Role of on-screen visual stimuli reaction times, subcomponents of attention, and gender in RAN and reading fluency association.

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ABSTRACT

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Rapid automatized naming (RAN) is the capacity to retrieve and fluently designate serially displayed stimuli, e.g. letters or objects. RAN, as a speeded task, is correlated with processing speed and reaction times. RAN is a strong predictor of reading skills in transparent orthographies and it has been found that this association might be due to underlying attentional processes. The Attention Network experiment (ANT) is the most common experiment obtained for measuring the three subcomponents of attention (alerting, orienting, inhibition). The purpose of this study is to examine whether the reaction times in different visual stimuli and the subcomponents of attention predict RAN performance as well as whether they moderate the relationship between RAN and reading fluency.

This study obtains psychometric data from the eSeek project and an ANT experiment conducted by Santhana Gopalan (2019; 2020). 166 participants completed the psychometric tests and 115 of those participated in the ANT experiment. Analysis was conducted using SPSS 26 and Pearson's correlations, hierarchical regression and moderation analysis were used to answer the research questions.

This study showed that RAN predicts reading fluency and that gender acts as a moderator in the relationship between RAN and reading fluency. Reaction times were a significant predictor of RAN performance in both the letters and the objects tasks and moderated RAN performance in objects, together with gender. Orienting was found to predict and moderate RAN performance in the letters task. Alerting and inhibition were a significant predictor of RAN performance in objects.

The main results managed to clarify the connection between reading fluency, RAN performance, reaction times and the subcomponents of attention. As this topic has not been investigated before, it provided new insight in this matter.

Keywords: Rapid Automatized Naming, Reading Fluency, Reaction times, ANT experiment, Alerting, Orienting, Inhibition

CONTENTS

1. INTRODUCTION

Reading fluency is the ability to read rapidly, accurately and with the appropriate expression (Álvarez-Cañizo et al., 2015; Bigozzi et al., 2017; Elhassan et al., 2015; Kuhn & Stahl, 2003). It is characterised by accuracy, automaticity and prosody (Sarris & Dimakos, 2015). Reading fluency is an extremely complex process which is dependent on the development of various internal skills, for instance phonological awareness (Ziegler and Goswami, 2005 as cited in Elhassan et al., 2015), letter knowledge (Blaiklock, 2004 as cited in Elhassan et al., 2015), visual recognition (Sereno and Rayner, 2003 as cited in Elhassan et al., 2015), attention (Kinsey et al., 2004 as cited in Elhassan et al., 2015), working memory (Daneman and Carpenter, 1980 as cited in Elhassan et al., 2015), naming speed (Logan, 1997 as cited in Elhassan et al., 2015) and speed of processing (Breznitz and Misra, 2003 as cited in Elhassan et al., 2015). The role of gender in reading fluency is critical. Research suggests that girls tend to be better readers compared to boys (Akyol, 2014; Bank et al., 1980; Mullis et al. 2017; OECD, 2019) and that boys are more likely to experience reading difficulties (1.83 times), especially when they are severe, in which case a moderation effect is observed (Qinn, 2018). In transparent orthographies, such as Finnish, reading difficulties are mostly observed in reading fluency and reading speed (Aro et al., 2011; Escribano, 2007; Holopainen et al., 2001; Seymour et al., 2003) and not so much in accuracy (Wimmer, 1993).

Rapid automatized naming (RAN) can be described as the capacity to retrieve and fluently designate serially displayed familiar stimuli such as letters, colors, objects or digits (Georgiou et al., 2006). Studies have presented a significant correlation between RAN and reading fluency (Neuhaus et al. 2001a; Neuhaus et al. 2001b; Siddaiah & Padakannaya, 2015), RAN and reading comprehension (Georgiou et al. 2010; Neuhaus et al. 2001a; Neuhaus et al. 2001b; Padakannaya et al. 2008; Siddaiah & Padakannaya, 2015) as well as between RAN and reading speed (Siddaiah & Padakannaya, 2015; Wimmer, 1993). In transparent orthographies, RAN is the strongest predictor of literacy among children exhibiting deficiencies in reading

(Holopainen et al., 2001; Puolakanaho et al., 2007; Torppa et al., 2010). Even though the importance of RAN as a predictor of reading fluency is well established, the reasons underlying this association are still uncertain (Papadopoulos et al., 2016). One theory suggests that RAN is correlated to reading due to underlying attentional processes (e.g. Bexkens et al., 2015; Shao et al., 2013).

As demonstrated above, attention plays a crucial role in reading fluency and RAN performance. Attention is a complicated cognitive ability (Adolfsdottir et al., 2008) and is comprised of distinct but interconnected subcomponent processes (Dash et al., 2019; Fan et al., 2009; Posner & Fan, 2008). Those processes are alerting, orienting and inhibition (Posner & Raichle, 1994; Posner & Fan, 2008; Posner & Petersen, 1990). Alerting is the ability to reinforce and maintain response readiness in preparation for a forthcoming stimulus. Orienting is the ability to choose particular information from among multiple sensory stimuli (Raz & Buhle, 2006). Inhibition involves several mechanisms responsible for the resolution of conflicts, detection of errors and choice of action in response to other stimuli (Posner and Rothbart, 2007; Raz & Buhle, 2006; Santhana Gopalan et al., 2019; Santhana Gopalan et al., 2020). The Attention Network experiment (ANT) is the most common experiment obtained for measuring the three subcomponent processes and examining their interaction (Fan et al., 2002). As a task based on speed choice, the ANT gives two measures of performance; reaction time (RT) and error rate (ER) (Macleod et al., 2010b).

Reaction time, or processing speed, plays a role in both reading and RAN. It has been found that processing speed is strongly associated with the development of reading achievement, particularly during the elementary school years when children acquire reading skills and improve their speed and automaticity abilities (Weiss et al., 2016). Together with RAN, processing speed is another indicator of automaticity that probes the speed of mental activity with non- linguistic stimuli (Lam et al., 2017). Processing speed is, also, playing a role in RAN, as studies have demonstrated that there is a significant correlation between RAN and processing speed (He et al., 2013) as well as that impairments in RAN performance can imply deficits in generalized processing speed (Kail & Hall, 1994; Kail et al., 1999). Reseach suggests that the general processing speed explains the relationship between RAN and reading (DeMann, 2011).

This study obtains psychometric tests data (RAN, TOWRE, NMI) from the eSeek project and EEG data from an ANT experiment conducted with participants from the eSeek project. The eSeek project is a multidisciplinary project conducted by the University of Jyväskylä and implemented during the years 2014- 2017. The aim of the project was to identify, among others, how children (10- 13 years old) with different learning difficulties differ in Internet seeking skills and neural processes in comparison to typical learners.

The purpose of this study is to examine the role of on-screen visual stimuli reaction times, subcomponents of attention and gender in RAN and reading fluency association. Linear regression and moderation analysis will be obtained in order to determine whether the reaction times, subcomponents of attention and gender predict RAN performance as well as whether they moderate the relationship between reading fluency and RAN. The aim of this study is to shed light to the potential associations present, as this phenomena have not been investigated before.

2. READING FLUENCY AND RAN

2.1. Reading fluency

Reading fluency refers to the capacity to read rapidly, accurately and with the appropriate expression (Álvarez-Cañizo et al., 2015; Bigozzi et al., 2017; Elhassan et al., 2015; Kuhn & Stahl, 2003). According to Kuhn and Stahl (2003) a fluent reader is able to decode words accurately, presents automaticity in recognizing words and obtains prosodic features (e.g. stress, pitch, and appropriate text phrasing) in a correct and appropriate manner.

The first characteristic of fluent reading is accuracy, which can be defined as the ability to correctly decode words (Sarris & Dimakos, 2015). For the achievement of fluent and accurate reading the development of phonological awareness, a metacognitive skill which refers to the ability to discriminate, analyze and manipulate sounds, is important. Phonological awareness is an important predictor of successful reading acquisition (Knoop-van Campen et al., 2018).

Fluent reading is characterized by automaticity. Automaticity can be defined as the ability to quickly, effortlessly and accurately identify words at the single world level, with speed and accuracy of word identification being the primary predictors of comprehension (Hook & Jones, 2004). Speed is an important element of automaticity; as learners gain more automaticity with reading practice and engagement in different tasks (e.g. perceptual - motor activities) their reading skills not only become more accurate but they, also, become faster. Furthermore, automaticity is characterized by effortlessness, which is the sense of ease in the performance of a task as well as the capacity to accomplish a second task simultaneously with the first, automatic task. When it comes to reading, a fluent reader is able to recognize and decode most words in a text without struggle while simultaneously being able to comprehend what they are reading. Automatic reading is also autonomic, meaning that it can occur without intention, with a fluent reader being capable of inadvertently read texts. Finally, automaticity is characterized by the lack of conscious awareness, that is the ability of readers to identify nearly every word that they come upon without any conscious effort (Kuhn et al., 2010). Automatic reading is a process that requires the development of substantial orthographic representations which enables the quick and accurate identification of entire words comprised of particular letter patterns (Hook & Jones, 2004).

Another important characteristic of fluent reading is prosody. Prosody includes a variety of features such as pitch or intonation, stress and duration, all of which can assist in expressive reading (Kuhn & Stahl, 2003). Prosody also refers to the capacity to construe a text into syntactically and semantically appropriate units. Fluent readers have the ability to use expression while reading, inflect their pitch and highlight significant words (Sarris & Dimakos, 2015).

It has been suggested that the potential differences in alphabetic orthographies can play a role in the emergence of reading fluency. Alphabetic orthographies can be divided into two categories, opaque (deep) and transparent (shallow) (Aro, 2004). This distinction is based on differences in the extent of systematicity with which letter sequences chart into their matching phoneme sequences (e.g., Aro, 2004; Landerl et al., 2013; Protopapas and Vlahou, 2009). Opaque orthographies, such as English, are characterized by ambiguous orthography- phonology relationships (Frost, 2012; Seymour et al., 2003), with the written script not completely corresponding to the phonemic structure of the language (Aro, 2004). Transparent orthographies, on the other hand, such as Finnish, are characterized by a high consistency of how surface phonology is displayed in spelling, with the pronunciation of a given letter of the alphabet being almost always the same regardless of the word they appear in (Aro, 2004).

Regarding the Finnish language, it is considered to be optimal for literacy acquisition as it is comprised by a regular grapheme- phoneme correspondence system, small number of phonemes, simple phonemic structure of syllables and almost non-existing consonant clusters. All the above are advantageous for reading acquisition as they enable a systematic use of left-to-right phonological decoding at the single word level, without requiring explicit grapheme translation. That being said, Finnish is a complex language, with complexities arising mostly due to its complicated morphological system as well as the length of the words and the coding of phonemic length (Aro, 2004).

In transparent orthographies, such as Finnish, decoding skills and reading accuracy can be acquired early in reading development (Aro et al., 2011; Escribano, 2007; Holopainen et al., 2001; Seymour et al., 2003). In Finland approximately 85% – 95% of children achieve word-level reading accuracy by the end of first grade (Aro & Wimmer, 2003; Aro, 2006; Seymour et al., 2003; Torppa et al., 2010). The Finnish language allows the readers to pay attention to very small units and adopt a serial, letter-by-letter strategy in reading (Pagliuca & Monaghan, 2010; Ziegler & Goswami, 2005).

A study by Seymour et al. (2003), revealed that English- speaking children require more time to achieve basic competence in reading words and pseudowords compared to those children learning to read in more transparent orthographies. There are two possible explanations for that. Ziegler and Goswami (2005) proposed that children who learn to read in a deep orthography, which is characterized by inconsistency in orthographical and phonological mappings, will acquire different types of representations than children who learn to read in a shallow orthography. The second theory has its foundations in the 'Orthographic Depth Hypothesis' (Frost et al., 1987), which suggests that even though lexical and sub-lexical mappings exist for orthography-to-phonology coding and for word recognition, the respective weighting of each strategy relies upon the depth or transparency of the orthography being read.

Reading fluency and comprehension are strongly interconnected concepts, which present strong connections with crucial elements of academic life such as school performance (Álvarez-Cañizo et al., 2015; Bigozzi et al., 2017), or training success (Bigozzi et al., 2017; Krumm et al., 2008). Reading comprehension is comprised of two categories of cognitive skills: lower level processes that include translating the written code into meaningful language units and higher level processes that include combining these units into a meaningful and coherent mental representation (Kendeou et al., 2014). Both cognitive processes of reading comprehension start to emerge prior to reading education and they independently are strong predictors of reading comprehension ability later on (Kendeou et al., 2009).

Gender differences in reading fluency have been investigated broadly. Previous research suggested that gender can significantly indicate reading accomplishment (Namaziandost et al., 2020). Research suggests that girls tend to perform better compared to boys in verbal and linguistic functions (Halpern, 1986; Maccoby & Jacklin, 1974; McCormack & Knighton, 1996 as cited in Vlachos & Papadimitriou, 2015) as well as in reading (Bank et al., 1980; Akyol, 2014). A study conducted by Logan & Johnson (2009) discovered that girls have better performance in reading comprehension and present better attitudes towards reading, even though their reading ability did not differ significantly from that of boys. The 2016 Progress in International Reading Literacy Study (PIRLS) demonstrated that in 48 of the 50 participating countries, 10 year old girls displayed better reading performance in comparison to boys (Mullis et al. 2017). Similar results were observed in the Program for International Student Assessment (PISA) (OECD, 2019).

Other studies, however, have shown no differences among gender in reading achievement, at least not in the elementary school years. Studies conducted by Klein & Jimerson (2005) and Below and colleagues (2010) revealed no gender differences in terms of oral reading fluency. A study conducted by Vlachos and Papadimitriou (2015) in 7 and 8 year old children found no gender differences in reading performance. Limbrick and colleagues (2011) in a longitudinal study demonstrated that when it comes to elementary school children (eight to eleven years of age) no significant gender differences were observed in performance in the WARP and TOWRE tests. All the above could be due to the fact that it has been found that gender differences become obvious after the age of 11 years (Shackleton & Fletcher, 1984 as cited in Vlachos & Papadimitriou, 2015).

Reading fluency is an extremely complex process which is dependent on the development of various internal skills, for instance phonological awareness (Ziegler and Goswami, 2005 as cited in Elhassan et al., 2015), letter knowledge (Blaiklock, 2004 as cited in Elhassan et al., 2015), visual recognition (Sereno and Rayner, 2003 as cited in Elhassan et al., 2015), attention (Kinsey et al., 2004 as cited in Elhassan et al., 2015), working memory (Daneman and Carpenter, 1980 as cited in Elhassan et al., 2015), naming speed (Logan, 1997 as cited in Elhassan et al., 2015) and speed of processing (Breznitz and Misra, 2003 as cited in Elhassan et al., 2015). What is more, external factors, for example text characteristics, purpose for reading and reading topic, also, play a role in reading fluency (Elhassan et al., 2015).

Despite a strong focus on the development of reading skills, some individuals struggle to achieve functional levels of reading comprehension. It is estimated that approximately 5–12% of school age children display reading problems, regardless of average intelligence, typical education, intact hearing and vision, sufficient motivation and socio-cultural opportunities (Lagae, 2008). Males are more likely to experience reading difficulties than females (1.83 times), especially when reading difficulties were severe, in which case a moderation effect is observed (Qinn, 2018).

Problems with reading might emerge due to deficits in lower level processes that include translating the written code into meaningful language units (e.g., phonological processes, decoding processes, etc.), to higher level processes that involve connecting these units into a meaningful and coherent mental representation (e.g. inferential processes, executive function processes, attention–allocation abilities), or both (Kendeou et al., 2014). Dysfluent readers present problems in the three elements of reading fluency: accuracy in decoding, automaticity in word recognition, and the appropriate use of prosodic elements (Sarris & Dimakos, 2015). Moreover, dysfluent readers might present delayed retrieval of names, meaning, or both as well as deficits in creating higher order semantic and phonological connections between words, meaning, and ideas (Wolf et al., 2000).

Problems with reading fluency and comprehension can be associated with deficits in the capacity to create inferences. Inferences are critical for reading as it enables the reader to build substantial associations between text aspects and related background knowledge (Oakhill et al., 2003). Dysfluent readers face problems with the creation of inferences, resulting into poor text comprehension regardless of text difficulty as they are not able to identify significant connections that provide coherence to their text representations (Kendeou et al., 2014).

Impairments in reading fluency and comprehension are, also, related to executive functions, which are the cognitive processes that enable the control and regulation of one's behavior while executing a specific task (Diamond, 2013). They include working memory and inhibition (Kendeou et al., 2014). Working memory is crucial for reading as it allows the reader to sustain information during the processing of incoming information, enabling the integration of old and new information (Swanson & O'Connor, 2009). Inhibition implements the elimination of irrelevant information, ensuring the maintenance of relevant information in the working memory. Differences in working memory are a strong predictor of reading fluency skills (Cain et al., 2004; Sesma et al., 2009 as cited in Kendeou et al., 2014). Readers with low working-memory capacity display problems in information processing, comprehension and recall performance (Linderholm & van den Broek, 2002). Furthermore, they struggle with inference making, comprehension monitoring as well as with applying appropriate reading strategies (Kendeou et al., 2014). Inhibition is highly related to reading comprehension. Dysfluent readers are often facing impairments in excluding information that is not any more applicable in both short-term memory tasks and working memory tasks (Cain, 2006).

Another area that dysfluent readers often exhibit difficulties is attention allocation, which refers to the capacity to accommodate attentional and processing abilities as demanded by each particular task performed (Liu et al., 2013), resulting in difficulty forming mental representations from texts (van den Broek, 2013). Children with attentional problems might, also, exhibit reading comprehension difficulties, as they might be more likely to be distracted by details and not focus on main ideas, particularly when encountering longer texts (Long et al., 1997 as cited in Kendeou et al., 2014). They, also, present impairments in coherence breaks in texts, something that can lead to less coherent mental depictions of texts (Cain & Oakhill, 2007).

Different orthographic systems can cause difficulties in different areas of reading. It has been found that in transparent orthographies deficiencies exist primary in reading fluency and reading speed (Aro et al., 2011; Escribano, 2007; Holopainen et al., 2001; Seymour et al., 2003) and not so much in accuracy (Wimmer, 1993). Much like in other transparent orthographies, in Finnish language reading deficits arise in the fluency aspect of reading performance (Leppänen et al., 2006). Lyytinen and colleagues (2006) suggested that after developing the regular grapheme–phoneme mappings, deficits in accuracy are rare, but instead slow reading speed is a better indicator of reading difficulties. Reading speed deficiencies can be due to a failure to formulate lexical orthographic input representations (Wimmer, 1993), a failure to acquire a more parallel, less serial mode of grapheme-to-phoneme coding (Davies et al., 2007) or a failure to automatize reading processes (Nicholson & Fawcett, 1990).

Even though reading difficulties can emerge without a particular reason, there are certain risk factors that heighten the likelihood of developing reading difficulties. Children at risk of developing reading difficulties present impairments with rhyming games, learning the alphabet and relating sounds with letters. Moreover, they have decreased capacity for the distinction of the letters of the alphabet by the start of kindergarten and they often present delayed or impaired speech or language (Shaywitz, 1998).

Experiencing other difficulties, such as attentional problems, can, also elevate the risk for developing reading difficulties (Willcutt & Pennington. 2000), as can receiving intervention (e.g., speech and language therapy) for identified risk factors (Rescorla, 2002). Furthermore, external factors can play a role too. Premature birth and low birth weight elevate the risk of developing various disabilities, including language deficits (Litt et al., 2005). Organic causes such as cognitive impairments, low IQ score

(75 to 90) and hearing impairments could also result in language problems (Squires et al., 1997). Family history of learning impairments or deficits with speech, language, spelling, or reading is an important factor (Shaywitz, 1998). Twin studies demonstrated that phonological deficiency has an approximate 60% concordance between identical twins (Wadsworth & DeFries, 2005). Moreover, research suggests that 23% to 65% of children with a parent who present reading deficits will also experience deficits (Shaywitz, 1998). Finally, other environmental factors include poverty, low parental education, unstimulating home environment and inadequate instruction (Squires et al., 1997).

2.2. Rapid automatised naming (RAN)

Rapid automatized naming (RAN) can be described as the capacity to retrieve and fluently designate serially displayed familiar stimuli such as letters, colors, objects or digits (Georgiou et al., 2006). RAN is a strong predictor of reading skills (e.g. Georgiou et al., 2006; Papadopoulos et al., 2016), as deficits in RAN may result in or signify reading difficulties (Araújo & Faísca, 2019; Siddaiah & Padakannaya, 2015).

A meta-analytical study conducted by Araújo and colleagues (2015), demonstrated that the relationship between RAN and reading fluency is .48. Studies have presented a significant correlation between RAN and reading fluency (Neuhaus et al. 2001a; Neuhaus et al. 2001b; Norton and Wolf, 2012; Siddaiah & Padakannaya, 2015), RAN and reading comprehension (Georgiou et al. 2010; Neuhaus et al. 2001a; Neuhaus et al. 2001b; Padakannaya et al. 2008; Siddaiah & Padakannaya, 2015) as well as between RAN and reading speed (Siddaiah & Padakannaya, 2015; Wimmer, 1993). Georgiou and colleagues (2013) indicated that RAN is correlated with reading because both include serial processing and oral production of the stimuli's names. The importance of RAN lies in the fact that it enables the prediction of unique variance in reading that is different than that predicted by other well- established predictors of reading capacity, such as phonological awareness and letter knowledge (Kirby et al. 2003; Siddaiah & Padakannaya, 2015). A study conducted by Poulsen and colleagues (2015) found that the phonological awareness and letter knowledge acted as an important mediator for the relationship between RAN and reading, moderately explaining this relationship, revealing that the relationship between RAN and reading was only partly explained by the processes that precede reading.

RAN plays an important role in transparent orthographies as it has been found that RAN is the strongest predictor of literacy among children exhibiting deficiencies in reading (Holopainen et al., 2001; Puolakanaho et al., 2007; Torppa et al., 2010). A longitudinal study by Torppa and colleagues (2013) demonstrated that in Finland a single RAN deficit is a strong predictor of poorer reading fluency. Other studies done in Finland displayed a strong a strong correlation between RAN and reading fluency in non-selected samples of children (Holopainen et al., 2001; Lepola, et al., 2005; Torppa et al., 2013), in children with reading deficits (Lyytinen et al., 2006b) and in individuals with naming deficits (Berg et al., 2014).

This relationship can be explained by differences in reading development between different orthographic systems. In transparent languages, like Finnish, reading accuracy is acquired early on, something that does not occur in less transparent orthographies (Seymour et al., 2003). Hence, phonological awareness predict reading skill for a shorter period of time as accuracy is acquired faster (Aarnoutse et al., 2005; Papadopoulos et al., 2009; Torppa et al., 2012; Wimmer et al., 2000) and naming speed explains a bigger proportion of the total variance in reading performance (Heikkilä, 2015).

Regarding the type of stimuli, research suggests that RAN performance on nonalphabetic stimuli (e.g. objects, colors) in preschool children predicts later reading development (Araújo et al., 2015; Landerl & Wimmer, 2008). However, after the emergence of literacy, and while children experience more and more contact with letters and numbers, alphanumeric stimuli predict better reading, with correlations between alphanumeric RAN performance and reading being higher compared to non-alphanumeric RAN performance (Lervåg & Hulme, 2009; Araújo et al., 2015). A study conducted by Savage and colleagues (2005) demonstrated that the correlation between RAN and reading level was essentially higher when digit naming was obtained compared to when object naming was obtained. Similarly, Vaessen and Blomert (2010) discovered that RAN digits were correlated to a higher degree displays with reading fluency in comparison to RAN letters in first to sixth graders, with RAN objects presenting the lowest correlations.

Even though the significance of RAN as a predictor of reading fluency is well established, the reasons underlying it is still rather uncertain (Papadopoulos et al., 2016). Wolf and colleagues (2000) indicated that this uncertainty might emerge due to the fact that RAN's multi-componential nature as it demands the coordination of multiple sub-processes related to reading, for instance attentional, phonological, orthographic, memory, motor, and articulatory processes. According to Wimmer et al. (2000) RAN and reading could be associated because both rely on the speed of phonological retrieval from long-term memory. RAN, also, compels the activation of visual processes, which are important for stimuli detection, visual discrimination, and letter/letter-pattern identification as well as lexical processes such as access and retrieval of phonological codes. Furthermore, one should be able to integrate the visual information with stored orthographic and phonological representations as well as have the necessary skills in order to organize the articulatory output (Araújo et al., 2015; Wolf & Bowers, 1999). Processing speed is also crucial for RAN performance (Kail et al., 1999).

There have been several explanations about why RAN performance might be correlated to reading fluency. A first theory was developed by Torgesen and colleagues (1997; Papadopoulos et al., 2016) who suggested that the correlation between RAN and reading can be explained by the fact that they both demand adequate access to, and recovery of, phonological representations from long-term memory. They suggested that RAN tasks can be seen as an indicator of the speed with which one can retrieve phonological or lexical information from memory (DeMann, 2011; Torgesen et al., 1997).

A second theory is proposed by Bowers and colleagues (e.g. 2002; Papadopoulos et al., 2016), who indicated that RAN is a predictor of reading via the effects of orthographic processing, which is the ability to process arrays of letters or entire words as single units instead of as a string of grapheme-phoneme correspondences (Ehri, 1987; Papadopoulos et al., 2016). Bowers and Wolf (1993 as cited in Papadopoulos et al., 2016) suggested that if the progress of letter identification processes is too slow, as implicated by slow naming speed performance, there will not be a fast enough activation of letter representations to generate responsiveness to frequently arising orthographic patterns. In a similar manner, Manis and colleagues (2000) demonstrated that RAN uniquely predicts orthographic processing. Furthermore, it has been found that children who experience weaknesses in RAN also present substantial weaknesses in orthographic processing in comparison to children with no weaknesses in RAN (Bowers & Sunseth, 2002; Papadopoulos et al., 2016).

A third theory is based on domain-general components that impact performance in both RAN and reading. Kail and colleagues (1999) claimed that the relationship between RAN and reading exists due to the fact that skillful performance in both naming and reading is partially dependant on the speed with which the underlying processes are accomplished. Amtmann and colleagues (2007; Papadopoulos et al., 2016) suggested that the association between RAN and reading is explained by the fact that both need the preservation of an array of names in working memory that enables the time-dependant assimilation of phonological and orthographic representations of names. Other studies (e.g. Bexkens et al., 2015; Shao et al., 2013) revealed that RAN is correlated to reading due to underlying attentional processes. As RAN requires the storage of a big amount of information (different stimuli) into the working memory in a highly accessible condition, there is a competition between the activations of previously named stimuli and the current stimulus when choosing a response. For that reason, inhibition is crucial for choosing the correct among all competing alternatives.

As demonstrated above, RAN tasks involve the speeded identification and naming of individual, familiar objects (e.g. letters, digits, objects). They involve visual sensory processes, stimulus identification, and response retrieval and vocal production. The most unique element of RAN is that it is characterized by sequence (Arnell et al., 2009). Wolf and Bowers (1997 as cited in Arnell et al., 2009) indicated that RAN highlights aiming sustained attention over time. RAN requires regulating eye movement sequences to fixate on consecutive stimuli as well as coordinate their eye movements with the cognitive and articulatory processes implicated in naming each item. Furthermore, RAN incorporates inhibitory capacities, as one should dynamically suppress earlier and impending responses while choosing the current response (Arnell et al., 2009).

2.3. Processing speed

Processing speed refers to the capacity to identify, distinguish, accommodate, decide and respond about visual and verbal information. During speeded tests, response processes are usually motoric (e.g. written response) or oral (e.g. saying an object's name).Processing speed measures can inform about the adeptness of performing basic, overlearned tasks or tasks that demand processing of novel information (Weiss et al., 2019). Individual differences in processing speed are associated with individual differences in intelligence and working memory as well as in basic verbal and quantitative capacities, with faster processing speed signifying better performance in psychometric tests (Geary, 2010).

Regarding reading skills, it has been demonstrated that processing speed is strongly related to the development of reading and math achievement, particularly during the elementary school years when children acquire reading and math skills and improve their speed and automaticity abilities (Weiss et al., 2016). Together with RAN, processing speed is another indicator of automaticity that probes the speed of mental activity with non- linguistic stimuli. Processing speed is perceived as a key aspect of the cognitive system, supporting the automatization of learning that is central for successful reading (Lam et al., 2017).

It has been found that processing speed plays a role in RAN performance. A research done by He and colleagues (2013) demonstrated a significant correlation between naming speed and cognitive abilities (IQ score) as well as between RAN and reaction times. A study conducted by Kail and his colleagues (Kail & Hall, 1994; Kail et al., 1999) demonstrated that impairments in RAN performance can imply deficits in generalized processing speed. They suggested that general processing speed explains the relationship between RAN and reading and that this relationship indicates the gradual raise in children's processing speed which emerges as they develop (DeMann, 2011). Cutting and Denckla (2001) discovered a strong correlation between RAN, reading and processing speed, with processing speed directly contributing to RAN performance.

Several studies have focused on the role of articulation time and pause time in RAN. A study conducted by Georgiou and colleagues (2008) employed 48 children, who underwent RAN measurements in first, second and third grade and discovered that pause time displayed a high correlation with both reading accuracy and reading fluency measures and was a stronger predictor of orthographic knowledge rather than phonological awareness or processing speed. On the contrary, articulation time presented a weak correlation with the reading measures and was not connected to any processing skill at any point of measurement. Research, also, indicates that the pause time (instead of the articulate time) assisted in the differentiation of children with and without dyslexia (Araújo et al. 2011; Neuhaus et al. 2001a). Regarding the type of stimuli, Neuhaus and colleagues (2001a; 2001b) discovered that the pause time in the letters task was particularly related to processing speed related to letters and that the pause time in the object task consisted a more general processing speed determinant. Hence, the letter pause time more accurately predicted reading as measured by decoding and comprehension tasks.

Powell and colleagues (2007) conducted a study in order to examine which elements of processing speed govern its association with reading. In their study there were a total of 160 nine and ten year old participants, half of which displayed low RAN performance (37 in third grade and 43 in fourth) and half of them were controls (37 in third grade and 43 in fourth). They demonstrated that children who presented impairments in alphanumeric RAN exhibited slower processing speed and slower reaction times compared to the control group. One interesting finding was that simple reaction times and processing speed (as estimated by the time to respond by pressing a computer key after the appearance of a target stimulus) are associated RAN but not to reading. However, choice reaction times and processing speed (as estimated by the time to respond by pressing a computer key after making a decision regarding two target stimuli) are related to both RAN and reading. This can imply that the introduction of decision making (and other cognitive processes implicated in choice reaction time tasks) may provide additional insight into the underlying components of RAN and processing speed.

A longitudinal study done by Stainthorp and colleagues (2010) employed 1010 student participants, following them from third to fifth grade, in order to examine deficits in visual processing in children with slow RAN performance. They found that students with a single RAN deficit presented significantly slower response times when they were asked to recognize the appearance of a stimulus. Similarly, even though there were no differences between the groups in their capacity to accurately decide whether the pairs of stimuli were the same or different, the children in the low RAN groups were slower to decide (on average 115 ms). Children with low RAN performance also took longer to decide about letter-like forms as well as to discriminate between more complex, unfamiliar non-nameable stimuli.

Cohen and colleagues (2018) conducted a study in order to examine whether the relation between RAN and reading depend on age or on reading level. Participants were 32 children aged 7–10 years which performed two RAN task (letters and objects), while EEG/ERP measurements were recorded. They discovered that young and older children display differences in their performance in the letters task but not in the objects, with younger children having slower responses. In the letters task, young children presented bigger amplitudes in the N170 time-window and that younger children differed in regards to their electrophysiological responses for a longer and later time frame (from 400 to 750 ms). They also discovered that RAN objects task is a better predictor of reading level. ERPs of both letter and objects RAN presented differences across age groups, but concerning reading performance only the ERPs in the objects task differed across reading levels.

Several studies have found an association between processing speed and reading performance, with children exhibiting reading difficulties presenting slower reaction times in comparison to controls (Santhana Gopalan et al., 2020). There are two main approaches as to why processing speed is predicting reading performance; a generalized processing deficit, which presented a general slowness in reaction times (Wolf & Bowers, 1999) and a specific deficit, which is presented as an isolated slowness in reaction time, particularly when processing phonological, orthographic (Breznitz & Misra, 2003; Miller-Shaul & Breznitz, 2004) and/or semantic information (Betjemann & Keenan, 2008). Concerning the first approach, it views processing speed as a global domain- general aspect that is related to performance in reading as well as in non- reading tasks, with no other factors (e.g. IQ) playing a role. It is based on evidence from the early 1990s, when it was found that children exhibiting reading deficits responded slower in choice reaction time tasks in comparison to their IQ-matched peers (Nicolson & Fawcett, 1994). This approach perceives poor reading performance as something related to a general deficit of fluency, automaticity, or procedural learning and suggests that reading disability (and all other developmental learning disabilities) are governed by this deficit (Fawcett et al., 2001; Nicolson & Fawcett, 2006, Nicolson & Fawcett 2007; Stoodley et al., 2006; Wolf, et al., 2002 as cited in Naples et al., 2012).

The second approach is focused more on particular deficits such as asynchrony in processing speed for phonological versus orthographic information (Breznitz & Misra, 2003; Miller-Shaul & Breznitz, 2004), delayed activation for semantic information in priming tasks (Betjemann & Keenan, 2008) as well as delayed inhibition capacities among those displaying poor comprehension skills (Faust & Gernsbacher, 1996). It is based on the assumption that an individual may have delayed processing only on lexical information and that this delayed processing can lead to deficits in reading performance (Naples et al., 2012). Studies (e.g. Breznitz & Misra, 2003; Miller-Shaul & Breznitz, 2004) have shown that poor readers display significantly slower reaction times and delayed ERP components in high-level lexical tasks (e.g. lexical decision), but not in low-level perceptual tasks (e.g., auditory tone or visual line discrimination). This can indicate that low-quality lexical representations can result in slow and impaired reading performance (Perfetti, 2007; Perfetti & Hart, 2002 as cited in Naples et al., 2012).

Naples and colleagues (2012) studied the relationship of reading performance and processing speed in 188 children aged 7- 12. They obtained four choice reaction time tasks and they demonstrated that reading is indeed associated with processing speed and that this association is compelled by information accumulation and not by sensory or motor elements of processing. Furthermore, they discovered that information accumulation for letters contributed significantly more than information accumulation for numbers, implying that letters are more associated with reading expertise than are numbers and that processing of lexical information regulates this relationship. Finally, they discovered that processing speed, as measured by information accumulation, can explain reading performance when other, more established predictors of reading such as intelligence or phonological processing are taken into account.

2.4. Attention Network

Attention is a complicated cognitive ability, which depends on interacting neural systems of the brain (Adolfsdottir et al., 2008). It is comprised of subcomponent processes that are distinct but at the same time interconnected, and which are responsible for regulating the order of attention processing. (Dash et al., 2019; Fan et al., 2009; Posner & Fan, 2008). According to Posner and colleagues (e.g. Posner & Raichle, 1994; Posner & Fan, 2008; Posner & Petersen, 1990) those separate networks are alerting, orienting and inhibition, which is also referred to as executive control.

The Attention Network experiment (ANT) is the most common experiment obtained for measuring the three subcomponent processes and examining their interaction

(Fan et al., 2002). The ANT is a consolidation of a flanker task with arrows (Eriksen & Eriksen, 1974 as cited in Macleod et al., 2010b) and a cued reaction time task (Posner, 1980 as cited in Macleod et al., 2010b). In the experiment five arrows are presented in a row, and the participant are asked to announce the direction of the middle arrow. The flanker arrows can either look in the same as the middle arrow (congruent condition) or in the opposite direction (incongruent condition). In the neutral condition, straight lines might flank the middle arrow or alternatively the central arrow might be separately displayed. Before the appearance of the arrows there might be no cue or one of three types of cues (center cue, double cue, spatial cue) might be presented. The center and double cues imply that the arrow stimulus will occur soon, and the spatial cue predicts the target location. As a task based on speed choice, the ANT gives two measure of performance; response time (RT) and error rate (ER). The three subcomponent processes are measured based on those measures (Macleod et al., 2010b).

Alerting is the first attention network and can be defined as the capacity to reinforce and maintain response readiness in preparation for a forthcoming stimulus (Raz & Buhle, 2006). Hence, alerting is related to the stimulation and attentiveness implicated in the realization and preservation of a state of responsiveness to consecutive stimuli (Posner and Petersen, 1990; Santhana Gopalan et al., 2019; Santhana Gopalan et al., 2020). Alerting is task specific and can be differentiated from the domain-general cognitive control of arousal (Raz & Buhle, 2006).

In ANT, alerting effect can be estimated by the reaction times on separate target stimuli preceded by non-informative visual warning cues and informative cues (Fan et al., 2002; Santhana Gopalan et al., 2019; Santhana Gopalan et al., 2020). This is based on the assumption that the presentation of the double cue alerts participants to the imminent onset of the target display, and due to the fact that such a warning does not exist in the no cue condition, the difference in the RT between those conditions can estimate alerting ability (McConnell, & Shore, 2011). Previous research suggests that a warning cue can assist with boosting alertness and decrease RTs to the target stimulus (Konrad et al., 2005; Neuhaus et al., 2010; Rueda et al., 2004; Santhana Gopalan et al., 2019). Children, also, present alerting effects, even though their RTs differ with age and are slower compared to those of adults. RTs tend to decrease with age. A study conducted by Mezzacappa (2004) shows that five-year-old children generally displayed longer RTs in comparison to seven-year-old children.

The second attention network is orienting, which can be defined as the capacity to choose particular information from among multiple sensory stimuli, and can be characterized as either overt or covert as well as either exogenous or endogenous (Raz & Buhle, 2006). Orienting is correlated with spatial selection (Santhana Gopalan et al., 2019). Spatial orienting is comprised of three separate sub-functions: the involvement of visual attention to a particular stimulus, the detachment of visual attention from a stimulus, and the alteration of visual attention from one stimulus to another (Posner & Petersen, 1990; Santhana Gopalan et al., 2019; Santhana Gopalan et al., 2020).

In the ANT experiment, and in a similar manner to alerting, orienting can be estimated by a reaction times difference between center-cued and spatially cued target stimuli (Neuhaus et al., 2010; Santhana Gopalan et al., 2019; Santhana Gopalan et al., 2020). The assumption behind this is that the spatial cue warns the participant of the exact location of the target stimulus, enabling the participant to orient their attention to the target location before the target appears. This does not occur in center cued stimuli (McConnell, & Shore, 2011). Several studies have revealed that the development of orienting effect is progressive as the capacity to switch attention between stimuli is apt to improvement between 5 and 14 years of age, continuing further into adulthood (Rueda et al., 2004; Santhana Gopalan et al., 2019; Schul et al., 2003).

The third attention network is inhibition, which is also known as executive control or executive attention. Inhibition includes several mechanisms responsible for the resolution of conflicts, detection of errors and choice of action in response to other stimuli (Posner and Rothbart, 2007; Raz & Buhle, 2006; Santhana Gopalan et al., 2019; Santhana Gopalan et al., 2020).

In the ANT experiment, the effects of inhibition are measured based on the reaction times difference between incongruent and congruent target stimuli (Fan et al., 2002; Neuhaus et al., 2010; Santhana Gopalan et al., 2019; Santhana Gopalan et al., 2020). The idea behind this is that when incongruent target is presented, participants should handle the conflicting information provided at the same time by the target and flanker arrows, something that does not occur in congruent target (McConnell, & Shore, 2011). Conflict resolution in children and adults can lead to elevated inhibition of rival visual information and hinder response choice (Fan et al., 2002; Konrad et al., 2005; Mezzacappa, 2004; Neuhaus et al., 2010; Santhana Gopalan et al., 2019). Children tend to present slower reaction times in comparison to adults (Rueda et al., 2005; Santhana Gopalan et al., 2019) as well as delayed latency (Kratz et al., 2011; Santhana Gopalan et al., 2019; Santhana Gopalan et al., 2020), indicating the role of development in the assessment of the target direction (Falkenstein et al., 1994 as cited in Santhana Gopalan et al., 2020).

3. RESEARCH PROBLEMS

The aim of this study is to examine the role of on-screen visual stimuli reaction times, subcomponents of attention and gender in RAN and reading fluency association. Reading fluency is the ability to read rapidly, accurately and with the appropriate expression (Álvarez-Cañizo et al., 2015; Bigozzi et al., 2017; Elhassan et al., 2015; Kuhn & Stahl, 2003). Reading fluency is a crucial aspect of academic life as it can impact school performance (Álvarez-Cañizo et al., 2015; Bigozzi et al., 2017), or training success (Bigozzi et al., 2017; Krumm et al., 2008). The role of gender in reading fluency is critical. Research suggests that girls tend to be better readers compared to boys (Akyol, 2014; Bank et al., 1980; Mullis et al. 2017; OECD, 2019) and that boys are more likely to experience reading difficulties that females (1.83 times), especially when reading difficulties are severe (Qinn, 2018). Reading fluency problems are rather common and it has been found that in transparent orthographies deficiencies exist primary in reading fluency and reading speed (Aro et al., 2011; Escribano, 2007; Holopainen et al., 2001; Seymour et al., 2003). Processing speed plays a role in reading fluency as slower processing speed is associated with reading deficits (Santhana Gopalan et al., 2020).

The relationship between RAN and reading fluency is well established as several studies have demonstrated that RAN is a strong predictor of reading skills (e.g. Georgiou et al., 2006; Papadopoulos et al., 2016), especially in transparent orthographies, such as Finnish (Heikkilä, 2015; Holopainen et al., 2001; Puolakanaho et al., 2007; Torppa et al., 2010). RAN is significantly associated with reading fluency (Neuhaus et al. 2001a; Neuhaus et al. 2001b; Siddaiah & Padakannaya, 2015), reading comprehension (Georgiou et al. 2010; Neuhaus et al. 2001a; Neuhaus et al. 2001b; Padakannaya et al. 2008; Siddaiah & Padakannaya, 2015) and reading speed (Siddaiah & Padakannaya, 2015; Wimmer 1993). Deficits in RAN may lead to or signify reading difficulties (Siddaiah & Padakannaya, 2015). Research suggests that in transparent orthographies RAN deficits are a strong predictor of poorer reading fluency (Torppa et al., 2013) and that reading difficulties exist primary in reading fluency and reading speed (Aro et al., 2011; Escribano, 2007; Holopainen et al., 2001; Seymour et al., 2003). Processing speed is crucial for RAN performance. It has been found that children with poor RAN performance displayed significantly slower reaction times and were significantly slower to make decisions regarding simple visual features (Stainthorp et al., 2010).

Attention is a complex cognitive ability, which consists of subcomponent processes (alerting, orienting, inhibition), that are distinct but at the same time interconnected (Dash et al., 2019; Fan et al., 2009; Posner & Fan, 2008). The Attention Network experiment (ANT) is the most common experiment obtained for measuring the three subcomponent processes and examining their interaction (Fan et al., 2002).

Based on previous research, it can be hypothesized that underlying attentional processes play a role in reading fluency and RAN as well as in their association.

Reading is an extremely complex process which is dependent on the development of various internal skills, including attention (Kinsey et al., 2004 as cited in Elhassan et al., 2015), working memory (Daneman and Carpenter, 1980 as cited in Elhassan et al., 2015), naming speed (Logan, 1997 as cited in Elhassan et al., 2015) and speed of processing (Breznitz and Misra, 2003 as cited in Elhassan et al., 2015). Impairments in reading fluency and comprehension can, among others, related to executive functions (Diamond, 2013), namely working memory and inhibition, and attention allocation. Readers with low working-memory capacity display problems in information processing, comprehension and recall performance (Linderholm & van den Broek, 2002). Inhibition present a significant correlation to reading comprehension, as dysfluent readers are often facing impairments in excluding information that is not any more applicable in both short-term memory tasks and working memory tasks (Cain, 2006). Furthermore, dysfluent readers often exhibit difficulties is attention allocation, which refers to the capacity to accommodate attentional and processing abilities as demanded by each particular task performed (Liu et al., 2013).

RAN requires aiming sustained attention over time (Wolf & Bowers, 1997 as cited in Arnell et al., 2009), storing a big amount of information into the working memory as well as obtaining inhibitory processes in order to select the correct among all competing alternatives (Bexkens et al., 2015; Papadopoulos et al., 2016; Shao et al., 2013).

This study obtains data from psychometric tests and the ANT experiment in order to answer the following research questions:

- Does RAN performance predict reading fluency among elementary education students? What is the role of gender?
- Is RAN performance among elementary education students predicted by reaction times to the ANT experiment, subcomponents of attention and gender?

- To what degree the association between RAN and reading fluency among elementary education students is moderated by reaction times to the ANT experiment, subprocesses of attention and gender?

Based on the above, the following hypotheses can be made. First of all, it can be hypothesized that RAN predicts reading fluency. Secondly, gender differences can be observed, with girls presenting better performance compared to boys. Thirdly, processing speed is associated with both reading fluency and RAN. Finally, and as mentioned before, attentional processes play a role in reading fluency and RAN.

4. IMPLEMENTATION OF THE STUDY

4.1. The Context of the Study

The eSeek project is a multidisciplinary project conducted by the University of Jyväskylä and implemented during the years 2014- 2017. The project was funded by the Academy of Finland. The purposes of the project were to enhance comprehension of online information seeking skills and their latent components in children between 11 and 13 years of age, formulate how children with different learning difficulties differ in online seeking skills and neural processes in comparison to conventional learners and produce knowledge which promotes the creation of teaching methods to effectively obtain online resources in school context.

The project was comprised of three multidisciplinary interrelated sub-studies: behavioral tests, online reading skill assessment (classroom assessment), eye-tracking study and neurocognitive study. A variety of methods was obtained, such as cognitive tests and reading assignments, internet reading assignments, eye movement and EEG measurement.

Behavioral tests aimed to evaluate the student's language, memory and attention skills. Behavioral tests included RAN (Ahonen et al., 2012), TOWRE (Torgesen et al., 2008), NMI (Holopainen et al., 2004), NEPSY- II (Korkman et al., 2008; Turok, 2017), WISC- IV (Wechsler, 2010; Turok, 2017), Salzburg test (Landerl et al., 2006; Turok, 2017). Students' reading fluency was evaluated using a word identification test (ALLU, Kanniainen et al., 2019; Lindeman, 1998; Santhana Gopalan et al., 2020; Kanniainen et al., 2021); a word chain test (Holopainen et al., 2004; Kanniainen et al., 2019; Kanniainen et al., 2021; Santhana Gopalan et al., 2020); and a oral pseudoword text-reading test (Eklund et al., 2015; Kanniainen et al., 2019; Kanniainen et al., 2021; Santhana Gopalan et al., 2020). Reading comprehension was measured using the ALLU test (Kanniainen et al., 2021; Kiili et al., 2018a; Lindeman, 1998) and online research and comprehension skills were assessed with the ILA test (Kanniainen et al., 2019; Kanniainen et al., 2021; Kiili et al., 2018b; Leu et al., 2013). Finally, attention was assessed using the ATTEX test (Klenberg et al., 2010; Santhana Gopalan et al., 2020; Kanniainen et al., 2021) and the non verbal reasoning ability was assessed using the Raven's Standard Progressive Matrices test (Raven & Court, 1998; Raven & Raven, 2003; Kanerva et al., 2019; Kanniainen et al., 2019; Kanniainen et al., 2021; Santhana Gopalan et al., 2020).

The principal investigator of the study is Professor Paavo Leppänen and the research group is comprised by six more researchers. More information about the study can be obtained upon request from the principal investigator.

As part of the eSeek study, an EEG study was organized by Santhana Gopalan and colleagues (2019; 2020). The purpose of this study was to examine the subcomponents of attention (alerting, orienting and inhibition) using reaction times, event- related potentials (ERPs), and their neuronal source activations during the Attention Network Test (ANT).

In this study data from both the eSeek project and the EEG study by Santhana Gopalan et al. (2019; 2020) will be used to answer my research questions. Data was obtained from the two investigators Paavo Leppänen (eSeek data) and Santhana Gopalan Praghajieeth Raajhen (ANT experiment data) and a verbal agreement was done concerning the use of the data. Special attention was set to data transfer, with data protection and data security issues being taken into account, and data was shared via encrypted transfer. Data included psychometric tests from the eSeek project (RAN, Towre, WISC-IV, NMI) and reaction times data from the ANT experiment. The data was shared into two separate SPSS files, one for the eSeek data and one for the reaction times data. Those files were merged into one SPSS file.

4.2. Participants

Data has been collected from 426 students (219 boys and 207 girls) attending sixth grade in eight elementary schools (24 classes) in Central Finland during 2014–2015. Schools were in both urban and rural areas. All students were between 12 and 13 years olds (*M* = 12.34, *S.D.* = 0.32), attended regular classrooms and were taught based on the Finnish National Curriculum (The Finnish National Board of Education, 2004). All students were native Finnish speakers. (Kanniainen et al., 2019; Kanniainen et al., 2021; Kiili et al., 2018a; Killi et al., 2018b). Of those 156 participants took part on the eSeek EEG measurement based on the completion of the ILA test and performance in the RAVEN test (Raven & Court, 1998; Santhana Gopalan et al., 2020). More information about the participants and the inclusion criteria can be found in Killi and colleagues' (2018a; 2018b) and Kanniainen and colleagues' (2019; 2021) articles.

115 of the eSeek participants (*N*: 115; 65 boys, 50 girls) who attended sixth grade and were aged between 12 and 13 years took part in an EEG study by Santhana Gopalan et al. (2019; 2020). All of them displayed typical visuospatial reasoning ability. Participants included students with attentional problems (*N* = 15; 14 boys, 1 girl; *M*: 12.67; *SD* = 0.31), students with reading difficulties (N = 23; 15 boys, 8 girls; mean age = 12.61; *SD*=0.31) as well as controls (*N* = 77; 36 boys, 41 girls; *M* = 12.86 years, *SD* = 0.31). Regarding the attentional problems group, inclusion criteria were an ATTEX score above 30 (Klenberg et al., 2010) and a reading fluency score above the 10th percentile [which is a composite score of three reading tasks (ALLU, word chain test, oral pseudoword text-reading test) created using Principal Axis Factoring (PAF)]. For the reading difficulties group inclusion criteria were an ATTEX score below 30 and a reading fluency score below the 10th percentile. For the control group, inclusion criteria were an ATTEX score below 30 and a reading fluency score above the 10th

percentile (Santhana Gopalan et al., 2020). In this study, these groups together represent population distribution. More information about the study can be obtained by the primary investigator.

Regarding the participants used in my study, there were 561 (*N* = 561; 299 boys, 255 girls, 7 missing) participants. 166 (*N* = 166; 100 boys, 66 girls) participants completed the psychometric tests from the eSeek study and 115 participants were part of the EEG study (*N*: 115; 65 boys, 50 girls).

4.3. Measurements

4.3.1. RAN

In the eSeek study, RAN was used for the assessment of how quickly a student can name aloud objects/images and letters. The test had two parts: one part was comprised of objects/images and one part was comprised of letters. The purpose of the task was to name the objects/images and letters as quickly and accurately as possible. The score was calculated based on the time (in seconds) used to complete the task (RAN test; Ahonen, Tuovinen & Leppäsaari, 2012; Turok, 2017). The task had a duration of 2 minutes for letters and 3 minutes for objects/images.

In this, in order to define RAN performance, variables from the eSeek data were obtained. As RAN refers to the ability to quickly name aloud a series of items (e.g. letters, objects), time is a crucial aspect for describing RAN performance. Hence, time measurements (RAN-letters: used time in seconds and RAN-objects: used time in seconds) were used for defining RAN performance.

4.3.2. Reading fluency

In the eSeek study, NMI test was obtained for the evaluation of the student's literacy skills. NMI is a test created by Niilo Mäki Institute and is broadly used in Finland by different professionals (e.g. teachers, psychologists) for the evaluation of reading fluency. It is a standardized screening method aiming at identifying reading difficulties (Holopainen et al., 2006). In this task the student was asked to read aloud a text passage (479 words) as fast and precisely as possible for three minutes. In order to score this task, incorrectly read words were summed (self- corrected words were excluded) and the words skipped and the reading error rate is calculated taking into account the number of all words read. Reading accuracy was then transformed into a percentage (Individual testing of reading and writing skills for young people and adults; Holopainen et al., 2006; Turok, 2017). The duration of the task was four minutes. The internal reliability (Cronbach's alpha reliability coefficient) of the test is .70.

Furthermore, in the eSeek study a Finnish variation of the T OWRE test (Test of word reading efficiency) was used for evaluating the student's technical literacy and letter encoding into sounds. Three measures are acquired by using the TOWRE assessment: Phonemic Decoding Efficiency, Sight Word Efficiency and Total Word Reading Efficiency. In this task the student had to read as accurately and quickly as possible different syllables and pseudowords within a limited time. The list started with simple one- syllable pseudowords and gradually became more difficult, including up to four- syllable words at the end. The score was calculated from the number of words read correctly and ranges from 1 to 90 (Test of Word Reading Efficiency; Torgesen et al., 2008; Turok, 2017). The task had a duration of 2 minutes. The internal reliability (Cronbach's alpha reliability coefficient) of the test was .64 The pseudoword reading task is testing phonemic decoding efficiency and aims to assess the student's capacity to read nonsense words or combinations of letters in a reading task, without the impact of other factors such as context clues (Torgesen, et al., 2008).

In this study, variables from the NMI (number of read words after 60, 120 and 180 seconds) and TOWRE (number of correct words) were obtained for defining reading fluency. Initially, a variable was computed which was the Z score of the NMI task variables combined (Z scores of the NMI variables divided by 3). After this step, the reading fluency variable (Z score) was computed, which included the Z score of the combined NMI task variables and the Z score of the TOWRE variables.

4.3.3. EEG Experiment: Attention Network Test for Children

For the evaluation of the three subcomponents of attention, namely alerting, orienting and inhibition a modified version of the ANT (Neuhaus et al., 2010) EEG experiment was obtained. ANT enables the independent evaluation of the competence of the three subcomponents of attention in the context of a fast and easy computerized task (Fan et al., 2002). It is a broadly used tool in neuropsychological studies and has been obtained for the investigation of attention network function of many different population, such individuals with dyslexia (Bednarek et al., 2004) or attention-deficit hyperactivity disorder (ADHD; Adolfsdottir et al., 2008). ANT experiments have also been obtained for the examination of theoretical questions referring to non- clinical populations, such the study of the attention networks as independent elements (Macleod et al., 2010a).

During the entire duration of the testing period, a fixation cross could be seen in the center of the white screen. The participant had to stare at the fixation cross and report the direction of the middle fish as fast and accurately as possible by pressing a matching button (Santhana Gopalan et al., 2020).

One of the four cue conditions (no cue, double cue, center cue, spatial cue) was shown before the appearance of the stimulus (group of fish). The duration of the fixation period randomly varied between 400 ms and 1600 ms, after which the cue emerged. The cue lasted 125 ms and then a waiting time of 375 ms duration followed, before the appearance of the stimulus (a total of 500 ms before stimulus appearance). In the double cue trial, two asterisks were displayed at the same time at a 1° angle above and below the fixation cross. In the center cue trial, an asterisk was displayed on the fixation cross. In the spatial cue trial, a single asterisk was shown in the location where the impeding stimulus would appear (Santhana Gopalan et al., 2020).

In order for the experiment to become more suitable for children, it was decided that the experiment will be modified and instead of arrows black fish drawing will be presented as stimuli. The stimulus involved a sequence of five horizontal fish. The center fish in the stimulus was considered the target, and the two fish on either side of the target were considered the flankers. The stimulus cluster in each trial was displayed above or below the fixation cross at the exact location where the double cue or spatial cue was presented. Each trial lasted maximum 400 ms and the stimulus cluster in each trial lasted maximum 1700 ms until a response was declared. After those 1700 ms had passed, and in case of no response, it was regarded as an abandoned trial and it was discontinued. The period between the emergence of the stimulus and the beginning time of the next trial lasted a maximum of 3500 ms, which differed depending on the span of the stimulus cluster. In the case of congruent stimuli, the flankers were in the same direction as the target and in the case of incongruent stimuli, the flankers were in the opposite direction. Participants were asked to maintain their look on the fixation cross during the entire experiment and notify the swimming direction of the center fish by pressing a left or right corresponding direction button in the button box (Santhana Gopalan et al., 2020).

One ANT session included 288 pseudo- randomized trials, which were broken down into four experimental blocks, each one including 72 trials. Each block was comprised of all eight potential conditions and included all four cue conditions (no cue, double cue, center cue, and spatial cue) and both target stimulus conditions (congruent, incongruent) (Santhana Gopalan et al., 2020).

The Reaction Times (RTs) were measured from the time the target stimulus first appeared (onset time) until the time the participant responded by pressing the button. The unattended trials, trials with wrong responses as well as trials that were rejected for ERP averaging were not included in calculations of the mean RTs. All participants were highly accurate in their responses and there were no participants who were excluded due to poor performance (Santhana Gopalan et al., 2020).

4.4. Data analysis

Data was analyzed using quantitative analysis, which is a powerful tool in neuropsychological research. Quantitative EEG (qEEG) is valuable in terms of neuropsychology and cognitive neuroscience because it enables the examination of physiological and pathological correlates of conditions where consciousness is normal or impaired, quantifying the escalation in low-frequency components of the background activity, obtaining coherence analysis to investigate the neural network functional state. QEEG, also, allows the comparison between groups of diseases using power spectra and administer three-dimensional source localization methods in order to determine the generators of pathological EEG activity. Several studies have demonstrated that when used in the study and evaluation of disability and learning disorders, qEEG discriminant accuracy was rather high and ranged between 46% and 98% (Kanda et al., 2009).

Data has been analyzed using IBM SPSS version 26. For examining potential moderation effects, the Hayes process macro (version 3) was downloaded from its official webpage (https://www.processmacro.org/download.html) and was added on SPSS.

Research Question 1

Variables used for this research question include RAN performance (objects and letters, used time in seconds), reading fluency and gender. The possible correlation between gender, RAN performance and reading fluency was examined using Pearson's correlation coefficients.

A two way hierarchical regression analysis was obtained to determine how a child's gender and RAN performance predict reading fluency. Reading fluency was set as dependant variable and gender, RAN performance in letters and RAN performance in objects were set as independent variables. The independent variables were entered into the model with following steps. In the first step, the gender of the children was set as an independent variable. In the second step, RAN performance in letters and objects was set as independent variables.

The Hayes macro was used and one- way moderation analysis (Hayes model 1) was conducted in order to examine whether the relationship between reading fluency and RAN performance in the letter task and objects task respectively is moderated by gender (or to set it otherwise if gender moderates the effect of RAN performance on reading fluency). The model is presented in figure 1:

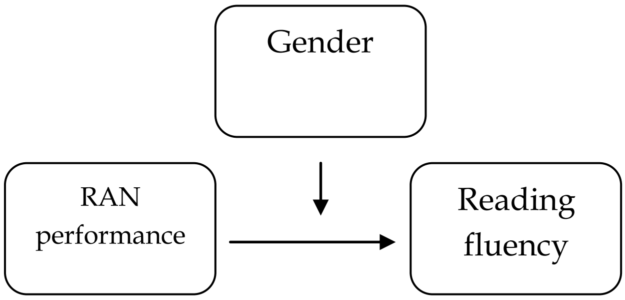

FIGURE 1: Moderation analysis between RAN performance, reading fluency and gender.

Research Question 2

In order to answer the second research question, the RAN performance (RAN-letters: used time in seconds and RAN-objects: used time in seconds) and reading fluency variables described above as well as reaction times variables were used. Initially, the reaction times variables were analyzed individually but because the pattern was the same, it was decided to create a sum score. A new variable was computed based on the grand averages of the reaction time data in the different stimuli conditions (non-cued, double-cued, center-cued, spatially cued, congruent and incongruent target stimuli).

Parametric correlations (Pearson's correlations) tests were used to examine whether there is a correlation between RAN performance in letters and objects task, reading fluency, reaction times and gender. Similarly, Pearson's correlation coefficients were used to study potential correlations between RAN performance in letters and objects task, reading fluency, subcomponents of attention (alerting, orienting, inhibition) and gender.

Hierarchical linear regression analysis was used in order to in order to study how the reaction times and gender predict RAN performance in the letters as well as in the objects task. RAN performance (in letters or objects task) was set as a dependent variable and the reaction time variables and gender were added as dependent variables in different steps (a total of 2 different steps).

Hierarchical linear regression analysis was, also, obtained for examining how the subcomponents of attention (alerting, orienting, inhibition) and gender predict RAN performance in the letters as well as in the objects task. RAN performance (in letters or objects task) was set as independent variable and the subcomponents of attention variables (alerting, orienting and inhibition) and gender were added individually in different steps (a total of 4 different steps).

Research Question 3

The means of the reaction times variable and the subcomponents of attention (alerting, orienting and inhibition) variables were estimated and they were mean centered in order to be used in the analysis.

Moderation analysis was conducted using the Hayes process macro. Initially, a two way interaction (Hayes model 2) was used to study whether the relationship between reading fluency and RAN performance in the letters and objects task (used time in seconds) is moderated by the reaction times and gender. Reading fluency was set as a Y variable, RAN performance (letters or objects task) was set as an X variable, reaction times were set as a W variable and gender was set as a Z variable. The same model was obtained in order to investigate potential moderation effects caused the subcomponents of attention and gender. The models are presented in figure 2

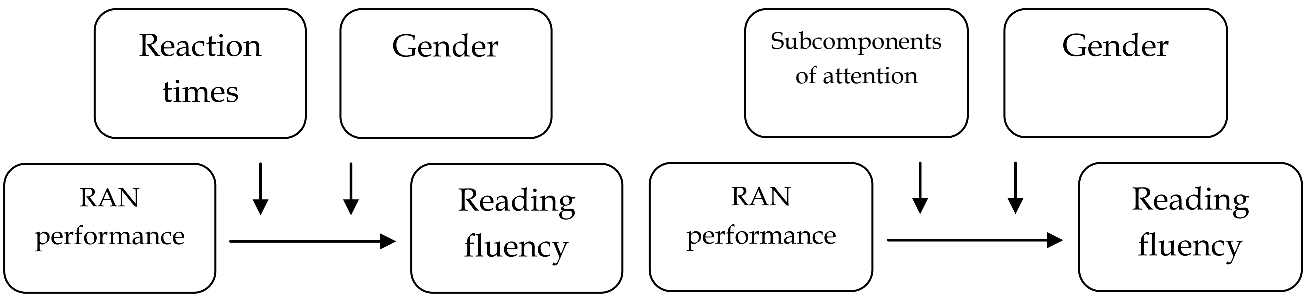

FIGURE 2: Two- way moderation analysis

Similarly, a three way interaction (Hayes model 3) was obtained in order to examine whether possible moderation relationships between reading fluency and RAN performance in the letters or objects task and reaction times and gender. The same model was used to investigate potential moderation effects caused by the subcomponents of attention and gender. The models are presented in figure 3.

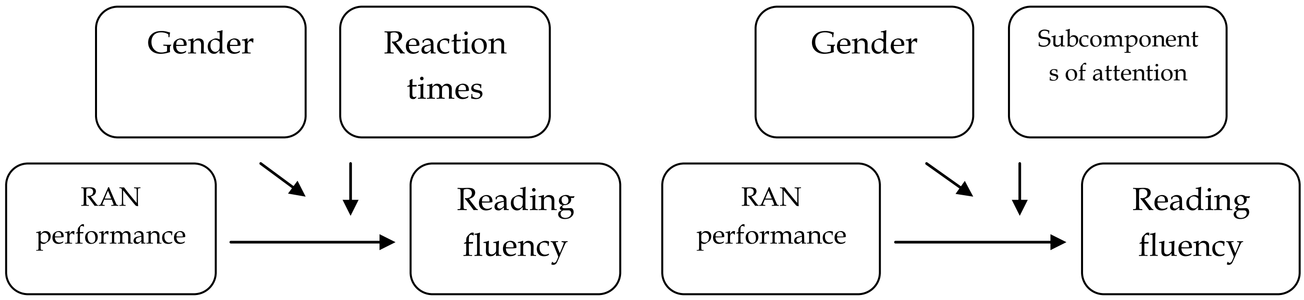

FIGURE 3: Three- way moderation analysis

5. RESULTS

5.1. The role of RAN performance and gender in reading fluency

The relationships between RAN performance, reading fluency and gender was investigated using Pearson's correlation coefficients (table 1). There was a statistically significant positive correlation between RAN performance in the letters and RAN performance in the objects task. Furthermore, there was a statistically significant negative correlation between reading fluency and RAN performance in letters and objects task. The higher the time used to complete the RAN test (letters and objects), the lower the reading fluency. Moreover, there was a statistically significant positive correlation between RAN performance in the objects task and gender.

Correlations among genders (table 2) showed corresponding results. In both boys and girls, RAN performance in letters was positively correlated to RAN performance in objects. This correlation was statistically significant in both genders. Reading fluency was negatively correlated to RAN performance in letters and in objects, in both boys and girls. Girls presented a slightly higher correlation in RAN performance in letters compared to boys, while boys had a slightly higher correlation in RAN performance in the objects task.

TABLE 1: Pearson correlation coefficients and descriptive statistics of RAN performance, reading fluency and gender (*N* = 166).

Variable	1	2	3	4
1. RAN performance in letters	1			
2. RAN performance in objects	.41***	1		
3. Reading fluency	-.54***	-.43***	1	
4. Gender	.03	-.17*	.19*	1
M	24.49	43.84	.00	.46
SD	5.56	7.73	1.09	.50

Note: * = $p < .05$, ** = $p <. 01$, *** = $p < .001$

TABLE 2: Pearson correlation coefficients and descriptive statistics of RAN performance and reading fluency in different genders.

	Boys (*N* = 100)			Girls (*N* = 66)		
Variable	1	2	3	1	2	3
1. RAN performance in letters	1			1		
2. RAN performance in objects	.37***	1		.51***		
3. Reading fluency	-.58***	-.30*	1	-.51***	-.57***	1
M	24.35	44.90	-.16	24.70	42.22	.25
SD	5.91	7.73	1.04	5.03	7.51	1.13

Note: * = $p < .05$, ** = $p <. 01$, *** = $p < .001$

Results (see Table 3) from hierarchical regression analysis showed that the RAN performance and gender explained a total of 37% of the variance in the children's reading fluency (F (3, 162) = 31.06, $p < .001$). RAN performance was entered at Step 1, which statistically significantly explained the children's reading fluency (F (2, 163) = 42.01, $p < .001$), explaining a total of 34% of the variance. RAN performance significantly predicts reading fluency. The effect of time used in RAN tests (letters and objects) was negative and statistically significant (p <.001): the lower the time used, the better the reading fluency, or the higher the time used, the lower the reading fluency. The children's gender was entered into the model in the second step and, in turn, increased the explanation rate of the model statistically significantly (increased 3%; *F* (3, 162) = 31.06, $p < .001$). Gender statistically significantly ($p = .012$) predicted reading fluency and girls and boys differ from each other in their reading fluency.

TABLE 3: Results of hierarchical regression analysis of the relationship between reading fluency, RAN performance and gender (*N*= 166).

Independent variables	Reading fluency							
	Step 1				Step 2			
	B	*β*	*t*	*95% C.I.*	*B*	*β*	*t*	*95% C.I.*
RAN performance in letters	-.09***	-.43***	-6.21***	[-.11, -.06]***	-.09***	-.45***	-6.56***	[-.12, -.06]***
RAN performance in objects	-.04***	-.25***	-3.64***	[-.06, -.02]***	-.03**	-.22***	-3.12**	[-.05, -.01]**
Gender					.36**	.16**	2.53**	[.08, .63]**
R2	.34*				.37*			
ΔR2	-				.03**			

Note: * = $p < .05$, ** = $p <. 01$, *** = $p < .001$, *β* = standardized regression coefficient, *ΔR2* = change in explanation

Moderation analysis presented no significant moderation effects in the letters task. In the objects task (figure 4) the model was statistically significant [*F* (3, 162) = 15.22, $p = .004$] and explained a total of 22% of the variance. The interaction between RAN performance in the objects task and gender was found to be statistically significant [$\beta = -.045$, 95% *C.I.* [-.09, -.01] $p = .029$]. The conditional effects of RAN performance in the objects task and gender displayed corresponding results ($p < .05$). That implies that gender acts as a moderator in the relationship between reading fluency and RAN performance in the objects task.

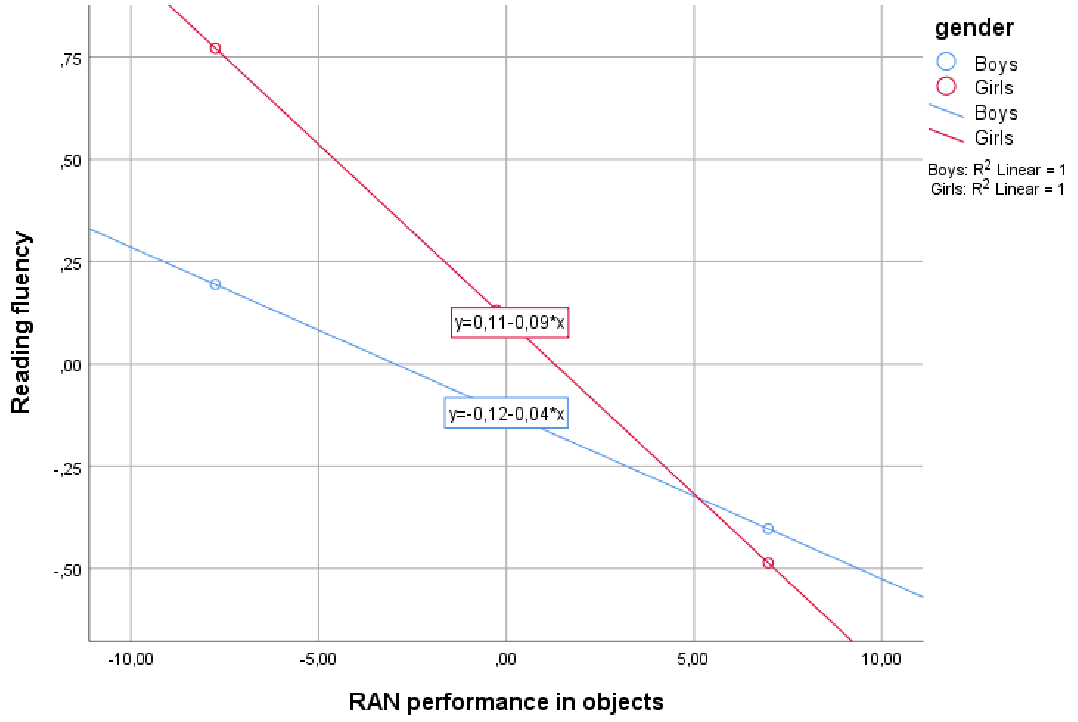

FIGURE 4: Results of moderation analysis between RAN performance in objects, reading fluency and gender (*N* = 166).

5.2. The role of reaction times and subcomponents of attention in RAN performance.

5.2.1. Reaction times

The relationship between RAN performance, reading fluency and reaction times was investigated using Pearson's correlation coefficients (table 4). There was a statistically significant positive correlation between RAN performance and reaction times. The higher the time used in RAN, the higher the reaction times and the lower the time used in RAN, the lower the reaction times. There was a negative statistically significant correlation between reading fluency and reaction times. The lower the reaction times, the higher the reading fluency. No gender correlations are found. Correlation among genders (table 5) displayed that girls present slightly higher reaction times correlation with RAN performance in letters, while boys present slightly higher reaction times correlation with RAN performance in objects.

TABLE 4: Pearson correlation coefficients and descriptive statistics of RAN performance, reading fluency, RTs and gender (*N* = 121).

Variable	1	2	3	4	5
1. RAN performance in letters	1				
2. RAN performance in objects	.41***	1			
3. Reading fluency	-.54***	-.43***	1		
4. Reaction times	.44***	.48***	-.36***	1	
5. Gender	.03	-.17*	.19*	.08	1
M	24.49	43.84	0	762.63	.46
SD	5.56	7.73	1.09	100.41	.50

Note: * = $p < .05$, ** = $p <. 01$, *** = $p < .001$

TABLE 5: Pearson correlation coefficients and descriptive statistics of RAN performance, reading fluency and reaction times between genders.

	Boys (*N* = 70)				Girls (*N* = 51)			
	1	2	3	4	1	2	3	4
1. RAN performance in letters	1				1			
2. RAN performance in objects	.37***	1			.51***	1		
3. Reading fluency	-.58***	-.30**			-.51***	-.57***	1	
4. Reaction times	.47***	.39**	-.34**	1	.43**	.63***	-.42**	1
M	24.35	44.90	-.16	755.85	24.70	42.22	.25	771.92
SD	5.91	7.73	1.04	85.74	5.03	7.51	1.13	117.90

Note: * = $p < .05$, ** = $p <. 01$, *** = $p < .001$

A two stage hierarchical linear regression was obtained in order to examine whether the reaction times and gender predict RAN performance in the letters task. The results (see Table 6) displayed that the reaction times and gender explained a total of 19% of the variance in the RAN performance in the letters task (F (2, 112) = 13.22, $p <$ .001). The reaction times variable was added in step 1, which statistically significantly explained the variance of the RAN performance in the letters task (F (1, 113) = 26.68, $p < .001$), explaining a total of 19% of the variance. The reaction times predict RAN performance in the letters task. The effect of the reactions times was positive and statistically significant ($p < .001$): the higher the reaction times, the more time used in RAN letters task. Gender was added in step 2 which was statistically significant but did not increase the explanation rate (increased 0%; F (2, 112) = 13.22, $p < .001$). Gender was not statistically significant ($p > .05$) and, hence, no gender differences were observed.

TABLE 6: Results of hierarchical regression analysis of the relationship between RAN performance in letters, reaction times and gender (N= 115)

Variables	RAN performance in letters task							
	Step 1				Step 2			
	B	*Β*	*t*	*95% C.I.*	*B*	*β*	*t*	*95% C.I.*
Reaction times	.02***	.44***	5.16***	[.02, .03]***	.02***	.44***	5.13***	[.02, .03]***
Gender					-.05	.00	-.05	[-1.93, 1.83]
R2	.19***				.19***			
ΔR2	.19***				0			

Note: * = $p < .05$, ** = $p <. 01$, *** = $p < .001$. β = standardized regression coefficient, $\Delta R2$ = change in explanation

Similarly, a two stage hierarchical linear regression was used for studying whether the reaction times and gender predict RAN performance in the objects task. The results (see Table 7) displayed that the reaction times and gender explained a total of 27% of the variance in the RAN performance in the objects task (F (2, 112) = 20.64, p <.001). The reaction times variable was added in step 1, which statistically significantly explain the variance of the RAN performance in the objects task (F (1, 113) = 32.95, p <.001) and had an explanation rate of 23%. The reaction times predict RAN performance in the objects task. The effect of the reactions times was positive and statistically significant (p <.001): the higher the reactions times, the more time used in RAN objects task. Gender was added in step 2 and, in turn, increased the explanation rate of the model statistically significantly (increased 4%; F (2, 112) = 20.64, $p < .001$). Gender predicts RAN performance in the objects task. The effect of gender was negative and statistically significant ($p = .011$), implying that there are gender differences in RAN performance in the objects task.

TABLE 7: Results of hierarchical regression analysis of the relationship between RAN performance in objects, reaction times and gender (*N*= 115).

Variables	RAN performance in objects task							
	Step 1				Step 2			
	B	*β*	*T*	*95% C.I.*	*B*	*β*	*t*	*95% C.I.*
Reaction times	.04***	.48***	5.74***	[.02, .05]***	.04***	.49***	6.07***	[.03, .05]***
Gender					-3.24**	-.21**	-2.58**	[-5.73, -.76]**
R2	.23*				.27*			
ΔR2	.23*				.04**			

Note: * = $p < .05$, ** = $p <. 01$, *** = $p < .001$. β = standardized regression coefficient, $\Delta R2$ = change in explanation

5.2.2. Subcomponents of attention

The relationship between RAN performance, reading fluency, gender and the subcomponents of attention (alerting, orienting, inhibition) was investigated using Pearson's correlation coefficients (table 8). There was a statistically significant positive correlation between orienting and RAN performance in the letters task. The higher the time used in RAN in the letters task, the higher the orienting. There was a statistically significant positive correlation between alerting and RAN performance in the objects task as well as between inhibition and RAN performance in the objects task. The higher the time used in RAN in the objects task, the higher the alerting and similarly the higher the time used in RAN in the objects task, the higher the inhibition. There was a statistically significant negative correlation between inhibition and reading fluency. The lower the reading fluency, the higher the inhibition. Correlations among genders are shown in table 9. Alerting was not statistically significant in either boys or girls. Orienting presented a positive, statistically significant correlation with RAN performance in letters in boys but not in girls. Inhibition displayed a positive, statistically significant correlation with RAN performance in objects as well as a negative, statistically significant correlation with reading fluency in girls but not in boys.

TABLE 8: Pearson correlation coefficients and descriptive statistics of RAN performance, reading fluency, subcomponents of attention and gender (*N* = 115).

Variables	1	2	3	4	5	6	7
1. RAN performance in letters	1						
2. RAN performance in objects	.41***	1					
3. Reading fluency	-.54***	-.43***	1				
4. Alerting	.06	.21*	-.07	1			
5. Orienting	.26**	-.03	-.12	.10	1		
6. Inhibition	.15	.27**	-.22***	.26**	.21***	1	
7. Gender	.03	-.17*	.19*	-.06	.01	-.10	1
M	24.49	43.84	0	67.31	53.37	126.28	.46
SD	5.56	7.73	1.09	43.81	49.27	49.79	.50

Note: * = $p < .05$, ** = $p <. 01$, *** = $p < .001$

TABLE 9: Pearson correlation coefficients and descriptive statistics of RAN performance, reading fluency and subcomponents of attention among genders.

	Boys (*N* = 65)						Girls (*N* = 50)					
	1	2	3	4	5	6	1	2	3	4	5	6
1. RAN performance in letters	1						1					
2. RAN performance in objects	.30*	1					.51***	1				
3. Reading fluency	-.55***	-.35**	1				-.48***	-.62***	1			
4. Alerting	.15	.20	-.08	1			-.12	.20	-.04	1		
5. Orienting	.28*	.06	-.20	.12	1		.21	-.19	-.02	-.13	1	
6. Inhibition	.16	.21	-.07	.27*	.25*	1	.14	.32*	-.36**	.12	.18	1
M	24.35	44.90	-.16	69.55	52.88	130.36	24.70	42.22	.25	64.24	54.04	120.69
SD	5.91	7.73	1.04	46.86	56.62	48.71	5.03	7.51	1.13	39.49	37.44	51.18

Note: * = $p < .05$, ** = $p <. 01$, *** = $p < .001$

Hierarchical regression analysis (Table 10) displayed that the subcomponents of attention and gender explained a total of 8% of the variance in the RAN performance in the letters task (F (4, 110) = 2.28, $p > .05$). Alerting was entered in the first step, had an explanation rate of 1% and did not statistically significantly explain the RAN performance in the letters task (F (1, 113) = 3.94, $p > .05$). Orienting was entered in the second step and, in turn, increased the explanation rate of the model statistically significantly (increased 6%; *F* (2, 112) = 4.02; *p* = .021). Orienting predicts RAN performance in the letters task. Its effect was positive and statistically significant (p = .007): the higher the orienting, the higher time was used in RAN letters task. Inhibition was entered in step 3 and, in turn, increased the explanation rate of the model statistically significantly (increased 1%; *F* (3, 111) = 3; *p* = .034). Even though inhibition was not statistically significant (*p* > .05), orienting remained statistically significant (*p* = 013). Gender was added in step 4 and did not increase the explanation rate in a statistically significant way (increased 0%; *F* (4, 110) = 2.27, *p* > .05). Gender was not statistically significant (*p* > .05) and, hence, no gender differences were observed. However, orienting remained statistically significant (*p* = .01).

Finally, hierarchical regression analysis (Table 11) showed that the subcomponents of attention and gender explained a total of 12% of the variance in the RAN performance in the objects task (*F* (4, 110) = 3.79, *p* =.006). Alerting was entered in the first step and statistically significantly explained RAN performance in the objects task (*F* (1, 113) = 4.99, *p* =.027), explaining a total of 4 % of the variance. Alerting predicts RAN performance in the objects task. Its effect was positive and statistically significant (*p* = .027): the higher the alerting, the higher time was used in RAN objects task. Orienting was entered in step 2 and, in turn increased slightly the explanation rate but not in a statistically significant way (increase: 1%; *F* (2, 112) = 2.62, *p* > .05). Even though orienting was not statistically significant (*p* > .05), alerting remained statistically significant (*p* = .025). Inhibition was added in step 3 and, in turn, increased the explanation rate statistically significantly (increase: 5%; *F* (3, 111) = 4.22, *p* = .007). Inhibition predicts RAN performance in the objects task. Its effect was positive and statistically significant (*p* = .009): the higher the inhibition, the higher time was used in RAN objects task. After inhibition was added, alerting was no longer of statistical significance (*p* > .05). Gender was added in the final step (step 4) and, in turn, statistically significantly increased the explanation rate (increase: 2%; *F* (4, 110) = 3.79, *p* =.006). Gender was not statistically significant (*p* > .05). However, inhibition remained statistically significant in this step as well (*p* = .013).

TABLE 10: Results of hierarchical regression analysis of the relationship between RAN performance in letters, subcomponents of attention and gender (*N*= 115).

Subprocesses of attention	RAN performance in letters task (used time in seconds)															
	Step 1				Step 2				Step 3				Step 4			
	B	*β*	*t*	*95% C.I.*	*B*	*β*	*t*	*95% C.I.*	*B*	*β*	*t*	*95% C.I.*	*B*	*β*	*t*	*95% C.I.*
Alerting	.01	.06	.63	[-.02, .03]	.00	.03	.36	[-.02, .03]	.00	.01	.12	[-.02, .03]	.00	.01	.13	[-.02, .03]
Orienting					.03**	.25**	2.76**	[.01, .05]**	.03*	.24*	2.52*	[.01, .05]*	.03*	.24*	2.50*	[.01, .05]**
Inhibition									.01	.09	.98	[-.01, 03]	.01	.10	1.01	[-.01, 03]
Gender													.42	.04	.41	[-1.62, 2.46]
R2	.01				.07*				.08*				.08			
ΔR2	.01				.06*				.01**				.00			

Note: * = *p* < .05, ** = *p* <. 01, *** = *p* < .001. *β* = standardized regression coefficient, *ΔR2* = change in explanation

TABLE 11: Results of hierarchical regression analysis of the relationship between RAN performance in objects, subcomponents of attention and gender (N= 115).

Subprocesses of attention	RAN performance in objects task (used time in seconds)															
	Step 1				Step 2				Step 3				Step 4			
	B	*β*	*t*	*95% C.I.*	*B*	*β*	*t*	*95% C.I.*	*B*	*β*	*t*	*95% C.I.*	*B*	*β*	*t*	*95% C.I.*
Alerting	.04*	.21*	2.23*	[.00, .07]*	.04*	.21*	2.27*	[.01, .07]*	.03	.15	1.62	[-.01, .06]	.03	.15	1.57	[-.01, .06]
Orienting					-.01	-.05	-.56	[-.04, .02]	-.02	-.10	-1.07	[-.o4, .01]	-.02	-.10	-1.02	[-.o4, .01]
Inhibition									.04**	.25**	2.67**	[.01, .07]**	.04*	.24*	2.54*	[.01, .07]*
Gender													-2.13	-.14	-1.53	[-4.89, .63]
R2	.04**				.05				.10*				.12*			
ΔR2	.04**				.01				.05*				.02			

Note: * = *p* < .05, ** = *p* <. 01, *** = *p* < .001. *β* = standardized regression coefficient, *ΔR2* = change in explanation

5.3. The role of reaction times, subcomponents of attention and gender in the reading fluency- RAN association

A two- way moderation analysis was utilized first but presented no moderation effects. A three- way moderation analysis demonstrated no moderation effects in the letters task but a significant moderation effect in the objects task.

In the objects task (figure 5), the model was statistically significant [F (7, 107) = 7.37, p < .001] and explained a total of 33% of the variance. The first interaction (RAN performance in objects task X reaction times) was statistically significant [β = .001, 95% *C.I.* (.000, .001), p = .042], meaning that the reaction times act as a moderator for the relationship between RAN performance in objects task and reading fluency. The interaction between RAN performance in the objects task and gender was, also, found to be statistically significant [β = -.06, 95% *C.I.* (-.125, -.002) p = .042]. The interaction between the reaction times in the double cue stimuli condition and gender was not statistically significant [β = .028, 95% *C.I.* (.006, .050), p > .05]. Finally, the fourth interaction (RAN performance in objects task X reaction times X gender) presented statistical significance [β = -.001, 95% *C.I.* (-.001, -.000), p = .024], demonstrating that the reaction times and gender moderate the relationship between RAN performance in objects task and reading fluency. The conditional effects of RAN performance in the objects task and gender displayed corresponding results. In the low group (16th percentile), both genders were statistically significant (boys: p= .005; girls: p= .002) and their effect was negative. In the average (50th percentile) and high (86th percentile) group, only girls were statistically significant (p < .001) and their effect was negative, revealing gender differences as well as the fact that girls tend to perform better (Figure 5).

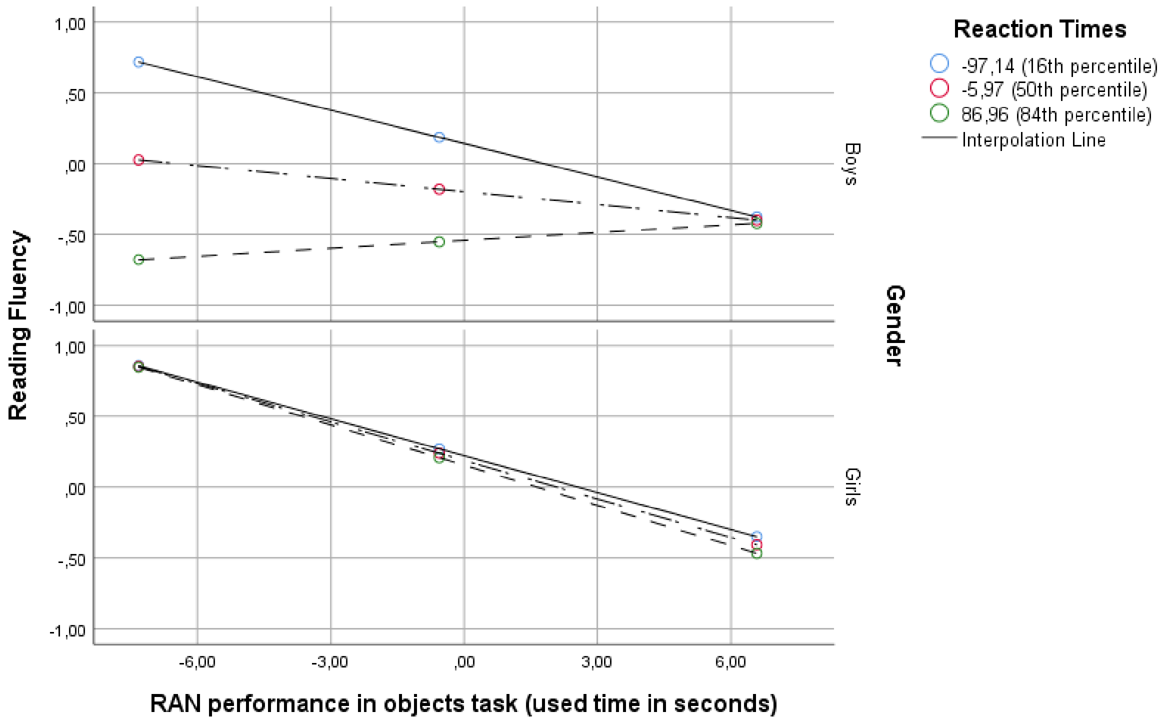

FIGURE 5: Results of moderation analysis between RAN performance in objects, reading fluency, reaction times and gender (*N* = 115).

Similarly, a two and a three- way moderation analysis (Hayes model 2 and 3) was conducted in order to study whether the relationship between RAN performance (in letters and in objects) and reading fluency is moderated by the subcomponents of attention and gender. No moderation effects were found when using two- way interaction. In three- way interaction, moderation effects were present. When examining whether the relationship between RAN performance in letters and reading fluency is moderated by orienting and gender a moderation effect was found (figure 6). The model was statistically significant [F (7, 107) = 7.41, p < .001] and explained a total of 33% of the variance. The interaction between RAN performance in letters and orienting was statistically significant [β = .001, 95% *C.I.* (.000, .001), p = .029], meaning that orienting acts as a moderator for the relationship between RAN performance in letters task and reading fluency. No other interactions were statistically significant (Figure 6).

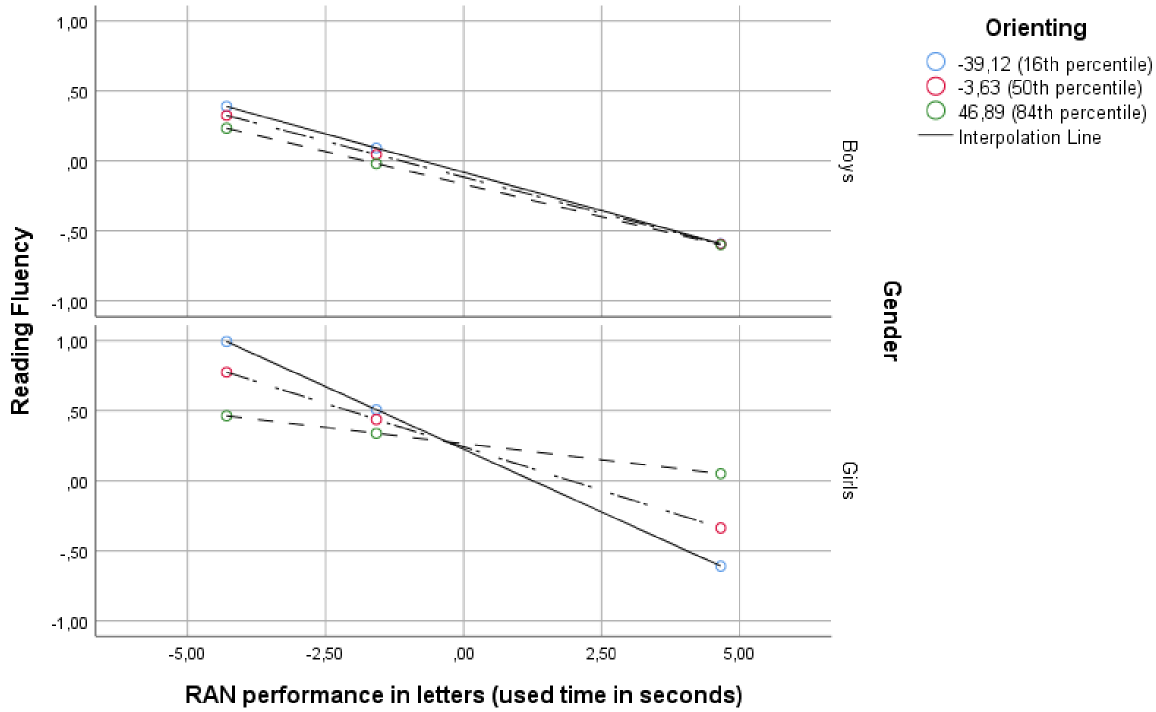

FIGURE 6: Results of moderation analysis between RAN performance in letters, reading fluency, orienting and gender (*N* = 115)

6. DISCUSSION

This study aimed to discuss the role of on-screen visual stimuli reaction times, subcomponents of attention, and gender in RAN and reading fluency association. The main purpose of the study was to examine whether the reaction times in different visual stimuli and the subcomponents of attention predict RAN performance as well as whether they moderate the relationship between RAN and reading fluency. Data include psychometric data from the eSeek project and data from an ANT experiment conducted by Santhana Gopalan (2019; 2020). Selecting the appropriate methodology was central for the final findings of this study, as it enabled.

6.1. Examination of results

My results presented a statistically significant correlation between RAN performance and reading fluency among elementary education students. The effect was negative, revealing that individuals who are fluent readers are faster in RAN tasks and that dysfluent readers tend to be slower. This relationship is well established in previous literature and is consistent with previous studies. In their metaanalytical study, Araújo and colleagues (2015) demonstrated that RAN is highly correlated with reading. Other studies have discovered a significant association between RAN and reading fluency (Neuhaus et al. 2001a; Neuhaus et al. 2001b; Siddaiah & Padakannaya, 2015), RAN and reading comprehension (Georgiou et al. 2010; Neuhaus et al. 2001a; Neuhaus et al. 2001b; Padakannaya et al. 2008; Siddaiah & Padakannaya, 2015) as well as between RAN and reading speed (Siddaiah & Padakannaya, 2015; Wimmer 1993). Georgiou and colleagues (2013) indicated that RAN is associated with reading because both include serial processing and oral production of the stimuli's names. For Kuhn and colleagues (2010) fluent reading is defined by automaticity. Automaticity is characterized by speed, effortlessness, autonomy as well as lack of conscious awareness.

Previous research suggests that alphanumeric RAN is more correlated to reading than non- alphanumeric RAN (de Jong, 2011; Lervåg & Hulme, 2009; Meyer et al., 1998; Van den Bos et al., 2003), especially after initial literacy development. A study conducted by Savage and colleagues (2005) in 10- year old subjects discovered that the association between RAN and reading level was significantly higher in digit naming compared to object naming RAN measurements. Similarly, Vaessen and Blomert (2010) demonstrated that RAN digits presented higher correlations to reading fluency in first to sixth grade students compared to RAN objects tasks. In my study, however, RAN performance in objects presented a higher correlation with reading fluency compared to letters. This effect was not reported in girls, where the correlation in RAN performance in letters was higher.

Hierarchical regression revealed that RAN performance is a significant predictor of reading fluency among elementary education students, accounting for a total of 37% of the variance in reading fluency. The effect of time used in RAN tests (letters and objects) was negative and statistically significant, indicating that the lower the time used, the better the reading fluency. Previous studies have reported that RAN is a strong predictor of reading skills (e.g. Georgiou et al., 2006; Papadopoulos et al., 2016), as deficits in RAN may result in or signify reading difficulties (Siddaiah & Padakannaya, 2015). Cohen and colleagues (2018) discovered that RAN objects task is a better predictor of reading level, something consistent with the findings of this study as RAN performance in objects presented higher effects.

This effect can, also, be explained by the transparency of Finnish language. Studies suggest that in transparent orthographies RAN is the strongest predictor of literacy among children exhibiting deficiencies in reading (Holopainen et al., 2001; Puolakanaho et al., 2007; Torppa et al., 2010) and that naming speed explains a bigger proportion of the total variance in reading performance (Heikkilä, 2015). Furthermore, a longitudinal study by Torppa and colleagues (2013) demonstrated that in Finland a single RAN deficit is a strong predictor of poorer reading fluency. In transparent orthographies deficiencies exist primary in reading fluency and reading speed (Aro et al., 2011; Escribano, 2007; Holopainen et al., 2001; Seymour et al., 2003) and not so much in accuracy (Wimmer, 1993).

Even though the significance of RAN as a predictor of reading fluency is well established, there is still a debate about the reasons underlying this connection. Several explanations have been provided. Torgesen and colleagues (1997) proposed that the relationship between RAN and reading can be explained by the fact that they both demand adequate access to, and recovery of, phonological representations from long-term memory. Bowers and colleagues (e.g. 2002) indicated that RAN is a predictor of reading via the effects of orthographic processing. Other factors include speed of processing (Kail et al., 1999), working memory (Amtmann, 2007) and attention (e.g. Bexkens et al., 2015; Shao et al., 2013).

The role of gender was central. Gender displayed a statistically significant correlation with RAN performance in the objects task. Girls tend to perform better in the RAN objects task, something that is consistent with previous studies as it has been found that females are better in rapid naming tasks in comparison to males (Roivainen, 2011). Certain studies (e.g. Majeres, 1999; Majeres, 2007) have found that females tend to perform better than boys in speeded tasks concerning phonological coding, for instance matching digits, but not in those concerning objects where only few gender differences were observed. However, a study done by Camarata and Woodcock (2006) showed that females perform better not only to tasks related to verbal items but also to rapid object naming and matching tasks.

Gender was also correlated with reading fluency, implying that girls are more likely to be fluent readers. Hierarchical regression analysis demonstrated that gender predicts reading fluency, with the effects of girls being higher. All those are corresponding to previous research findings, where it has been suggested that females tend to perform better in reading than males (Akyol et al., 2014; Mullis et al., 2007). It has also been found that males are more prone to display deficits in reading compared to females (1.83 times), especially when they are severe (Qinn, 2018).

A novel finding of this study was that gender moderates the relationship between reading fluency and RAN performance in the objects task, but not in letters, revealing that there are gender differences present. Even though there has been a lot of research investigating the role of gender in reading fluency and RAN test, to the best of the authors' knowledge there has not been any previous study focusing on potential moderation effects between reading fluency and RAN.

Reaction times displayed a statistically significant negative correlation with reading fluency, revealing that fluent readers tend to have faster reaction times compared to dysfluent readers. Previous research has found an association between processing speed and reading performance, with children experiencing reading deficits (Santhana Gopalan et al., 2020). This association can be either due to a generalized processing deficit (general slowness in reaction times) (Wolf & Bowers, 1999), or a specific deficit (isolated slowness in reaction time) particularly when processing phonological, orthographic (Breznitz & Misra, 2003; Miller-Shaul & Breznitz, 2004) and/or semantic information (Betjemann & Keenan, 2008). Naples and colleagues (2012) suggested that this association is compelled by information accumulation and not by sensory or motor elements of processing. Processing speed is strongly related to the development of reading and math achievement, particularly during the elementary school years when children acquire reading and math skills and improve their speed and automaticity abilities (Weiss et al., 2016).

Reaction times presented a statistically significant positive correlation with RAN performance in both the letters and objects task. This illustrates that the higher time used in RAN the higher the reaction times. It has been found that processing speed plays a role in RAN performance. Previous studies have focused on the role of processing speed in RAN tasks. A study conducted by Kail and his colleagues (Kail & Hall, 1994; Kail et al., 1999) demonstrated that impairments in RAN performance can signify deficits in generalized processing speed. Cutting and Denckla (2001) suggested that processing speed directly contributes to RAN performance. Several studies have established that children who exhibit deficits in RAN have slower processing speed and slower reaction times compared to controls (Cutting & Denckla, 2001; Powell et al., 2007; Stainthorp et al., 2010; He et al., 2013) and were slower to make decisions about a stimulus and distinguish between different stimuli (Stainthorp et al., 2010).

Hierarchical regression analysis showed that the reaction times statistically significantly predicted RAN performance in letters as well as in the objects tasks, explaining a total of 19% and 23% of the variance in RAN performance respectively. The effects were higher in the objects task.

Gender differences were observed in the objects tasks. Even though it has been found that males present faster reaction times in various tasks in comparison to females (Der & Deary, 2006), this study discovered that girls perform better and are quicker to respond. This might be due to the type of the test (RAN) examined, as, like discussed above, it has been shown that girls do better in RAN in comparison to males (Roivainen, 2011).

Moderation analysis revealed that the relationship between reading performance in the objects task and reading fluency is moderated by reaction times and gender. Similarly to previous analyses in this study, gender differences were obvious, with girls performing better. This is a novel finding of this study as to the best of the authors' knowledge there has been no other study presenting corresponding results.

Regarding the subcomponents of attention, this study illustrated that orienting is statistically significantly correlated with RAN performance in letters tasks. The correlation was positive, revealing individuals who are faster in RAN, are more capable in orienting. Hierarchical regression analysis indicated that orienting statistically significantly predicts RAN performance in the letters task. Orienting refers to the capacity to select particular information from among multiple sensory stimuli and is associated with spatial selection (Raz & Buhle, 2006). Orienting can be related to RAN because RAN requires the activation of visual processes, which are important for stimuli detection, visual discrimination, and letter/letter-pattern identification (Wolf & Bowers, 1999; Araújo et al., 2015). This is a novel finding of this study as to the best of the authors' knowledge there has been no other study presenting corresponding results.

Furthermore, orienting has been found to moderate the relationship between RAN performance in letters and reading fluency. Some studies have discovered that orienting is crucial for reading and reading acquisition and that orienting can successfully predict reading ability (Casco et al., 1998; Facoetti et al., 2010b; Hari & Renvall, 2001; Roach & Hogben, 2007; Vidyasagar & Pammer, 2010). A study conducted by Franceschini and colleagues (2012) has shown that poor readers exhibited deficits in visual search, visual attention and spatial cueing even before reading emerge. Attention orienting can improve visual perception both by boosting the signal inside the focus of attention and decreasing the effect of noise outside the focus of attention (Battelli et al., 2010, Corbetta et al., 2011), hence deficits in orienting can be associated with higher interference between letters (Roach & Hogben, 2007) and impaired serial reading (Whitney & Cornelissen, 2005). Despite all the above, this moderation effect is a novel finding, as, to the best of the author's knowledge, no previous research has been conducted on the topic.

Alerting has been found to be statistically significantly correlated with RAN performance in objects tasks. The correlation was positive, indicating that those who perform better in RAN objects have better alerting abilities. Hierarchical regression analysis indicated that alerting statistically significantly predicts RAN performance in the objects task. Alerting refers to the ability to reinforce and maintain response readiness in preparation for a forthcoming stimulus (Raz & Buhle, 2006). This connection might be due to the fact that RAN, as a speeded task, requires fast responses in order to succeed, and hence, alerting abilities are crucial for it as more response readiness leads to faster responses. This is a novel finding of this study as to the best of the authors' knowledge there has been no other study presenting corresponding results.

This study, also, demonstrated that inhibition is statistically significantly correlated with RAN performance in the objects task. The correlation was positive, implying that individuals with better RAN performance in the objects task display better inhibitory capacities. Hierarchical regression analysis showed that inhibition statistically significantly predicts RAN performance in the objects task. Interestingly, when inhibition was entered to the model, alerting was no longer statistically significant. This is a novel finding, as, to the best of the author's knowledge, no previous research has been conducted on the topic. Inhibition includes several mechanisms responsible for the resolution of conflicts, detection of errors and choice of action in response to other stimuli (Posner and Rothbart, 2007; Raz & Buhle, 2006; Santhana Gopalan et al., 2019; Santhana Gopalan et al., 2020). The role of inhibition in RAN is well established. Research suggests that RAN is correlated to reading due to underlying attentional processes. Due to the fact that RAN demands the storage of a big amount of information (different stimuli) into the working memory in a highly accessible condition, there is a competition between the activations of previously named stimuli and the current stimulus when choosing a response. Thus, inhibition is crucial for choosing the correct among all competing alternatives (Bexkens et al., 2015; Shao et al., 2013).

Finally, inhibition was found to be statistically significantly correlated with reading fluency. The correlation was positive, revealing that fluent readers exhibit better inhibitory abilities. Inhibition is central for reading fluency as it implements the elimination of irrelevant information, ensuring the maintenance of relevant information in the working memory (Cain et al., 2004; Sesma et al., 2009 as cited in Kendeou et al., 2014). Inhibition is highly associated with reading comprehension. Dysfluent readers exhibit deficits in excluding information that is no longer applicable in both short-term memory tasks and working memory tasks (Cain, 2006). An ANT study by Bednarek and colleagues (2014) suggested that children presenting reading difficulties had problems with inhibition.

6.2. Limitations and future studies

This study sought to examine whether the reaction times in different visual stimuli and the subcomponents of attention predict RAN performance as well as whether they moderate the relationship between RAN and reading fluency. As this topic has not been examined before, it provided novel findings that can bring a new insight in those issues.

That being said, this study didn't come without limitations. The first limitation refers to the sample size. The number of the participants used in this study was rather small for quantitative analysis, something that can inhibit the exclusion of generalisability. A study with a bigger number of participants could had provided a better insight to these phenomena and enabled a deeper analysis in order to achieve a better comprehension.

Furthermore, the nature of the sample was another limitation. The sample was comprised of sixth grade students attending school in central Finland. As the scope of the sample was rather limited, the results might not be corresponding to the general population. A broader population could have provided more general results and ensure better reliability.

A final limitation lies in the fact that, regarding the association of RAN performance and subcomponents of attention, there was not enough research on the topic. Even though this provided the possibility to work on something novel, it also made creating potential hypotheses difficult, as previous literature is central for understanding the research problem.

Future research is needed in order to understand better how RAN performance and reading fluency connect to reaction times and subcomponents of attention. As this study had a limited number of participants, further research should investigate those phenomena in a bigger group as well as in a broader setting. This could provide a better insight about the potential relationship and enhance the generability of the results. A study in different age ground could also be interesting as it could enable to distinguish potential differences amongst age group, especially if it is conducted in a longitudinal setting.

The relationship between RAN and attention should be investigated further. Studies should opt to explore and decompose intraindividual variability in terms of RAN and attention and determine the underlying the reasons behind this variability. The neural correlates of attention in terms of RAN should be studied using EEG or MEG measurements, as comprehending those correlates can lead to a better and broader understanding of this association.

Future research should, also, concentrate on the relationship between reading fluency and RAN, as this relationship is still not completely understood. The underlying mechanisms governing this relationship should be examined because understanding those mechanisms can result in the creation of better ways to achieve reading fluency as well as efficient ways to determine potential reading deficits early on.

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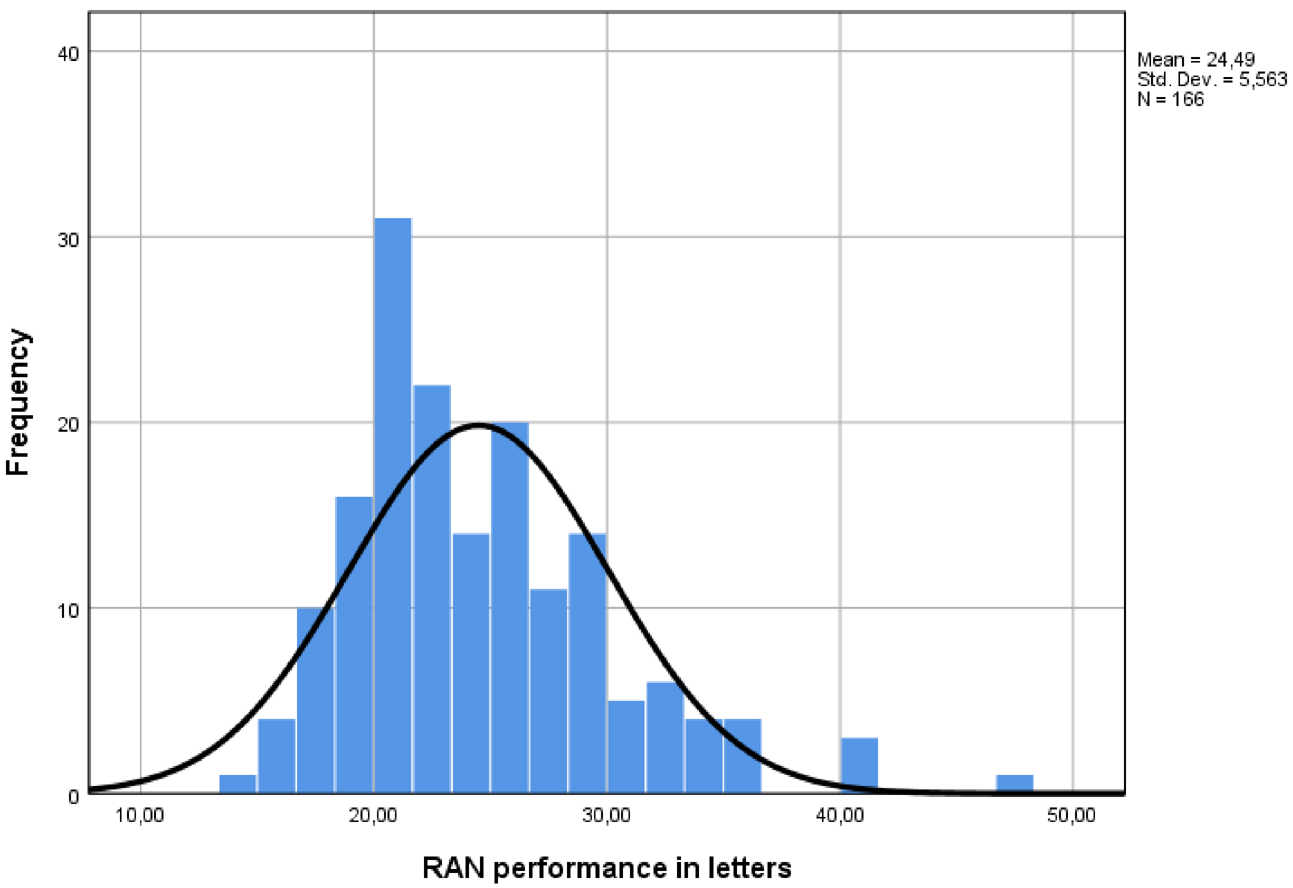
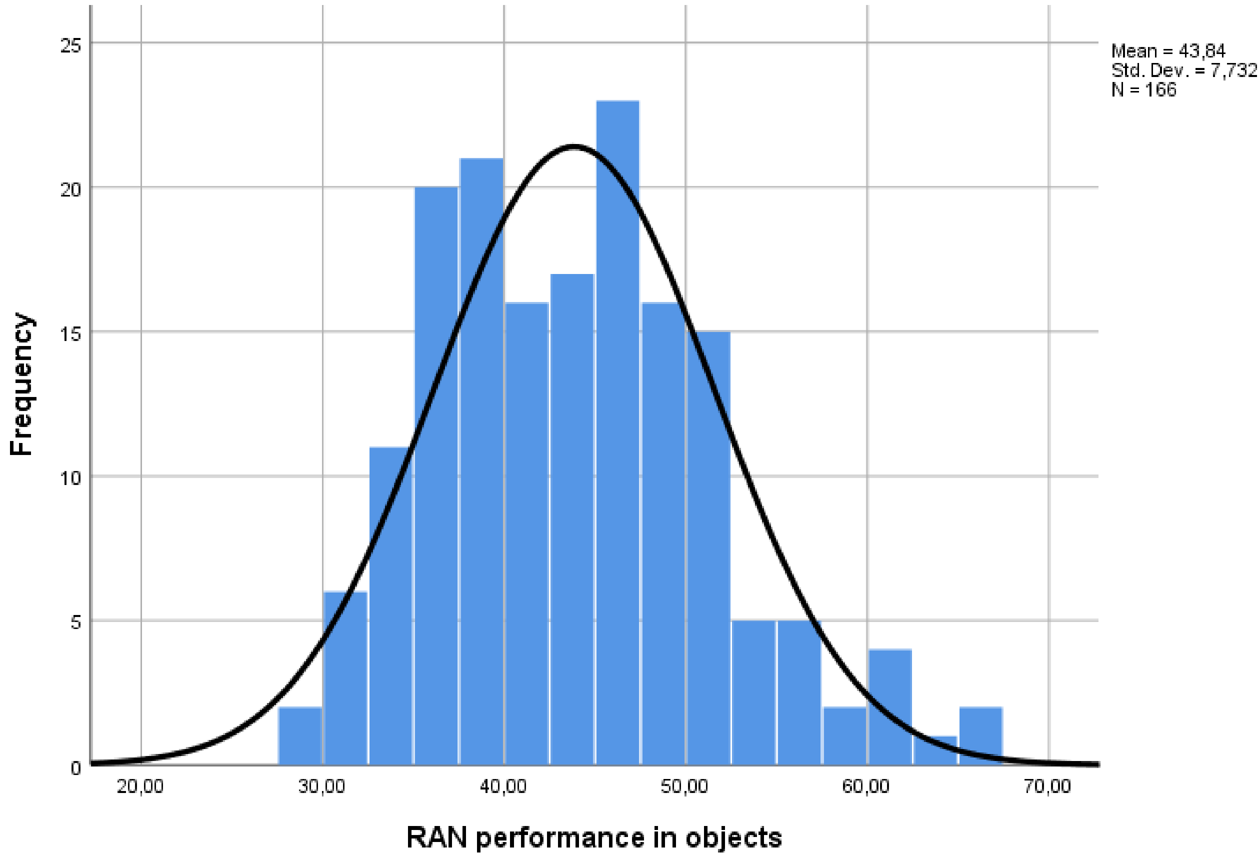
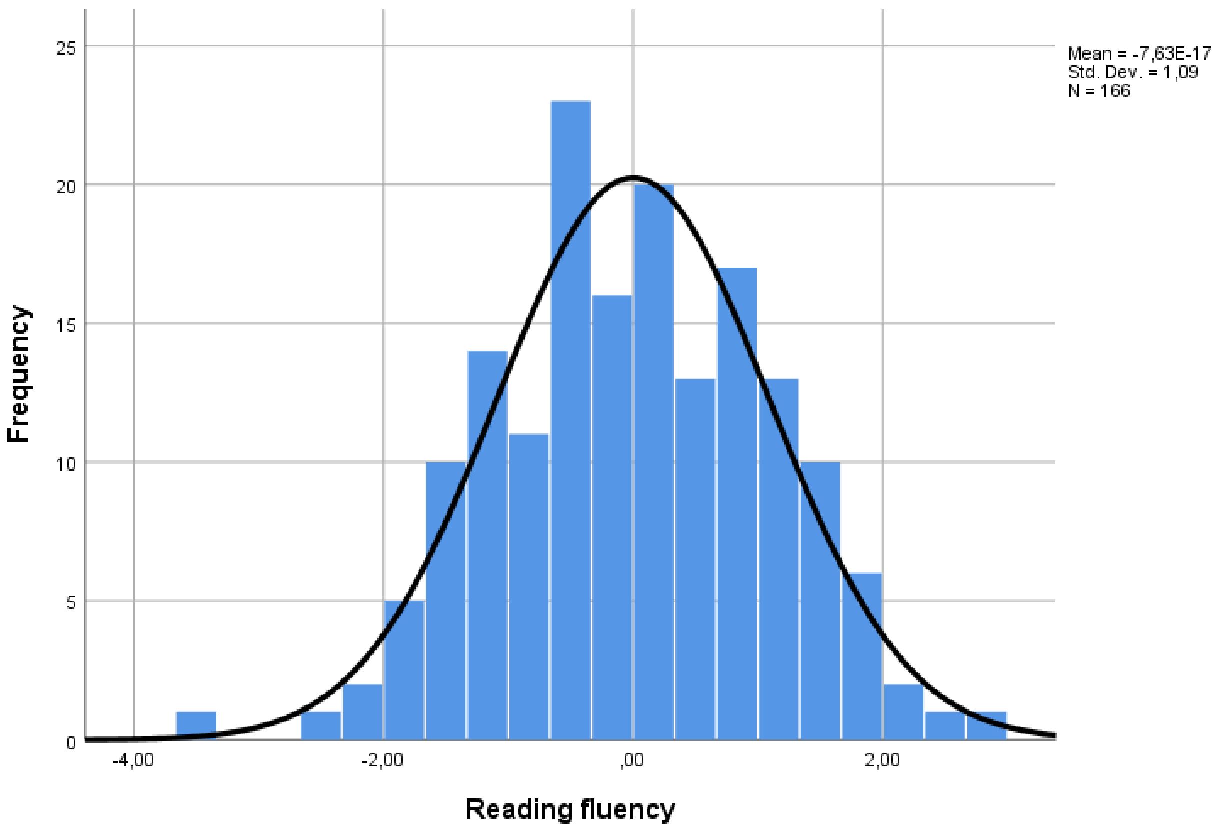
APPENDICES

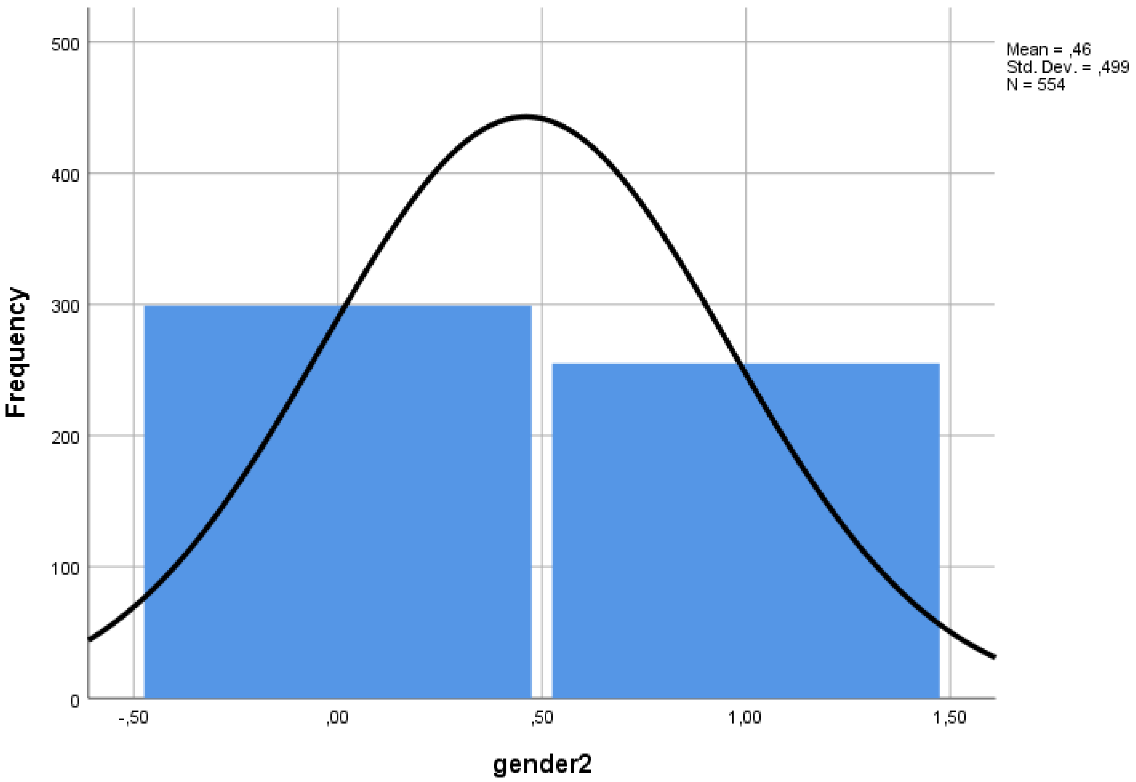
TABLE 12: Skewness and kurtosis of variables used in the analysis.

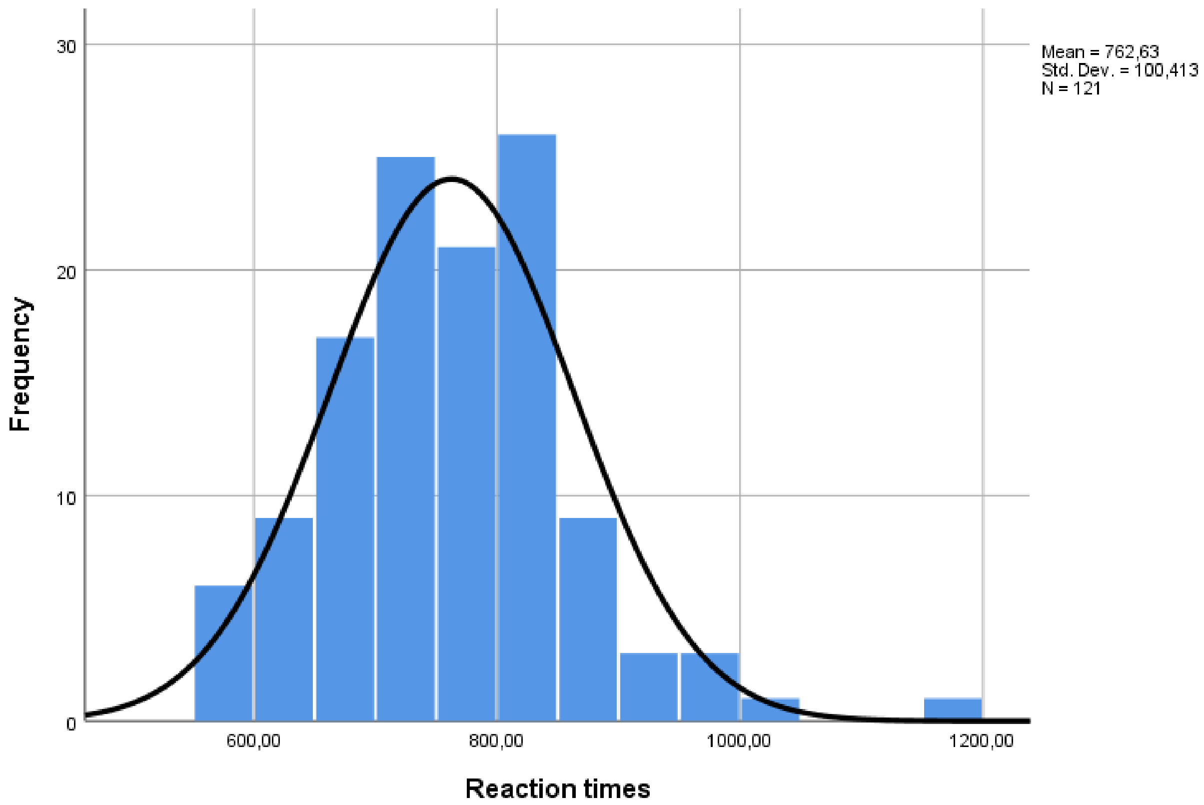
Variables	Skewness	Kurtosis
RAN performance in letters	1.08	1.72
RAN performance in objects	.53	.07
Reading Fluency	-.04	-.20
Reaction times	.64	1.72
Alerting	.24	.27
Orienting	.05	2.22
Inhibition	.11	.43
Gender	.16	-1.98

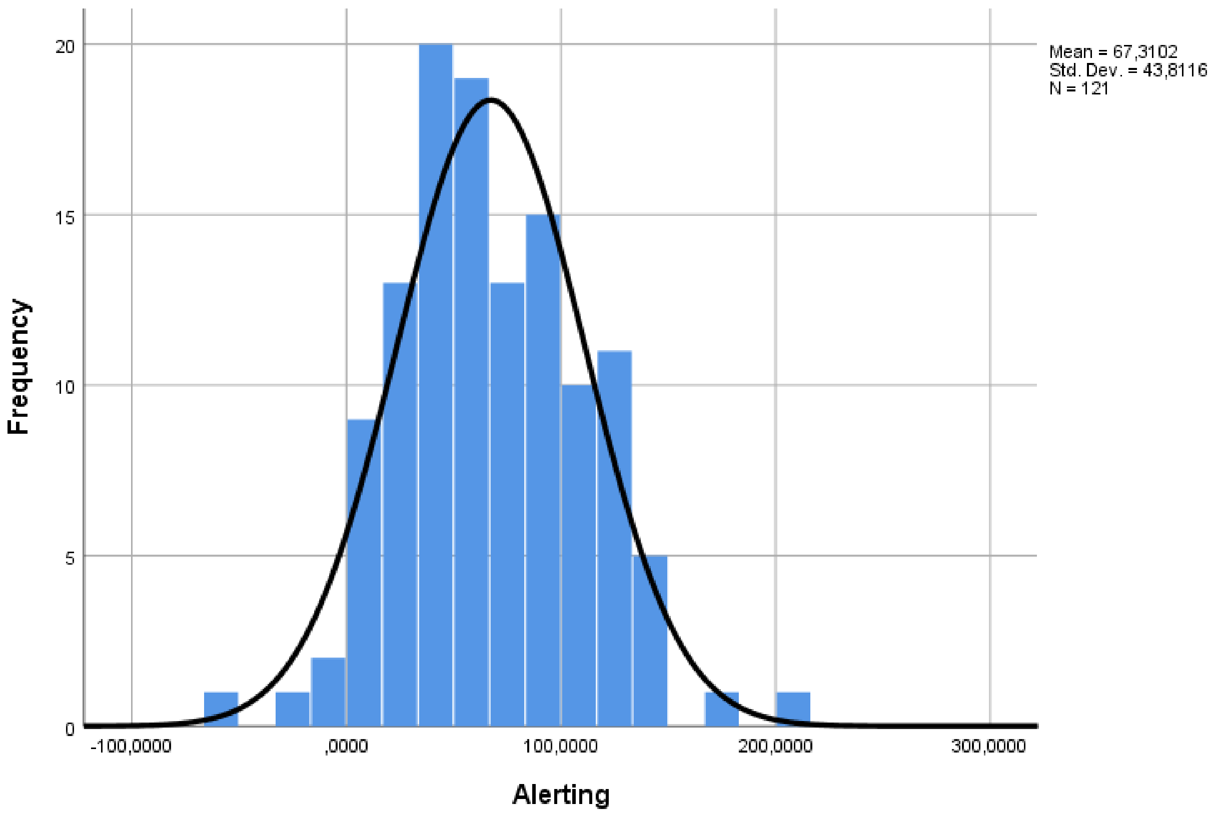


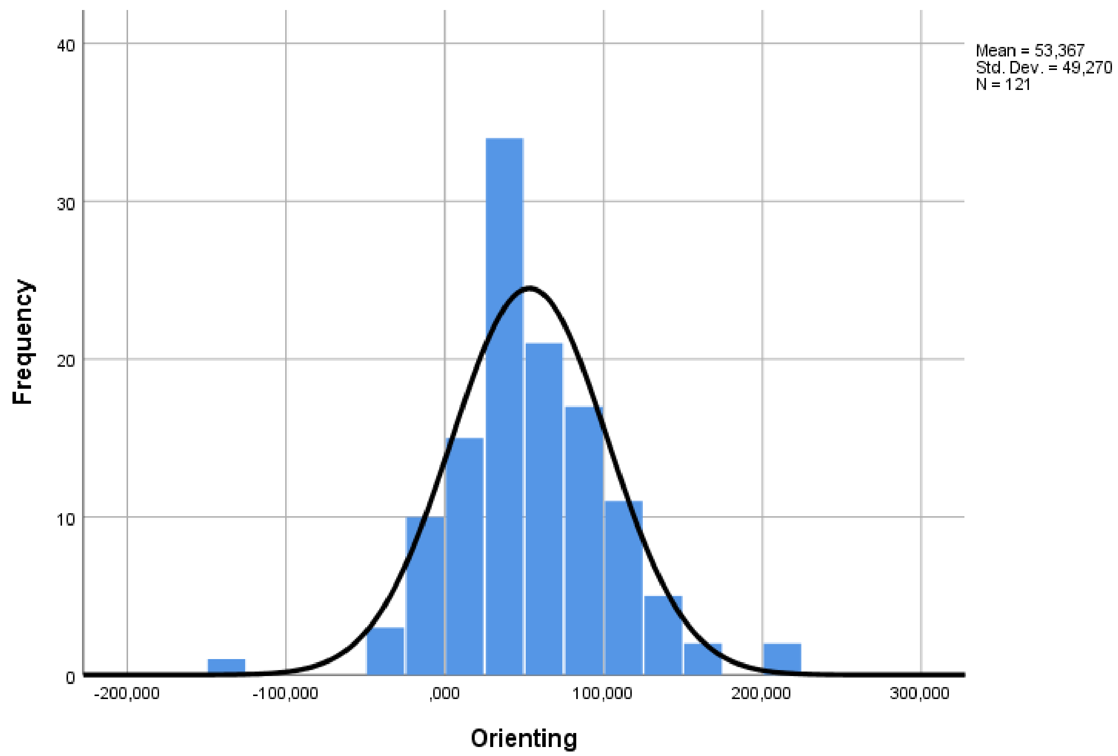

Mean = 43,84
Std. Dev. = 7,732
N = 166
Frequency
RAN performance in objects
0
5
10
15
20
25
20,00
30,00
40,00
50,00
60,00
70,00

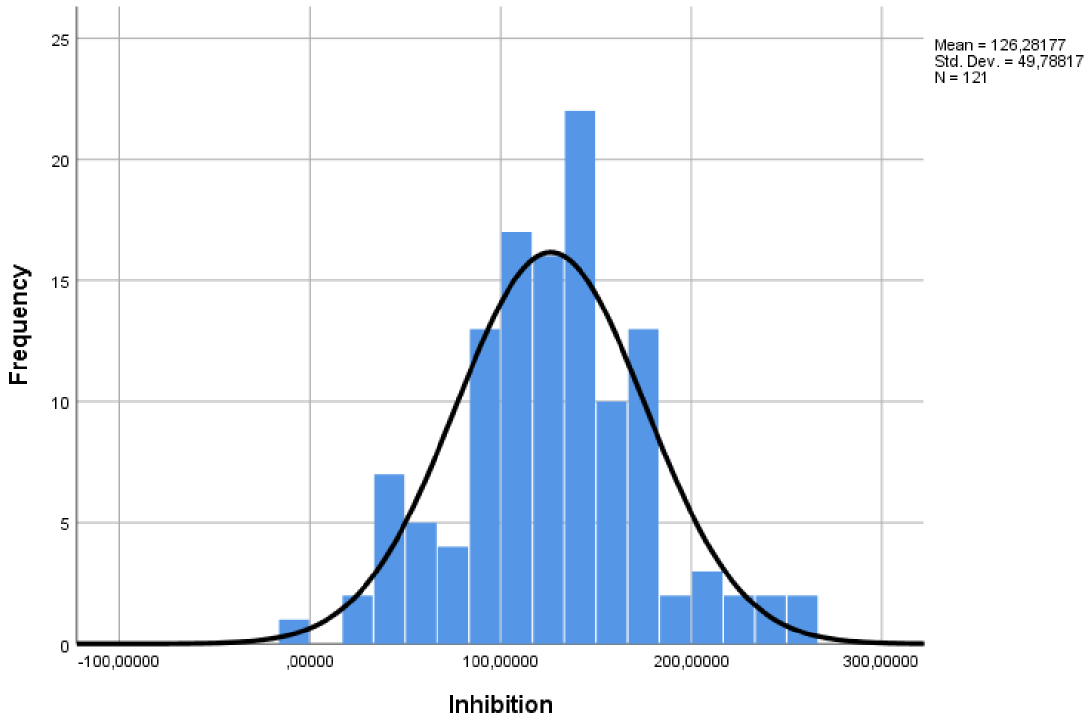

Mean = -7,63E-17
Std. Dev. = 1,09
N = 166
Frequency
Reading fluency
0
5
10
15
20
25
-4,00
-2,00
,00
2,00


Mean = ,46
Std. Dev. = ,499
N = 554
Frequency
500
400
300
200
100
0
-,50
,00
,50
1,00
1,50
gender2


Mean = 762,63
Std. Dev. = 100,413
N = 121
Frequency
30
20
10
0
600,00
800,00
1000,00
1200,00
Reaction times


Mean = 67,3102
Std. Dev. = 43,8116
N = 121
Frequency
20
15
10
5
0
-100,0000
,0000
100,0000
200,0000
300,0000
Alerting


Mean = 53,367
Std. Dev. = 49,270
N = 121
Frequency
40
30
20
10
0
-200,000
-100,000
,000
100,000
200,000
300,000
Orienting



FIGURE(s) 7: Histograms of the variables used in the analysis.

TABLE 13: Spearman's correlations coefficients and descriptive statistics of the variables used in the analysis.

Variables	1	2	3	4	5	6	7	8
1. RAN performance in letters	1							
2. RAN performance in objects	.40*	1						
3. reading fluency	-.53*	-.51*	1					
4. Reaction times	.41*	.48*	-,29**	1				
5. Alerting	.06	.24**	-.08	.23***	1			
6. Orienting	.20***	-.05	-.10	.10	.06	1		
7. Inhibition	.15	.25**	-.23***	.30*	.25**	.27**	1	
8. Gender	.06	-.18	.18	.03	-.06	.08	-.08	1
N	166.00	166.00	166.00	121.00	121.00	121.00	121.00	554.00
M	24.49	43.84	.00	762.63	67.31	53.37	126.28	.46
S.D.	5.56	7.73	1.09	100.41	43.81	49.27	49.79	.50

Note: * $p < .001$, ** $p < .01$, *** $p < .05$

TABLE 14: Pearson's correlations coefficients and descriptive statistics of the reaction times variables

Variable	Non cued target stimuli	Double cued target stimuli	center cued target stimuli	Spatial cued target stimuli	Congruent target stimuli	Incongruent target stimuli
RAN performance in letters	.41*	.42*	.49*	.38*	.42*	.42*
RAN performance in objects	.48*	.44*	.44*	.46*	.43*	.50*
Reading fluency	-.32*	-.33*	-.39*	-.34*	-.32*	-.37*
Gender	.09	.13	.06	.05	.10	.04
M	806.20	738.89	776.31	722.94	702.57	828.85
SD	109.49	98.05	107.10	103.90	94.09	110.12

*Note: * $p<.001$

TABLE(s) 15: Multicollinearity diagnostics of the variables used in the analysis.

Independent variables	Reading fluency	
	Tolerance	VIF
RAN performance in letters	.83	1.21
RAN performance in objects	.80	1.25
Gender	.96	1.04

Independent variables	RAN performance in letters	
	Tolerance	VIF
Reaction times	.99	1.01
Gender	.99	1.01

Independent variables	RAN performance in objects	
	Tolerance	VIF
Reaction times	.99	1.01
Gender	.99	1.01

Independent variables	RAN performance in letters	
	Tolerance	VIF
Alerting	0.95	1.05
Orienting	0.95	1.05
Inhibition	0.90	1.12
Gender	0.98	1.02

Independent variables	RAN performance in objects	
	Tolerance	VIF
Alerting	0.95	1.05
Orienting	0.95	1.05
Inhibition	0.90	1.12
Gender	0.98	1.02