# Comparing the performance of people who stutter and people who do not stutter on the Test of Everyday Attention

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# Abstract

Introduction: Compelling findings into the relationship between stuttering and attentional ability have started to emerge with some child and adult studies indicating poorer attentional ability among people who stutter (PWS). The purpose of the present research was to provide a more complete picture of the attentional abilities of PWS as well as to gather insights into their individual attentional performance. Method: We compared the attentional ability of PWS to that of people who do not stutter (PWNS) by using the Test of Everyday Attention (TEA). TEA is a clinical assessment battery with a very good validity and reliability comprising 8 subtests that pose differential demands on sustained attention, selective attention, attentional switching and divided attention. 50 age- and gender-matched PWS and PWNS (aged between 19 and 77 years) took part in the study. Importantly, we also examined stuttering severity in the PWS group. Results: PWS performed significantly worse on tasks tapping into visual selective and divided attentional resources. Furthermore, despite non-significant, the results also revealed an interesting trend for stuttering to be associated with poorer performance on two subtests measuring attentional switching and one tapping into auditory selective attention. Moreover, as hypothesized, there was also a negative association between stuttering severity and performance on two TEA subtests measuring visual selective attention. Finally, the type of TEA test variant produced no significant effect on performance. Conclusions: We interpret these results as indicative of stuttering being associated with poorer performance on tasks measuring certain attentional abilities. These tie well with theoretical models identifying speech production as particularly attention-demanding in stuttering or approaches placing attentional dysfunction at the heart of the condition. The present research also has practical implications for the use of attentional training to improve fluency.

Keywords:attention, cognitive control,stuttering; adults; TEA

# Introduction

Stuttering can be a debilitating speech disorder that may adversely affect one’s functional communication abilities. This in turn can diminish the individual’s overall quality of life by causing one to experience negative emotion associated with their speech problem (Craig, 2006; Corcoran & Stewart, 1998; Iverach et al., 2009), compromising one’s social relationships (Erickson & Block, 2013; Van Borsel, Brepoels & De Coene, 2011) and even reducing one’s career prospects (Klein & Hood, 2004). However, while classical research into the disorder has mainly focused on the speech difficulty that the condition produces and how it adversely affects other aspects of the life of people who stutter (PWS), current authors have started to investigate whether stuttering is indeed a unitary problem as once suggested and whether instead, it might be associated with some other difficulties, not overtly related to stuttering (e.g., Bajaj, 2007; Eggers, De Nil & Van den Bergh, 2009, 2010, 2012, 2013; Felsenfeld, van Beijsterveldt & Boomsma, 2010; Maxfield et al., 2010, 2012, 2015, 2016[[1]](#endnote-2); Vasic & Wijnen, 2005). Usually, this is done by comparing the performance of PWS to people who do not stutter (PWNS) on a variety of tests, assessing different capabilities, such as motor coordination (Sommer, Koch, Paulus, Weiller & Büchel, 2002), working memory (Bajaj, 2007; Bosshardt, 2002, 2006), concentration (Felsenfeld et al., 2010) or comorbidity with other conditions (e.g., ADHD; Alm & Risberg, 2007).

**1.1 Stuttering and cognitive function: findings**

Related to the latter, compelling findings into the relationship between stuttering and cognitive function have started to emerge (e.g., Bosshardt, 1999, 2002, 2006; Eggers et al., 2009, 2010, 2012, 2013; Felsenfeld et al., 2010; Karrass et al., 2006; Maxfield et al., 2010, 2012, 2015, 2016; Schwenk, Conture & Walden, 2007). For example, child studies have revealed that stuttering is associated with increased impulsivity (Blood, Blood, Maloney, Weaver & Shaffer, 2007) and poor inhibitory control (IC)[[2]](#endnote-3). IC has been defined by Eggers et al. (2013, p.1) as the ability ‘to interrupt or delay an inappropriate response under instructions or in novel or uncertain situations or to ignore irrelevant information’. Moreover, Eggers et al. (2013) found that children who stutter (CWS) have difficulties adapting their response style after making an error, and that they experience problems in selecting information from numerous sensory inputs (i.e., a less efficient orienting network; Eggers et al., 2012). More in detail, Eggers et al. (2012) tested orienting efficiency in CWS in a modified version of the Attention Network Test (ANT; Fan, McCandliss, Sommer, Raz & Posner, 2002) by subtracting median reaction times (RTs) when children responded to central targets (1) from median RTs when children responded to targets presented either above or below a centrally displayed fixation cross (2). The study results revealed that the difference in RT (i.e., 1-2) was significantly bigger in the CWS sample, as compared to the healthy children, demonstrating that CWS, as a group, had a lower efficiency of the orienting network compared to CWNS.

 Furthermore, research with adults who stutter (AWS) has suggested that the stability of their speech often depends on the complexity of the utterance, as well as on whether additional cognitive demands have been placed on the task, such as the introduction of a secondary task (e.g., Bosshardt, 2006; Smits-Bandstra & De Nil, 2009; Saltuklaroglu, Teulings & Robbins, 2009). For example, a review by Bosshardt (2006) indicated that in contrast to heathy comparisons, PWS experienced greater interference from phonological distractors, and when the cognitive demands of the task increased (e.g., dual task condition), their speech became more dysfluent and they generated conceptually simpler sentences as compared to the single-task condition. Maxfield et al. (2016) also recently provided ERP[[3]](#endnote-4) evidence for atypical attentional performance in stuttering during such conditions. More in detail, in their task paradigm participants had to name a target picture, presented together with three distractor words that could either be phonologically-related, semantically-related or unrelated to the target. In the dual task condition, participants had to also make a judgement between two tone types (a frequent low tone versus a rare high one) that were presented either after a short or a longer delay. The latter was the only task in the simple-task condition. While there was no difference between the two groups neither in their behavioural nor neuropsychological data in the simple task condition, in the dual task condition PWS exhibited poorer naming accuracy when the printed distractors were semantically related to the target and were presented after a longer delay[[4]](#endnote-5). Moreover, the researchers detected a P3 effect in the fluent participants during all dual task conditions, while the P3 component was either missing or attenuated in the PWS group when the secondary task was presented with a short delay. As P3 indexes perceptual processing and categorization, Maxfield et al. (2016) interpreted the findings as indicative of phonological and semantic competition being extremely resource-demanding for the PWS group, which likely let them to ‘… severely draw cognitive resources away from tone categorization’ (Maxfield et al., 2016, p. 1954). Furthermore, atypical attentional inhibition of target information has also been identified in earlier research by Maxfield et al. (2010, 2012). Finally, there is evidence that the act of stuttering itself can draw attention exclusively to one’s speech and thus take away one’s focus from the task at hand (Saltuklaroglu et al., 2009).

**1.2 Attentional ability, cognitive control and how these could relate to speech**

To understand the association between poorer attentional ability and stuttering, these findings should be examined from an attentional point of view. Every day individuals are bombarded with an abundance of complex information, while at the same time they have limited processing resources (Lavie, Hirst, de Fockert & Viding, 2004). Thus, how successfully one attends to information is determined by the interplay between the amount and specifics of the presented stimuli (perceptual load) and how much resources one can allocate to their processing (cognitive control/cognitive load; Lavie et al., 2004). Good cognitive control (i.e., executive function), amongst other functions, supports the prioritizing of relevant over irrelevant information (selective attention/inhibitory control[[5]](#endnote-6)), the successful performance of multiple tasks at the same time (divided attention), it helps the individual maintain focus on the task at hand (sustained attention) and finally, it ensures a quick and efficient switching between tasks (attentional switching[[6]](#endnote-7)) (Chan, Shum, Toulopoulou & Chen, 2008). Thus, cognitive control is at the heart of the three types of attentional function.

In support, according to Thomson Besner and Smilek (2015, p.89) ‘executive control is required to sustain active goal maintenance and to prevent task-irrelevant thoughts from consuming attentional resources needed for the primary task’. Furthermore, McVay and Kane (2012, p. 543) suggest that [their] results, … directly support the claims of executive attention theory (e.g., Kane, Conway, et al., 2007) that [working memory capacity] WMC’s predictive power derives to some degree from its tapping into variation in attention-control processes involved in the regulation of both thought and behavior’. The same has been reported by authors, studying the relationship between executive function and attentional (i.e., task) switching (Cohen, Bayer, Jaudas & Gollwitzer, 2008). For instance, Cohen et al. (2008) wrote that executive control ‘is synonymous with the construct executive function’ (p. 12) and that it ‘encompass[es] a wide variety of cognitive processes such as dealing with novelty, planning, using strategies, monitoring performance, using feedback to modify performance, vigilance, and inhibiting irrelevant information’ (p. 12) and finally, that task switching is ‘a common paradigm that is used to measure cognitive control’ (p. 13).

It can, therefore, be seen why attentional performance suffers when cognitive control is compromised. The latter could occur either because of an increase in the complexity of the higher-order task (i.e., cognitive load; Grandjean & Collette, 2011; Lavie et al., 2004), due to a lower executive capacity (e.g. McVay & Kane, 2009, 2012) or because of conditions, associated with a reduction in cognitive resources, such as ageing (e.g., Maylor & Lavie, 1998; Hedden & Gabrieli, 2004), trait anxiety (e.g. Eriksen & Hoffman, 1973) and powerlessness (e.g., Guinote, 2007). Indeed, it is a common practice to use the term ‘attentional control’ as synonymous to ‘cognitive control’ in the context of attentional allocation of resources (e.g., Eggers et al., 2013; Maxfield et al., 2016, etc.). Given the above, it is intriguing to examine the potential relationship between stuttering and executive function. It has been found that both phonological processing and language production require sufficient cognitive control (Cook & Meyer, 2008; Roelofs & Piai, 2011) and that even the speech of fluent healthy comparisons can ‘break down’ under conditions of an increased cognitive demand (e.g., Ferreira & Pashler, 2002). There are two models that imply such a relationship – (1) the Demands and Capacities model according to which language production is atypically demanding in the stuttering population and thus one’s capacities (motor, linguistic, socio-emotional or cognitive) cannot meet the numerous external demands that come with speech (e.g., time pressure, speech continuity, communicating to negative listeners, etc.; Adams, 1990; Andrews et al., 1983; Starkweather, 1987; Starkweather & Givens-Ackerman, 1997). And (2) Eggers et al. (2012, 2013)’s theory that impeded inhibitory control negatively affects error monitoring and can possibly result in stuttering. Furthermore, in Eggers et al. (2012, 2013)’s view, fluency is seen as a part of a broader network of processes that interact and influence one another and are sensitive to a disruption from the environment (Conture et al., 2006; De Nil, 1999; Eggers et al., 2012, 2013). This account has been indirectly based on Levelt’s model (1983), according to which the output at each stage of language production (conceptualization, formulation and articulation) is internally monitored for errors. When an error is detected, a self-repair process takes place, which leads to either an overt (pre-articulation) or a covert (post-articulation) repair. There is evidence that in order to prevent such errors, the language production system relies on inhibitory control (Engelhardt, Corley, Nigg & Ferreira, 2010). However, importantly, neither the authors of these models nor the present paper aim to suggest that weaker cognitive control causes stuttering or vice versa; this question is beyond the scope of the present research. We are however interested in examining this potential association and believe novel, interesting insights about the nature of stuttering could arise from such research.

**1.3 The Test of Everyday Attention**

We tested participants’ attentional function with the Test of Everyday Attention which has been based on Posner and Peterson (1990)’s theoretical model of attention[[7]](#endnote-8) (TEA; Robertson, Ward, Ridgeway & Nimmo-Smith, 1994, 1996; See Section 4.3). TEA is sensitive to different aspects of attentional ability and thus, could yield a more complete picture of the attentional abilities of PWS when these are compared to PWNS. It can also provide us with insights into how individual performance varies on the different subtests and which aspects of attentional ability correlate to one another. TEA has been developed on the basis of on an imaginary trip to Philadelphia in the US. Participants are required to perform various simulated daily activities with familiar materials in the scenarios of each of the eight TEA subtests (Map Search,Elevator Counting, Elevator Counting with Distraction, Visual Elevator, Elevator with Reversal, Telephone Search, Telephone Search While Counting Dual Task and Lottery; See Section 2.2 for more details). According to the literature examining the latent structure of TEA, these subtests tap into four different types of attentional ability, requiring cognitive control (Chan, 2000; Robertson et al., 1994, 1996; Bate, Mathias & Crawford, 2001). These are selective attention (i.e., Map Search, Telephone Search and Elevator Counting with Distraction) sustained attention (i.e., Elevator Counting, Lottery), attentional switching (i.e., Visual Elevator, Elevator with Reversal), and divided attention (Telephone Search While Counting Dual Task). Finally, the test has been found to have very good validity (Bate et al., 2001; Chan, 2000) and reliability (Chen, Koh, Hsieh, & Hsueh, 2013; Crawford, Sommerville & Robertson, 1997) and has not been previously administered in the stuttering population.

**1.4 The present study**

The main purpose of the present investigation was to examine the attentional ability of adults who stutter by using a particularly robust and complete battery of tests. Previous studies have usually used a single task to measure attention (e.g., dual tasking in Maxfield et al., 2016). Thus, the basis for comparison between the different attentional abilities in the stuttering population has come from studies, utilising very different methodologies, as well as by drawing conclusions based on the performance of different samples of PWS on different instruments (e.g., a computerized ANT in Eggers et al., 2012; questionnaires used in Eggers et al., 2009, 2010; two different dual tasks, used in Bosshardt, 2006 and Maxfield et al., 2016, respectively). Based on previous research, it was hypothesised that differences in performance on TEA will emerge between the PWS and matched healthy comparisons. More specifically, it was predicted:

 (1) In light with previous studies, it was hypothesised that as compared to PWNS, PWS would perform more poorly on TEA, especially on tasks, requiring sufficient cognitive control (e.g., selective attention, attentional switching and divided attention; Eggers et al., 2010, 2012, 2013; Bosshardt, 2006; Smits-Bandstra & De Nil, 2009; Maxfield et al., 2010, 2012, 2016; Saltuklaroglu et al., 2009). In terms of sustained attention, reported findings have been mixed. For example, although poorer sustained attention has been identified in several studies with CWS (e.g., Embrechts, Ebben, Franke & van de Poel, 2000; Karrass et al., 2006), some have found the opposite (Anderson, Pellowski, Conture & Kelly, 2003; Eggers et al., 2010, 2012). Furthermore, it has been suggested that maintaining attentional focus is only problematic in childhood and then it continuously improves during adolescence (Klenberg, Korkman, & Lahti-Nuuttila, 2001; Rebok et al., 1997). Thus, while we expected poorer performance in the PWS group on tasks measuring selective, divided attention and attentional switching, we did not have specific predictions for the outcome of the sustained attention factor.

(2) An association between stuttering severity and attentional ability was also hypothesised based on previous findings that speech production might be especially resource-demanding of attentional resources in this population (Crowe & Kroll, 1991; Bosshardt, 2006; Maxfield et al., 2010, 2012, 2016; Watson et al., 1994). Thus, negative associations between stuttering severity and performance on tasks, requiring a higher level of cognitive control (selective attention, divided attention, attentional switching) was predicted.

**2.0 Method and Materials**

The present study was approved by the Ethics Committees of the University of Suffolk (UOS), UK and University College London (UCL), UK. A written informed consent was obtained from all participants prior to taking part in the study. Finally, at the end of the experimental session, all participants were fully debriefed about the purposes of the study.

# 2.1 Participants

A total of 50 participants took part. There were 25 PWS and 25 healthy comparisons, matched for gender and age group. The sample of PWS consisted of 19 male and 6 female participants[[8]](#endnote-9) with an age range between 19 and 77 years and a mean of 38.6 years (*SD* = 18.0). The PWNS group also consisted of 19 males and 6 females with an age range of 19 to 67 years and a mean age of 37.0 years (*SD* = 16.1). It was ensured that an equal number of PWS and PWNS fell within each TEA age group (18-34; 35-49; 50-64; 65-80; as identified by Robertson et al., 1994, 1996). Thus, a total of 26 participants were aged between 18 and 34; 10 were between 35 and 49; 8 were between 50 and 64 years of age and 6 were between 65 and 80 years of age. No measure of IQ was collected as previous research has suggested that IQ accounts for little of the variance in most subtests of both the adult (e.g., Robertson et al., 1996) and the children’s versions (TEA-Ch; Manly, Robertson, Anderson & Nimmo-Smith, 1999; e.g., Baron, 2001). As there is no clear rule on how to administer TEA if participants are tested on a single occasion (Robertson et al., 1996) and the three test variants have been devised to overcome practice effects, rather than to vary in difficulty, we predicted that performance on TEA would not differ as a function of test variant. Thus, for validation purposes we administered all three forms (A, B and C) to participants. We controlled for the effect of test variant by assigning an equal number of PWS and PWNS to each form, so that a total of 12 participants completed variant A (6 PWS; 6 PWNS), 26 – variant B (13 PWS; 13 PWNS), while the remaining 12 did variant C (6 PWS; 6 PWNS).

The majority of the PWS were recruited from the client database of the City Lit, London – an adult education college, providing a range of different courses. The rest were recruited in response to a study invitation advertisement, posted on the official website of the British Stammering Association, as well as from local stuttering self-support groups. The healthy comparisons group was recruited in response to study invitation advertisements, posted across London and Ipswich. All participants in the PWS group had received a form of speech therapy in the past. Their level of fluency was also determined based on the percentage of stuttering-like dysfluencies (SLDs) participants exhibited in their 5-minute speech recording collected from each PWS at the end of the study. SLDs stand for repetitions, prolongations, blocks, interjections and revisions in speech. None of the PWNS had a previous history of any kind of speech disorder.

# 2.2 Materials

As mentioned in Section 2.1, TEA has two versions – the adult TEA, used in the present study (Robertson et al., 1994, 1996) and the children’s version called the Test of Everyday Attention for Children (TEA-Ch; Manly et al., 1999). The adult version consists of eight subtests (Map Search,Elevator Counting, Elevator Counting with Distraction, Visual Elevator, Elevator with Reversal, Telephone Search, Telephone Search While Counting Dual Task and Lottery). A detailed description of each of these has been given below:

(1*) Map Search:* Participants search for symbols (e.g., a knife-and-fork sign representing eating facilities) on a coloured map of Philadelphia. The score is the number of symbols they find (out of 80) in 2 minutes. Participants perform two identical sessions of 1 min each, labeled as Map Search 1 (MS1) and Map Search 2 (MS2) in this study. Importantly, MS1 and MS2 provide two different measures - MS1 refers to the number of symbols identified by participants in the first minute of the task, while MS2 represents the total score on this task (how many symbols participants circled for the total time of 2 min, i.e., MS2 does not refer to their score for the second minute only). Therefore, MS1 and MS2 are presented separately and should not be averaged (consult Robertson et al., 1996; Chan, Hoosain & Lee, 2002). A *higher* score on this subtest indicates better performance. Map Search (MS) measures visual selective attention.

(2) *Elevator Counting*: Participants are requested to pretend they are in an elevator whose floor indicator is not functioning. Their task is to establish which ‘floor’ they have arrived at by counting a series of tape-presented tones. A *higher* score on this subtest indicates better performance. Elevator Counting (EC)measures sustained attention.

(3) *Elevator Counting with Distraction*: As in the previous task, while imagining they are in an elevator, participants have to count the low tones they hear, while at the same time ignoring any high tones. A *higher* score indicates better performance. Elevator Counting with Distraction (ECWD) taps into auditory selective attention and also draws upon auditory-verbal working memory.

(4) *Visual Elevator timing score*: This is a self-paced task where participants count up and down as they follow a series of visually presented ‘floors’ in the elevator. The final score is the time-per-switch estimate which is the average time one takes to perform a switch (i.e., to go up and down) for correct responses. A *lower* time-per-switch score indicates better performance. Visual Elevator (VE) measures attentional switching.

(5) *Elevator Counting with Reversal*: This test is similar to that of the visual elevator subtest, except that it is presented to participants at a fixed speed on an audio tape. A *higher* score on this subtest indicates better performance. Elevator Counting with Reversal (ER) measures attentional switching.

(6) *Telephone Search*: Participants look for key symbols while searching for plumbers, restaurants or hotels (depending on test variant) in this simulated telephone directory. As here the final score is the time per target estimate, a *lower* score indicates better performance. Telephone Search (TS) measures visual selective attention.

(7) *Telephone Search While Counting Dual Task Decrement*: Here participants search in the telephone directory, while simultaneously counting strings of tones presented by a tape recorder. A ‘Dual Task Decrement’ is derived from a time per-target score weighted for accuracy of tone-counting and subtracted from the score of the Telephone Search subtest. Here a *lower* score indicates that there is less difference in performance between the single (subtest 6) and the dual task (subtest 7) and therefore it represents a better performance. Telephone Search While Counting Dual Task Decrement (DTD) measures divided attention.

(8) *Lottery*: Participants’ task is to spot all winning numbers in a lottery list, which end in a particular number (e.g., ‘55’, ‘33’ or ‘88’ depending on test variant). They must listen to a 10-minute series of tape-presented numbers of the form ‘BC143’, ‘LF488’ and so forth. The task is to write down the two letters of all lottery numbers that end in the numbers of interest (e.g., ‘55’, ‘33’ or ‘88’ depending on test variant). There are a total of 10 letter pairs in the 10-minute sample. A *higher* score represents better performance. Lottery (L) measures sustained attention.

# 2.3 Design and Procedure

The full version of TEA was administered to all participants in the present research as none suffered from a stroke or a head injury (Robertson et al., 1994). As performance on TEA is sensitive to the participants’ level of vision and hearing abilities, it was also ensured that all participants had normal hearing and normal or corrected to normal vision. Furthermore, all three variants of TEA were used in the present study, so that an equal number of PWS and PWNS were assigned to the same test variant (See Section 2.1).

The study was done by a qualified psychologist (SD; the first author) in a quiet cubicle either at UCL, London or UOS, Ipswich depending on the location of the participant. A 5-minute long speech sample of all participants in the PWS group was collected at the end of the testing session. Demographics were also collected from each participant. No-one else was present during the testing. The duration of the experimental session was between 1.5 and 2 hours.

# 3.0 Results

# 3.1 Conceptual rationale for using raw scores in the present study

All TEA subtests have been found to be sensitive to age differences (Robertson et al., 1994, 1996; Chan et al.2002 in the Cantonese version). Thus, in the official TEA manual participants were divided into four age groups (18-34; 35-49; 50-64; 65-80) after which their raw scores for each TEA subtest were transformed into normalized standard scores, labeled age-scaled scores (Robertson et al., 1994). However, in the present study both the PWS and the PWNS group have been sampled from the non-clinical population. Hence, more subtle differences are expected between these as compared to when a clinical population is examined (e.g., patients with a head injury, Bate, 2001; Chen et al., 2013; ADHD individuals; Hood, Baird, Rankin & Isaacs, 2005; Manly et al., 2001). Therefore, to maximise variability of scores wedecided to rely on the raw scores of the observed data for each subtest, while controlling for age group effects by entering age as a covariate (See Davies & Gavin, 1999).

# 3.2 The type of TEA variant used produced no significant effects

First, it was determined that the type of the administered TEA test variant (i.e., A, B or C) did not produce significant effects on the test results. Data were submitted into two mixed MANCOVAs where test form (A, B, C) was entered as a between-participants factor, the within-participants factor was attentional score which had 7 levels (these were all TEA subtests, excluding those that produced a ceiling effect[[9]](#endnote-10), See Table 1 and Section 3.2 for more details), while participants’ actual age was entered as a continuous covariate. The results revealed that first the Box’s M test statistic of 94.64 was associated with a *p* = .107 which confirmed that the covariance matrices across the two test groups were equal and that therefore this assumption to proceed with a MANCOVA analyses, was met. Further, there was no significant main effect of type of test variant (λ = .641, *F* (14, 80) = 1.42, *p* = .160, η2p = .199), neither did type of test variant interact with attentional score (λ = .650, *F* (12, 82) = 1.64, *p* = .100, η2p = .194).

# 3.3 Main analyses of TEA performance

As no outliers were identified, all data were used in the present analyses, apart from data coming from the subtests Elevator Counting and Lottery as these produced ceiling effects in both groups (See Table 1). The latter is a common finding in previous research (Robertson et al., 1994; Chan, Lai & Robertson, 2006; Chen et al., 2013). This left a total of 7 TEA subtest measures to be entered into further analyses. These were: Map Search 1 min (MS1), Map Search 2 min (MS2); Elevator Counting with Distraction (ECWD); Visual Elevator timing score (VE); Elevator with Reversal (ER); Telephone Search (TS) and Telephone Search while Counting Dual Task Decrement (DTD).

Data were submitted into a mixed MANCOVA where Test group (PWS, PWNS) was entered as a between-participants factor, the within-participants factor was Attentional score which consisted of the 7 TEA constructs, listed above, while participants’ actual age was entered as a covariate. First, the Box’s M test statistic of 42.2 was associated with a *p =* .154 which confirmed that the covariance matrices across the two test groups were equal and that therefore this assumption to proceed with a MANCOVA analysis, was met. The main effect of attentional score was significant (λ = .939, *F* (6, 42) = 107, *p =* .001, η2p= .939), suggesting that there was a difference between participants’ performance between the different TEA subtests. Importantly a significant Test group x Attentional score interaction emerged (λ = .289, *F* (6, 42) = 2.85, *p =* .020, η2p= .289). Furthermore, participants’ age strongly correlated with performance on 5 out of the 7 TEA subtests (MS1: *r* (48) = -.507, *p* = .001; MS2: *r* (48) = -.571, *p* = .001; ER: *r* (48) = -.434, *p* = .002; TS: *r* (48) = .362, *p* = .010; DTD: *r* (48) = .391, *p* = .005), suggesting that participants’ actual age has been correctly entered as a covariate in the analysis. Moreover, the latter was further confirmed by the identified significant effect of age on attentional score (*F* (1, 47) = 30.9, *p =* .001, η2p= .397). Finally, the analysis yielded no significant main effect of Test group (*p* = .178).

The simple main effects of the observed Test group x Attentional score interaction were examined via a series of 7 planned two-sided pairwise comparisons, corresponding to the number of subtests included in this analysis. Based on other authors (e.g., Bate et al., 2001) we kept α uncorrected (α = 0.05) when making comparisons between the PWS and the PWNS group to avoid committing a Type II error. Two of these comparisons were both significant at the 3% level. These were Map Search 1 (*F* (1, 47) = 4.83, *p =* .033, η2p= .093; PWS: *M* = 30.8; *SD* = 9.27; PWNS: *M* = 36.3; *SD* = 7.85) and the Dual Task Decrement (*F* (1, 47) = 5.23, *p* = .030, η2p= .100; PWS: *M* = 1.21; *SD* = 1.08; PWNS: *M* = 0.580; *SD* = 0.790). However, despite non-significant at α >.05, 3 of the other comparisons were associated with a Cohen’s *d* > .05, indicating medium effect size (ECWD: *d =* .531; VE: *d =* .557 and ER: *d =* .572). Refer to Table 2 for all comparisons.

Finally, the significant correlations between the TEA subtests, identified in the present data, are presented in Table 3.

# 3.4 Speech sample analysis and performance on TEA

A speech sample analysis on the 5-min speech sample collected from all participants in the PWS group was performed. Speech samples from 24 participants were analysed as one sample had been damaged during recording.

The SLD analysis was performed by an experienced researcher in the field of stuttering (the second author). Where necessary, the audio files were converted to .wav format and imported into Speech Filing System (SFS; Huckvale, 2013) software. The number of syllables analysed in each sample ranged from 184 syllables to 643 syllables with a mean of 560 syllables (*SD =* 114). The percentage of SLDs in the sample ranged from 1.80% to 22.3% with a mean of 6.20% (*SD =* 4.55; Table 4). Severity level categorization is based on Ryan (1974)’s Fluency Rating Scale. We performed Pearson correlational analyses between the participants’ percentage of SLDs and each of the 7 TEA subtest measures. Two of these analyses reached statistical significance. The analyses revealed significant negative associations between stuttering severity and performance on MS1 *r* (22) = -.496, *p =* .014, as well as between stuttering severity and performance on MS2 *r* (22) = -.470, *p* = .021. Neither of the other 5 tests yielded a significant correlation between participants’ percentage of SLDs and performance on TEA subtest (ECWD: *r* (22) = -.113 *p =* .598; VE: *r* (22) = .011, *p* = .961; ER: *r* (22) = -.036, *p =* .867; TS: *r* (22) = .198, *p* = .353; DTD: *r* (22) = .133, *p* = .534).

# 4.0 Discussion

By using one of the most complete tests of attentional ability, the present study examined whether PWS and PWNS differ in terms of their performance on a variety of tests, designed to pose differential demands on sustained attention, selective attention, attentional switching and divided attention. Significant differences in performance between the two groups were identified on two TEA subtests – the Map Search 1(MS1) and the Dual Task Decrement (DTD), measuring visual selective attention and divided attention, respectively. Furthermore, despite non-significant, three of the other comparisons, tapping into auditory selective attention and attentional switching, respectively reached a medium effect size. Our results also revealed that stuttering severity was negatively associated with a good performance on both Map Search 1(MS1) and Map Search 2(MS2). Finally, there was no difference in performance as a function of which test variant was administered.

**4.1 Interpretation of the present results**

Two of our comparisons reached statistical significance. On first place, the PWS group identified significantly fewer target symbols for 1 min as opposed to healthy controls (MS1). This is indicative of a poorer selective attentional ability in the visual domain – PWS experienced greater difficulty prioritizing the information of interest (i.e., the target symbol, a knife and a fork) while ignoring any irrelevant symbols on the map. Moreover, although a significant difference between the two groups only emerged in the first part of the task (MS1), performance on both MS1 and MS2 negatively correlated with stuttering severity. This result suggested that greater stuttering severity was associated with poorer performance on tasks, requiring visual selection, even when no detectable difference between the stuttering and the healthy comparisons group emerged (as on MS2). Speculatively, the improvement in performance of the PWS on MS2 (compared to MS1) might be due to learning effects (the two tasks were identical). Therefore, this could hint to a less efficient selective attentional ability in PWS; in other words, as compared to PWNS, the PWS group appeared to need more time to adapt to the task and start performing optimally. These findings are in line with previous studies, examining the perceptual and visuomotor abilities of PWS. For example, in a series of tasks measuring visuomotor performance, Jones, White, Lawson and Anderson (2002) reported evidence for impaired visual perception, less accurate visual tracking and overall longer RTs in their sample of adults who stutter. For instance, one task in which PWS were significantly slower than healthy comparisons was the ballistic movement task which required an arm movement in response to a non-target stimulus (accuracy was not recorded; Jones et al., 2002). Stuttering severity also significantly correlated with poorer perception of dynamic objects and longer RTs (Jones et al., 2002). The latter is of a particular interest for the interpretation of performance on the current Map Search task – as this task was timed, one’s target detection speed is likely to be a leading factor for successful performance. Therefore if one takes longer to identify targets, this would definitely result in poorer performance which is indeed what was observed in the present study. Others have also reported similar results for PWS, especially when targets were presented to the right (Forster & Webster, 1991). Finally, despite non-significant, there was a trend for PWS to achieve a lower score on the ECWD subtest, which taps into auditory selective attention (See Table 2). These together are indicative of stuttering being associated with poorer selective attention ability.

Our second statistically significant finding was that PWS had an overall higher Dual task Decrement, as compared to PWNS. This result suggested that this group performed worse than fluent speakers when they had to search for target symbols whilst simple tone counting in parallel. The latter is in line with previous studies examining dual tasking in the stuttering population where the introduction of a secondary task was found to impede performance and/or to negatively affect fluency (e.g., Bosshardt, 1999, 2002, 2006; Smits-Bandstra & De Nil, 2009; Smits-Bandstra, De Nil & Rochon, 2006; Saltuklaroglu et al., 2009; Maxfield et al., 2010, 2012, and 2016). In support, even carrying out a simple mental calculation (Bosshardt, 1999) or any other form of subvocal rehearsal (i.e., silent reading or word repetition; Bosshardt & Fransen, 1996; Bosshardt, 2002) have been reported to impede performance in this group. Importantly, performance has been discovered to suffer even when the two tasks were non-verbal, such as finger tapping and a colour recognition task (e.g., Smits-Bandstra et al., 2006). More in detail, Smits-Bandstra et al. (2006) found that despite a repeated practice of finger tapping sequencing, PWS failed to reach the level of automaticity on this task, compared to the PWNS group. The researchers speculated that ‘performing even a single task for PWS required the attentional resources that would normally be reserved for dual tasks in PNS [persons who do not stutter]’ (Smits-Bandstra et al., 2006, p.37). The latter has implications for the interpretation of the current findings as while the present counting task had a phonological element[[10]](#endnote-11), such simple counting is also known to be highly automised (Hitch, 1978; Logie & Baddeley, 1987). Therefore, our second finding is in line with previous studies reporting impeded dual task performance in PWS. However, unlike our results on selective attention, we did not identify an association between performance on the DTD and stuttering severity. It is unclear how this result ties with previous research, as dual task studies do not generally examine this correlation in PWS (Bosshardt, 1999, 2002, 2006; Maxfield et al., 2010, 2012, 2016; Smits-Bandstra et al., 2006).

Thirdly, our results also revealed a trend in the predicted direction for the VE and ER TEA subtests which both measure attentional switching. Given the low power associated with the present sample size, consistent with Sullivan and Feinn (2012) and Coe (2002) we submit that our effect sizes are meaningful, even at α > .05. As could be seen from Table 2, despite failing to reach statistical significance, these comparisons were both associated with a medium effect size, alluding to an overall more problematic attentional switching in our PWS group. This identified trend in our results is consistent with evidence that PWS are more prone to attentional inertia, suggesting that they cannot easily adjust their habitual responding to a situation, given the input of new information, nor can they easily switch between concepts and tasks. To our knowledge, there have been few studies investigating the attentional switching abilities in the adult stuttering population. However, support could be found in some older research examining cognitive flexibility in stuttering. For example, Wingate (1966) demonstrated that PWS had a difficulty switching between the generation of antonyms and synonyms for a given word and therefore suggested that PWS lacked flexibility ‘in mental tests requiring a rapid and contiguous change of set’ (p. 626), whereas Eisenson and Pastel (1936, p. 631) reported evidence that ‘stutterers perseverate more than non-stutterers’. Poorer attentional shifting has also been reported in children’s studies (Eggers et al., 2010, 2012, however, see Nejati, Pouretemad & Bahrami, 2013). We can only speculate about the reasons why these comparisons did not reach statistical significance.

The present results fit well with models predicting and advocating less proficient performance on attention-taxing tasks in people who stutter, such as the Demands and Capacities model (Adams, 1990; Andrews et al., 1983; Starkweather, 1987; Starkweather & Givens-Ackerman, 1997) and Eggers et al.’ (2012, 2013) of a weaker inhibitory control associated with stuttering. Importantly, while the Demands and Capacities model advocates that stuttering is due to an imbalance between a number of self-imposing and external demands that come with speaking and one’s capacity to produce speech, Eggers et al. (2012, 2013) suggested that instead, stuttering might be due to inefficient inhibitory control in this group that it negatively affects linguistic processing and error monitoring. As stated in the Introduction, it was beyond the scope of the present paper to examine which of the models accounts better for the identified association between stuttering and poorer attentional performance, however, as both predict PWS to be at a disadvantage in their performance on attentional tasks, these both fit with the present findings.

**4.2 Research implications**

Finally, the current research has important theoretical and practical implications. In the first instance, this is the first study to administer the Test of Everyday Attention to examine attentional ability in the stuttering population. As outlined in the Introduction, we wanted to use a more ecologically valid approach, designed on the basis of a theoretical model of attention (Posner & Peterson, 1990) as opposed to testing performance on a single attentional ability as carried out in previous research (e.g., Eggers et al., 2013; Bosshardt, et al., 1999, 2002, Maxfield et al., 2010, 2012, 2016). This allowed us to examine how PWS perform on tasks, tapping into several attentional systems in parallel, as well to detect any associations between them. To the authors’ knowledge, only one other study has previously administered a similar theory-based, full attentional battery to CWS (the ANT; Eggers et al., 2012; See Section 4.3). We believe this is an important implication as measures of attentional ability have not always conformed to particular theoretical models of attention (Joyce & Hrin, 2015; Bate et al., 2001).

The present results also have practical implications for informing future interventions in stuttering. Without trying to provide an answer to what comes first (whether stuttering compromises one’s attentional ability or vice versa), we suggest that PWS might benefit from a therapy aimed at strengthening one’s cognitive control. From a selective attentional perspective, such training could potentially allow individuals to more successfully focus their attention on relevant information, such as the meaning of what they would like to communicate and less on distractors that could impede speaking (i.e., the dysfluencies in their speech, the reactions and facial expression of their listener). Additionally, enhanced divided and attentional switching abilities may result in less strain on the system, due to a reduced mental rigidity and an improved ability to handle the execution of tasks in parallel, this could in turn free more cognitive resources to allow easier, more fluent speech. In support, directing attention away from one’s speech (i.e., and thus allowing one to simply engage in speaking without focusing on distracting information) has been shown to increase fluency in both children (Ntourou, Conture & Walden, 2013) and adults who stutter (Arends, Povel, & Kolk, 1988). Ntourou et al. (2013; p. 270) concluded that ‘diverting attention from a non-verbal task allows …[CWS] to devote greater attentional resources to speech-language planning and production processes and in turn helps them be more fluent’. However, such a strategy is likely to only have a temporary effect. Therefore, we suggest that the benefits of specially-devised attentional training programs should be explored as these are aimed at improving one’s cognitive control, which should have a more lasting positive effect on fluency. Only one such intervention has been devised and the outcomes of it reported (Nejati et al., 2013). 15 pre-teens who stutter and 15 matched healthy comparisons (aged between 10 and 14 years) took part in the program called Neurocognitive Joyful Attentive Training Intervention (NEJATI) that involved selective attention and inhibitory control training that participants received 3 times per week for 1 hour over a 4-week period. The results revealed a significant improvement in performance on all tasks used to evaluate executive function before and after treatment, as well as a significant reduction in stuttering severity (Nejati et al., 2013)*.* Investigations like the present study indicate that more research is needed on this line, as there are still many questions to be answered regarding the efficiency of such attentional interventions. Some of these concern the exact mechanism through which NEJATI improved fluency, how lasting the changes are and whether such treatment would also benefit adults who stutter.

Finally, the present work also has methodological implications. We validated that the three TEA parallel variants are equivalent and could be used interchangeably. This is in line with how other authors have used TEA when performance was tested on a single occasion. For example, Chan et al. (2002) and Chen et al. (2013) administered two TEA parallel forms to their participants, using different combinations (AB, BC or CA; Chen et al., 2013) and (AB, BA, Chan et al., 2002) as opposed to assigning them in order, which resulted in a very similar performance on all subtests, regardless of which test variants were used and in what order. Moreover, a change in performance due to test form is expected only if an individual is tested on three different occasions where a different test variant is used on each occasion because of learning effects (Robertson et al., 1994). This finding is a methodological contribution as to our knowledge this question was not specifically explored in previous research.

**4.3 TEA and the ANT**

This section briefly compares TEA to the other attentional assessment battery we mention in this paper – the Attention Network Test (ANT; Fan et al., 2002) as this might be useful for practitioners and researchers. First, there are a number of similarities between the two tests. For example, both have been based on the same model of attention – Posner and Peterson (1990)’s Attention Network framework that distinguishes between three separate attentional systems (i.e., networks). According to Posner and Peterson (1990), these are alerting (sustained attention), executive control (selective attention) and attentional orienting, where each is associated with discrete anatomical areas of the brain. Furthermore, both tests have a good validity and reliability and have an adult and children’s version (Rueda et al., 2004; Manly et al., 1999, respectively). Finally, both have been successfully used for the assessment of clinical populations (e.g., Wang et al., 2005; Bate, 2001), as well as healthy participants and thus, have implications for both clinical and research assessment of attention. However, importantly, the ANT and TEA also differ on several parameters. For instance, while the ANT evaluates all three systems in Posner and Peterson (1990)’s model, TEA has been devised to measure aspects of only selective and sustained attention but not attentional orienting[[11]](#endnote-12). Moreover, TEA tasks encompass both the auditory and visual domain, while the ANT has a visual (vANT; Fan et al., 2002) and a separate, auditory version (aANT; Roberts, Summerfield & Hall, 2006). Objectively, TEA uses more ecologically valid stimuli, devised to be as close as possible to tasks, which one encounters in their everyday life (e.g. searching maps, telephone directories, listening to lottery results). In contrast, the ANT relies on more schematic temporal and spatial stimuli (vANT: fixation cross, asterisks and black arrows; aANT: fixation tone, noise bursts and words spoken on a high or low pitch; Roberts et al., 2006). In terms of administration, TEA is a paper and pen test, while the ANT is computerized; while both of these have their pros and cons, it is an advantage that both methods exist as in some cases one type of administration might be found more suitable than the other. Finally, the ANT is objectively shorter to administer as it takes about 30 min, while an assessment with TEA lasts between 1.5 and 2 hours.

In conclusion, both tests are widely used in the literature and represent a valid and reliable measure of attentional ability. The superiority of one over the other is individual to the sample and research question of interest.

# 4.4 Conclusion

The present study demonstrated that adults who stutter and fluent, matched healthy comparisons significantly differ in their selective and divided attentional abilities. In addition, the results also revealed a trend for PWS to overall perform more poorly on tasks measuring attentional switching. Furthermore, a significant negative association emerged between stuttering severity and a good performance on one of the visual selective attention tasks. Our results are consistent with the growing literature suggesting that adults and children who stutter perform poorly on a number of attentional measures. It also ties well with theoretical models identifying speech production as particularly attention-demanding in stuttering or approaches placing attentional dysfunction at the heart of the condition. The present research provides support for the recent approach to stuttering interventions, aimed at improving fluency by training better attentional ability.

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**6.0 Disclosure statement**

No potential conflict of interest was reported by the authors.

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 **Endnotes**

1. Maxfield, Huffman, Frisch & Hinckley, 2010; Maxfield, Pizon-Moore, Frisch & Constantine, 2012; Maxfield, Morris, Frisch, Morphew & Constantine, 2015; Maxfield et al., 2016. [↑](#endnote-ref-2)
2. Some tests to study inhibitory control are go/no-go tasks, flanker tasks, delay gratification paradigms, the Simon effect (See Diamond, 2013 for a review). [↑](#endnote-ref-3)
3. ERP stands for event-related potential (ERP). ERPs are used to measure brain activity in response to different events (these could be sensory, cognitive, motor, etc.). [↑](#endnote-ref-4)
4. One interpretation is that semantic interference made it more difficult for AWS to encode and/or maintain target words in short-term memory until standard tones were verified at the Long Tone SOA. [↑](#endnote-ref-5)
5. IC is effectively the opposite process of selecting task-relevant information (See Zanto & Gazzaley, 2017 for a discussion). [↑](#endnote-ref-6)
6. Attentional switching stands for another aspect of the attentional system that requires cognitive control. It stands for how quickly one can switch between tasks and apply new rules. The latter is often used as an index of mental flexibility (Kreutzfeldt, Stephan, Sturm, Willmes & Koch, 2015). [↑](#endnote-ref-7)
7. Posner and Peterson (1990) identify three separate attentional systems – selective attention, sustained attention and attentional orienting. TEA measures selective and sustained attention but not attentional orienting (Robertson et al., 1994). [↑](#endnote-ref-8)
8. The present study included more male participants in line with the gender bias in stuttering. The disorder is 2.4 to 5.33 times more prevalent in males (Andrews & Harris, 1964; Howell, Davis & Williams, 2008). [↑](#endnote-ref-9)
9. These included 7 TEA subtests: Map Search 1 min (MS1), Map Search 2 min (MS2); Elevator Counting with Distraction (ECWD); Visual Elevator timing score (VE); Elevator with Reversal (ER); Telephone Search (TS); Telephone Search while Counting Dual Task Decrement (DTD). [↑](#endnote-ref-10)
10. It is likely that participants were subvocally repeating the tone count in memory. [↑](#endnote-ref-11)
11. Attentional orienting has not been included in TEA as it is difficult to assess with a paper and pen test, as explained in the TEA manual (Robertson et al., 1994). Attentional orienting has been defined as ‘the aligning of attention with a source of sensory input or an internal semantic structure stored in memory’ (Posner, 1980, p.4). [↑](#endnote-ref-12)