: 10.1002/dys.433.

Araujo, S., Pacheco, A., Faisca, L., Petersson, K. M., & Reis, A. (2010). Visual Rapid Naming and Phonological Abilities: Different Subtypes in Dyslexic Children. *International Journal of Psychology, 45*, 6, 442-452. DOI: 10.1080/00207594.2010.499949.

Arnell, K. M., Joanisse, M. F., Klein, R. M., Busseri, M. A., & Tannock, R. (2009). Decomposing the Relation between Rapid Automatized Naming (RAN) and Reading Ability. *Canadian Journal of Experimental Psychology, 63*, 3, 173–184.

Aro, M. (2004). Learning To Read. The Effect To Orthography. Jyvaskyla Studies in Education; *Psychology and Social Research 237*. University of Jyvaskyla.

Badian, N. A., Duffy, F. H., Als, H., & McAnulty, G. B. (1991). Linguistic profiles of dyslexic and good readers. *Annals of Dyslexia, 41*, 221-245.

Berninger, V. W., Abbott, R. D., Billingsley, F., & Nagy, W. (2001). Processes Underlying Timing and Fluency, Automaticity, Coordination, and Morphological Awareness. In Wolf, M. (ed.) *Dyslexia, Fluency and Brain* (pp. 383-414). Timonium, Maryland.

Breznitz, Z. 2006. *Reading Fluency: Synchronization of Processes*. Mahwah, NJ: Erlbaum.

Byrne, B., Olson, R. K., Samuelsson, S., Wadsworth, S., Corley, R., DeFries, J. D., & Willcutt, E. (2006). Genetic and environmental influences on early literacy. *Journal of Research in Reading, 29*, 1, 33–49.

Catts, H. W., Gillispe, M., Leonard, L. B., Kail, R. V., & Miller, C. (2002). The Role of Speed of Processing, Rapid Naming, and Phonological Awareness in Reading Achievement. *Journal of Learning Disabilities, 35*, 6, 509-525.

Catts, H. W. & Hogan, T. (2003). Language Bases of Reading Disabilities and Implications for Early Identification and Remediation. *Reading Psychology 24*, 223–246. DOI: 10.1080/02702710390227314.

Clarke, P., Hulme, C., & Snowling, M. (2005). Individual differences in RAN and reading: a response timing analysis. *Journal of Research in Reading, 28*, 73-86.

Compton, D. L. (2003). Modelling the Relationship between Growth in Rapid Naming Speed and Growth in Decoding Skills in First-Grade Children. *Journal of*

Educational Psychology, 95, 225-239.
Constable, A. (2007). A psycholinguistic approach to word-finding difficulties. In Stackhouse, J. & Wells, B. (eds.) *Children`s speech and literacy difficulties: Book 2. Identification and intervention* (pp. 330-365). London: Whurr Publishers.
Cronin, V. (2011). RAN and Double Deficit Theory. *Journal of Learning Disabilities.* Published online before print July 19, 2011, doi: 10.1177/0022219411413544.
Damasio, H., Grabowski, Th. J., Tranel, D., Hichwa, R. D., & Damasio, A. R. (1996). A neural basis for lexical retrieval. *Nature, 380*, 499-505, DOI: 10.1038/380499a0.
Damasio, H., Tranel, D., Grabowski, Th. J., Adolphs, & Damasio, A. R. (2004). Neural System behind word and concept retrieval. *Cognition, 92,* 1-2, 179-229.
Denckla, M. B., & Rudel, R. (1974). Rapid automatized naming of pictured objects, colors, letters and numbers by normal children. *Cortex, 10,* 186-202.
Denckla, M. B., & Rudel, R. (1976a). Rapid "automatized" naming (R.A.N.): dyslexia differentiated from other learning disabilities. *Neuropsychologia, 14*, 4, 471-179.
Denckla, M. B., & Rudel, R. (1976b). Naming of Objects-Drawings by Dyslexic and Other Learning Disabled Children. *Brain and Language, 3*, 1-15.
Deutsch, G. K., & Davis, R. N. (2010). Learning Disabilities. In Armstrong, C.L. (ed.) *Handbook of Medical Neuropsychology* (pp. 237-250). Springer: New York Dordrecht Heidelberg London.
Frijters, J. N., Lovett, M. W., Steinbach, K. A., Wolf, M., Sevcik, R. A., & Morris, R. D. (2011) Neurocognitive Predictors of Reading Outcomes for Children With Reading Disabilities. *Journal of Learning Disabilities, 44*, 2, 150-166. DOI: 10.1177/0022219410391185.
Frith, U. (1999). Paradoxes in the Definition of Dyslexia. *Dyslexia, 5,* 192-214.
Furnes, B., & Samuelsson, S. (2011). Phonological awareness and rapid automatized naming predicting early development in reading and spelling: Results from a cross-linguistic longitudinal study. *Learning and Individual Differences, 21*, 85-95. DOI: org/10.1016/j.lindif.2010.10.005.
Georgiou, G. K., Parrila, R., Kirby, J. R. (2006). Rapid naming speed components and early reading acquisition. Scientific *Studies of Reading 10,* 2, 199-220.
Georgiou, G. K., Parrila, R., Manolitsis, G., & Kirby, J. R. (2011) Examining the Importance of Assessing Rapid Automatized Naming (RAN) for the Identification of Children with Reading Difficulties. *Learning Disabilities, 9*, 2, 5-26.
German, D. J., & Newman, R. S. (2007). Oral Reading Skills of Children with Oral Language (wordfinding) Difficulties. *Reading Psychology, 28*, 397-442.
Goswami, U. (2000). The potential of a neuroconstructivist framework for developmental dyslexia: the abnormal development of phonological representations? *Developmental Sciences, 3,* 27-29.
Grigorenko, E. L. (2004). Genetic bases of developmental dyslexia: a capsule review of heritability estimates. *Enfance, 3*, 273-287.
Heikkilä, R., Närhi, V., Aro, M., & Ahonen, T. (2008). Rapid automatized naming and learning disabilities: does RAN have a specific connection to reading or not? *Children`s Neuropsychology, 1,* 1-16.
Ho, C. S. H., Chan, D. W. O., Lee, S. H., Tsang, S. M., & Luan, V. H. 2004. Cognitive profiling and preliminary subtyping in Chinese developmental dyslexia. *Cognition, 91*: 43–75.
Holopainen, L., Ahonen, T., & Lyytinen, H. (2001). Predicting Delay in Reading

Achievement in a Highly Transparent Language. *Journal of Learning Disabilities, 34*, 401-413.

Hutzler, F., Kronbichler, M., Jacobs, A. M., & Swimmer, H. (2006). Perhaps correlational but not causal: No effect of dyslexic readers' magnocellular system on their eye movements during reading. *Neuropsychologia, 44,* 637–648.

De Jong, P. (2011). What Discrete and Serial Rapid Automatized Naming Can Reveal About Reading. *Scientific Studies of Reading 15*, 4, 314-337.

Kail, R., Hall, L. K., & Caskey, B. J. (1999). Processing speed, exposure to print, and naming speed. *Applied Psycholinguistics, 20*(2), 303-314.

Kang, C. (2004). Phonological awareness and naming speed in good and poor Chinese readers. [Master Thesis] The University of Hong Kong.

Karlep, K. (2003). *Kõnearendus. Emakeele abiõpe II* [Speech Development. Supportive Teaching in Mother Tongue II]. Tartu Ülikooli Kirjastus.

Kasselimis, D. S., Margarity, M., & Vlachos, F. (2007). Cerebellar function, dyslexia and articulation speed *Child Neuropsychology, 12*, 1-11.

Katzir, T. (2008). How research in the cognitive neuroscience sheds lights on subtypes of children with dyslexia: Implications for teachers. *Cortex, 30*, 1-2.

Kim, H. (2004). The Effects of Phonological Awareness, Rapid-naming and Visual Skills on Early Elementary Students` Reading Fluency. [Doctoral Thesis] University of Florida.

Kleine, W., & Verwey B. (2009). Motor Learning and Chunking in Dyslexia. *Journal of Motor Behaviour, 41*(4) 331–337.

Korhonen, T. (1995). The Persistence of Rapid Naming Problems in Children with Reading Disabilities: A Nine-Year Follow-up. *Journal of Learning Disabilities, 26*, 232-239.

König, I. R., Schumacher, J., Hoffmann, P., Kleensang, A., Ludwig, K. U., Grimm, T., Neuhoff, N., Preis, M., Roeske, D., Warnke, A., Propping, P., Remschmidt, H., Nöthen, M. M., Ziegler, A., Müller-Myhsok, B., & Schulte-Körne, G. (2010). Mapping for dyslexia and related cognitive trait loci provides strong evidence for further risk genes on chromosome. *American Journal of Medical Genetics & Neuropsychiatric Genetics.* On-line version, published 02.11.2010. DOI: 10.1002/ajmg.b.31135 Accessed 15 March 2012.

Laine, M. (1995). Kuvan nimeäminen: kognitiivisen psykologian näkökulma [Naming of pictures from the perspective of cognitive psychology]. *Psykologia, 30*, 96-100.

Lee, L. W. (2008). Development and validation of a reading-related assessment battery in Malay for the purpose of dyslexia assessment. *Annals of Dyslexia, 58*, 37-57.

Leong, C. K., Tse, S. K., Loh, K. Y., & Hau, K. T. 2008. Text comprehension in Chinese children: Relative contribution of verbal working memory, pseudoword reading, rapid automatized naming, and onset-rime phonological segmentation. *Journal of Educational Psychology, 100*, 135–149.

Lervåg, A., Hulme, Ch. (2009). Rapid Automatized Naming (RAN) Taps a Mechanism That Places Constraints on the Development of Early Reading Fluency. *Psychological Science, 20,* 8, 1040-1048.

Lervåg, A., Bråten, I., & Hulme, Ch. (2009). The cognitive and linguistic foundations of early reading development: A Norwegian latent variable longitudinal study. *Developmental Psychology, 45*, 764–781.

Li, J., Cutting, L. E., Ryan, M., Zilioli, M., Dencla, M., & Mahone, E. M. (2009). Response Variability in Rapid Automatized Naming Predicts Reading Comprehension.

Journal of Clinical & Experimental Neuropsychology, 31, 7, 877-888, doi: 10.1080/13803390802646973.

Li, M., Kirby, J., & Georgiou, G. (2011). Rapid Naming Speed Components and Reading Comprehension in Bilingual Children. *Journal of Research in Reading, 34*, 1, 6-22, doi:10.1111/j.1467-9817.2010.01476.x.

Logan, J. (1997). Automaticity and reading: perspectives from the instance theory of automatization. *Reading & Writing Quarterly, 13*(2), 123-46.

Logan, J. A. R., Schatschneider Ch., & Wagner, R. K. (2009). Rapid serial naming and reading ability: the role of lexical access. *Reading and Writing* On-line version, published 12.08.2009. Accessed 15 Nov 2009.

Luria, A. R. (1962). *Võsshije korkovõje funktsii tsheloveka* [Higher Cortical Functions of Man]. Izdateljstvo Moskovskogo Universiteta. Moskva.

Lyytinen, H., Ahonen, T., Eklund, K., Guttorm, T. K., Laakso, M. L., Leinonen, S., Leppänen, P. H. T., Lyytinen, P., Richardson, U., & Viholainen, H. (2001). Developmental Pathways of Children With and Without Familial Risk for Dyslexia During the First Years of Life. *Developmental Neuropsychology, 20*, 2, 535-554.

Messer, D., & Dockrell, J. E. (2006). Children`s Naming and Word-Finding Difficulties: Descriptions and Explanations. *Journal of Speech, Language, and Hearing, 49*, 309-324.

Meyer, M. S., Wood, F. B., Hart, A. L., & Felton, R., H. (1998). Selective Predictive Value of Rapid Automatized Naming in Poor Readers. *Journal of Learning Disabilities, 31*, 2, 106-117.

Misra, M., Katzir, T., Wolf, M., & Poldrack, R. A. (2004). Neural Systems for Rapid Automatized Naming in Skilled Readers: Unravelling the RAN-Reading Relationship. *Scientific Studies of Reading, 8,* 241-256.

Nation, K. (2005). Connections between Language and Reading in Children with Poor Reading Comprehension. In Catts, H.W. & Kamhi, A.G. (eds.) *The connections between language and reading disabilities* (pp. 37-47). London: Lawrence Erlbaum Associates.

Neuhaus, G., Foorman, B., Francis, G. J., & Carlsson, C. D. (2001). Measures of information processing in rapid automatized naming (RAN) and their relation to reading. *Journal of Experimental Child Phycology, 78*, 359-373.

Neuhaus, G. F., & Swank, P. R. (2002). Understanding the Relations between RAN Letter Subtest Components and Word Reading in Understanding the Relations between RAN Letter Subtest Components and Word Reading. *Journal of Learning Disabilities, 35*, 158 – 176.

Nicolson, R. I., & Fawcett, A. J. (1999). Developmental dyslexia: The role of cerebellum. *Dyslexia, 5*, 155-177.

Nicolson, R. I., & Fawcett, A. J. (2008). Dyslexia and Cerebellum. In Reid, G., Fawcett, A. J., Manis, F. & Siegel, L. (eds.) *SAGE Handbook of Dyslexia* (pp. 77-98). London: SAGE.

Norton, E., & Wolf, M. (2012). Rapid Automatized Naming (RAN) and Reading Fluency: Implications for Understanding and Treatment of Reading Disabilities. Annual *Review of Psychology, 63*, 1, 427-452.

Närhi, V., Ahonen, T., Aro, M., Leppäsaari, T., Korhonen, T. T., Tolvanen, A., & Lyytinen, H. (2005). Rapid serial naming: Relations between different stimuli and neuropsychological factors. Brain *and Language, 92*, 45-57.

Papadopoulos, T. C., Georgiou, G. K., & Kendeou, P. (2009). Investigating the double-deficit hypothesis in Greek. *Journal of Learning Disabilites, 42,* 6, 528-547.

Pastarus, K. (1999). *5-6-aastaste laste lugemisoskuse eelduste uurimine* [Reading predictions in 5-6 y children]. In Karlep, K. (ed.) Töid eripedagoogikast XV [Papers in Special Education] (pp. 20-33). Tartu Ülikooli Kirjastus.

Pham, A., Fine, J. G., & Semrud-Clikeman, M. (2011). The Influence of Inattention and Rapid Automatized Naming on Reading Performance. *Archives of Clinical Neuropsychology 26*, 3, 214-224.

Ramus, F. (2003). Developmental dyslexia: Specific phonological deficit or general sensorimotor dysfunction? *Current Opinion in Neurobiology, 13*, 1–7.

Rapin, I., & Allen, D. A. (1983). Developmental language disorders: nosologic considerations. In Kirk, U. (ed.) *Neuropsychology of language, reading, and spelling* (pp. 155-184). New York: Academic Press.

Sadeghi, A., Everatt, J., Tehrani, L. G., Elbeheri, G., and Al-Menaye, N. (2009) *Comparisons of literacy levels and predictors across Arabic, English and Persian orthographies*. University of Canterbury, Christchurch, New Zealand: Literacy Research Symposium, 1-2 Oct 2009. (Conference Contribution - Poster presentation).

Salmi, P. (2008). *Nimeäminen ja lukemisvaikeus. Kehityksen ja kuntoutuksen näkökulma Akateeminen väitoskirja* [Naming and Reading Difficulties. Development and Treatment. Doctoral Thesis]. Jyvaskyla Studies in Education, Psychology and Social Research 345. Akateeminen väitoskirja. University of Jyvaskyla.

Samuelsson, S., Byrne, B., Quain, P., Wadsworth, S., Corley, R., DeFries, J. C., Willcutt, E., & Olson, R. (2005). Environmental and Genetic Influences on Prereading Skills in Australia, Scandinavia, and the United States. *Journal of Educational Psychology, 97,* 4, 705–722.

Savage, R., & Fredricson, N. (2005). Evidence of highly specific relationship between rapid automatic naming of digits and text-reading speed. *Brain and Language, 93,* 152-159.

Shaywitz, S. (2003). *Overcoming Dyslexia. A New and Complete Science-Based Program for Reading Problems at Any Level.* New York: Alfred A Knopf.

Swanson, H. L, Trainin, G., Necoechea, D. M., & Hammill, D. D. (2003). Rapid Naming, Phonological Awareness, and Reading: A Meta-Analysis of the Correlation Evidence. *Review of Educational Research, 73,* 407-440.

Taibah, N.J., & Haynes, Ch. W. (2011). Contributions of phonological processing skills to reading skills in Arabic speaking children. *Reading & Writing, 24,* 1019–1042, doi: 10.1007/s11145-010-9273-8.

Torppa, M., Lyytinen, P., Erskine, J., Eklund, K., & Lyytinen, H. (2010). Language Development, Literacy Skills, and Predictive Connections to Reading in Finnish Children With and Without Familial Risk for Dyslexia. *Journal of Learning Disabilities, 43*, 4, 308-321.

Tuovinen, S. (2003). Sananlöytämisongelmi-en kuntoutus [Treatment of Word Finding Difficulties]. In Ahonen, T. & Aro, T. *Oppimisvaikeudet. Kuntoutus ja opetus yksilöllisen kehituksen tukena* [Learning Difficulties. Treatment and Teaching] (pp. 254-272). Jyvaskyla: Ateena.

Van Bergen, E., de Jong, P. F., Regtvoort, A., Oort, F., van Otterloo, S., & van der Leij, A. (2011). Dutch Children at Family Risk of Dyslexia: Precursors, Reading

Development, and Parental Effects. Dyslexia 17, 2–18. DOI: 10.1002/dys.423.

Van der Leij, A., Lyytinen, H., & Zwarts, F. (2001). The study of infant cognitive processes in dyslexia. In Fawcett, A., J. (ed.) *Dyslexia: Theory and good practice* (pp. 160-181). London: Whurr.

Vaessen, A., & Blomert, L. (2010). Long-term cognitive dynamics of fluent reading development. *Journal of Experimental Child Psychology, 105*, 3, 213–231. doi: org/10.1016/j.jecp.2009.11.005.

Vellutino, F. R., Fletcher, J. M., Snowling M., & Scanlon, D. M. (2004). Specific reading disability (dyslexia): what have we learned in the past four decades? *Journal of Child Psychology and Psychiatry, 45*(1), 2-40.

Vukovic, R. K., & Siegel, L. S. (2006). The double-deficit hypothesis: A comprehensive analysis of the evidence. *Journal of Learning Disabilities, 39*, 25-47.

Waber, D. P., Wolff, P. H., Forbes, P. W., & Weiler, M. D. (2000). Rapid automatized naming in children referred for evaluation of heterogeneous learning problems: how specific are naming speed deficits to reading disability? *Child Neuropsychology, 6,* 251-261.

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

Wiig, E. H., Zuerich, P. & Chan, H-N. H. (2000). A Clinical Rationale for Assessing Rapid Automatized Naming in Children with Language Disorders. *Journal of Learning Disabilities, 33*, 49, 359-375

Wimmer, H., Mayringer, H., & Landerl, K. (1998). Poor Reading: A deficit in Skill-Automatization or a Phonological Deficit? *Scientific Studies of Reading, 2,* 4, 321-340.

Wolf M. (1982). The word-retrieval process and reading in children with aphasics. In Nelson, K. (ed.) *Children`s Language III* (pp. 437-493). Hillsdale: Erlbaum.

Wolf, M. (1986). Rapid Alternating Stimulus Naming in the Developmental Dyslexias. *Brain and Language, 27*, 360-379.

Wolf, M (1991). Naming Speed and Reading: The Contribution of the Cognitive Neurosciences *Reading Research Quarterly, 26,* 2, 123-141.

Wolf, M. (1999). What Time May Tell: Towards a New Conceptualization of Developmental Dyslexia. *Annals of Dyslexia, 49*, 3-28.

Wolf, M. (2008). *Proust and the Squid*. Icon Books.

Wolf, M., Bally, H. & Morris, R. (1986). Automaticity, Retrieval Processes, and Reading: A Longitudinal Study in Average and Impaired Readers. *Child Development, 57,* 988 -1000.

Wolf, M. ,& Bowers, P. G. (1999). The double-deficit hypothesis for the developmental dyslexia. *Journal of Educational Psychology, 91*, 1-24.

Wolf, M., Bowers, P. G., & Biddle, K. (2000). Naming-speed processes, timing and reading. A conceptual review. *Journal of Learning Disabilities, 33*, 4, 387-407.

Wolf, M., & Denckla, M. B. (2005). RAN/RAS. *Rapid Automatized and Rapid Alternating Stimulus Test*. Examiner`s Manual. Austin, Texas: Pro-Ed.

Yeung, P., Ho, C. S. -H, Chik, P. P., Lo, L., Luan, V. H., Chan, D. W. -O., & Chung, K. K. (2011). Reading and Spelling Chinese Among Beginning Readers: What Skills Make a Difference? Scientific Studies of Reading, 15, 4, 285-313, DOI: 10.1080/10888438.2010.482149.