University of Reading

Phonological Encoding in Adults Who Clutter and Adults Who Stutter

PhD

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Declaration

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

The work presented in chapter six has been published.

Bretherton-Furness, J., Ward, D., & Saddy, D. (2016). Creating a non-word list to match 226 of the Snodgrass standardised picture set.

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Abstract

Background: Stuttering and cluttering are related but contrasting disorders of fluency. Whilst stuttering has received a great deal of attention in the research literature over the last 100 years, cluttering has remained relatively neglected. There is ongoing debate regarding whether there is a language/phonological component to cluttering or whether it is solely a motoric and/or rate-based disorder. The following thesis aims to investigate the phonological encoding skills of both adults who stutter (AWS) and adults who clutter (AWC) in contrast to fluent controls.

Method: Three groups were used, comprising 14 AWS, 14 AWC and 15 matched controls. A variety of phoneme monitoring and syllable detection tasks designed to eliminate possible motor influences were used.

Results: It was found that AWS and AWC performed in a similar manner; they were both less accurate in detecting phonemes in real words than controls and in detecting phonemes in silent picture naming. There were no differences (between AWS, AWC and controls), however, in syllable detection accuracy or in time taken to make judgments on monitoring for phonological differences, nor were there any differences in phoneme monitoring in non-words or in the accuracy of phoneme monitoring in silent reading.

Discussion: Findings lend some support to the notion that phonological encoding may be impaired in both AWS and AWC. Findings are discussed in relation to phonological theories such as the covert repair hypothesis. Alternative interpretations, wider implications and the impact on participants accuracy of factors such as the type of phoneme being monitored for and the length of the word used are all discussed in greater depth.

1 CHAPTER ONE

1.1 Introduction

Fluency is the ability to express oneself in an articulate, clear and easy manner (Stevenson, 2010), but no person is truly fluent 100% of the time. We all have moments when we must revise sentences, when we use fillers like ‘umm’ and ‘err’ or when we repeat what we have just said. For those who have a fluency disorder, the ability to be fluent is interrupted to the extent that it negatively impacts upon their lives. Speaking to new people, speaking on the phone or attending an interview can all create high levels of anxiety and a desire to avoid these situations. The research project that follows focuses on two disorders of fluency: stuttering and cluttering. Both of these disorders interrupt a person’s ability to speak fluently, but they are very different disorders affecting speakers in a number of different ways.

1.1.1 Definitions

1.1.1.1 Stuttering

The World Health Organisation in their ICD-10 defines stuttering as:

> *Speech that is characterized by frequent repetition or prolongation of sounds or syllables or words, or by frequent hesitations or pauses that disrupt the rhythmic flow of speech. It should be classified as a disorder only if its severity is such as to markedly disturb the fluency of speech. (World Health organisation, ICD-10 2015a)*

It is apparent from this definition that the ICD-10 describes only what can be overtly heard when listening to someone who has a stutter, e.g. the repetition of sounds, syllables, words or even short phrases, or the prolongation of sounds and hesitations. The ICD-10 does not explicitly mention blocking, which occurs when the vocal tract closes and tension may be observed as the person cannot continue speaking. It also fails to mention word avoidance, covert stuttering or the psychological impact of stuttering. The DSM-5 also offers diagnostics criteria and now uses the term; ‘*Childhood-Onset Fluency Disorder*’, describing stuttering as:

> *Disturbances in the normal fluency and time patterning of speech that are inappropriate for the individual’s age and language skills, persist over time and are characterized by frequent and marked occurrences of one (or more) of the following*
>
> 1. *Sound and syllable repetitions*

2. *Sound prolongations of consonants as well as vowels*
3. *Broken words (e.g. pauses within a word)*
4. *Audible or silent blocking (filled or unfilled pauses in speech)*
5. *Circumlocutions (word substitutions to avoid problematic words)*
6. *Words produced with an excess of physical tension*
7. *Monosyllabic whole-word repetitions (e.g. "I-I-I-I see him")*

The disturbance causes anxiety about speaking or limitations in effective communication, social participation, or academic or occupational performance, individually or in any combination.

The onset of symptoms is in the early developmental period.

The disturbance is not attributed to a speech-motor or sensory deficit, dysfluency associated with neurological insult (e.g. stroke, tumour, trauma), or another medical condition and is not better explained by another mental disorder (APA, 2013, DSM-5).

This comprehensive description goes further than the ICD-10 above and describes the anxiety and avoidance that may be seen as well as when the disorder may begin.

1.1.1.2 Cluttering

Cluttering has received far less attention than stuttering, and until recently arguments were still made that the disorder is not one that stands alone in its own right but is better described as a group of symptoms from co-morbid disorders (Curlee, 1996). In fact, the DSM-5 does not acknowledge the disorder at all. There is also a great deal of disagreement within the literature regarding the core characteristics of cluttering. The World Health Organisation in the ICD-10 (2015) describes cluttering as being characterised by:

F98.6 A rapid rate of speech with breakdown in fluency, but no repetitions or hesitations, of a severity to give rise to diminished speech intelligibility. Speech is erratic and dysrhythmic, with rapid jerky spurts that usually involve faulty phrasing patterns. (World Health Organisation, ICD-10 2e-Volume 1, 2015b p442.)

St Louis and Schulte (2011) go into more detail and provide the lowest common denominator definition (LCD definition), which they believe focuses on what is core to the disorder and present in all of those who clutter:

"…a disorder wherein segments of conversation in the speaker's native language typically are perceived as too fast, too irregular, or both. The segments of rapid and/or irregular speech rate must further be accompanied by one or more of the following: (a) excessive 'normal' disfluencies; (b) excessive collapsing or deletion of syllables; and/or abnormal pauses, syllable stress, or speech rhythm." (St. Louis and Schulte, 2011, pp 241-242).

This is the definition now used by clinicians when diagnosing cluttering and by researchers when recruiting participants who clutter. The LCD definition requires that the person who clutters has speech that is *perceived* as too fast and/or too irregular. This means that a syllable count alone may not identify cluttering, but it is the perception, when listening, that a person's speech is too fast for them to be clear and fluent. This must also be accompanied by: excessive normal disfluencies or excessive collapsing, deletion of syllables and/or abnormal pauses, syllable stress or speech rhythm. Normal disfluencies are described by Myers, Bakker, St Louis and Raphael (2012) as including: interjections, revisions, incomplete utterances, whole word repetitions and phrase repetitions.

Those who clutter often have poor awareness of their dysfluency (Daly & Burnett, 1996; Daly & Cantrell, 2006; St Louis, 1992) but may become aware of it when listeners regularly ask them to repeat themselves or misunderstand what they say. They are often able to maintain fluency for short periods when they concentrate on their speech and work to keep their speech rate slow. This is in contrast to those who stutter, who can be more dysfluent if they feel under pressure to monitor their own speech (Guitar, 2013; Ward, 2006).

1.1.2 Epidemiology of stuttering and cluttering

Yairi and Ambrose (2013) reviewed what we know of the epidemiology of stuttering and describe how most studies find that stuttering begins in early childhood and not later than age nine. They do, however, report that there is disagreement in the literature regarding the mean age of onset. Yairi and Ambrose (2013) describe the rate of stuttering in males and females of pre-school age as being comparable. It is only as children get older that the ratio of males to females who stutter begins to widen, with more males than females stuttering (Yairi & Ambrose, 2013). Bloodstein (1995) states that in the adult population, the ratio is 4:1 of males to females who stutter demonstrating that more females than males recover. This has also been found by others, including Ambrose, Cox and Yairi (1997). Ambrose and Yairi (1999) report results from a longitudinal study finding that around 74% of the 84 children followed between age four and eight recovered fully, while 26% continued to stutter. There are reported cases of spontaneous recovery in adulthood (Finn, 1996; Quarrington, 1977; Shearer & Williams, 1965; Wingate, 1964), although most clinicians and researchers would agree that true recovery in adulthood is unlikely. It is more likely that the person who stutters has developed coping strategies, either through therapy or through environmental changes, which allow their capacity for fluent speech not to be outweighed by the demands placed upon them. Anderson and Felsenfeld (2003) interviewed six adults describing recovery from stuttering, who stated the following reasons for recovery: increased confidence, increased motivation and/or direct speech changes. It may be that these factors driving increased fluency mean increased fluency alone and not true recovery. The authors do state that several participants reported the need for increased vigilance to maintain fluency. This suggests that recovery has not occurred and that, as described above, 'late recovery' may simply be effective use of coping and compensatory strategies.

As with stuttering, cluttering is also thought to develop in the preschool years around three-four years of age, but there is very little published data to corroborate this (Ward, 2006). Arnold (1960), and St Louis and Hinzman (1988), report that, like stuttering, cluttering occurs more frequently in males than females with a ratio of 4:1. There are no reports in the literature of cluttering resolving at any age, therefore, the ratio of 4:1 in cluttering is thought to persist into adulthood. This is unlike stuttering, which resolves in around three quarters of cases (Ambrose & Yairi, 1999; Yairi & Ambrose, 2013). Another stark contrast between the two disorders is that those who clutter often have co-morbid disorders including attention deficit and hyperactivity disorder, learning disabilities including autism and Down's syndrome, articulation disorders, language disorders and stuttering (St Louis, Myers, Bakker & Raphael, 2007). Those who stutter do not show the same degree of co-morbidity with these other disorders.

1.1.3 Causes of Stuttering and Cluttering

There are numerous theories as to why stuttering may develop: genetic, motoric, linguistic, neurological, psychological, auditory processing and environmental phenomena have all been suggested as causes. There are also a variety of theories as to the aetiology of cluttering, although these are less well-researched, and many remain theories without data-driven evidence to support them.

1.1.3.1 Genetic

Both stuttering and cluttering have been suggested to run in families, with Riaz et al. (2005) stating that as many as 50% of those who stutter have a family history of the disorder. Kraft and Yairi (2012) in their review of the genetic base of stuttering report that genetic linkage studies are needed to investigate what we now know is a strong genetic component in stuttering. Family incidence, twin and adoption studies have all been used to examine the possibility of stuttering having a genetic component. We know less regarding the exact figures for a family link within cluttering but it is widely accepted that it does run in families (Drayna, 2011).

Raza, Riazuddin and Drayna (2010) conducted a genome-wide linkage study with a family from Pakistan in which a significant linkage was found on chromosome 3q13.2-3q13.33. The researchers collected blood and speech samples from all available members of a consanguineous family. Those who were identified by the Stuttering Severity Instrument 3rd edition (SSI-3) as having a stutter were over the age of eight years old and had stuttered for at least six months. The authors do not go on to suggest what this link may mean for those who stutter, but this study does suggest that an abnormality in a chromosome may be seen among family members who stutter.

Chromosome three is not the only one that has been implicated in stuttering; Kang and Drayna (2011) have also investigated chromosome 12. Forty Pakistani families were studied to investigate the possibility of there being a causative gene for stuttering. It was found that there were mutations within chromosome 12 on genes GNPTAB, GNPTG and NAGPA. The authors do highlight that it is important not to overstate these findings and that whilst abnormalities have been found, these can be identified in less than 10% of the cases in question. The authors conclude that further linkage studies are needed to make clear exactly which genes on which chromosomes can be implicated in stuttering.

1.1.3.2 Neurological Deficits

Packman, Code and Onslow (2007) stated that fMRI data from the past 10-15 years has demonstrated that adults who stutter have deviant brain activity and consistently found that there is increased activity in motor centres in the non-dominant hemisphere of the brain (Brown et al., 2005). De Nil, Kroll and Houle (2001) state that there were elevated levels of cerebellar activity prior to treatment for stuttering but that this decreased to the same level as controls post-treatment. Anatomical differences have also been suggested; e.g. by Sommer, Koch, Paulus, Weiller, and Buchel (2002), who state that there are disconnections between the white matter in the brain and the motor and premotor areas. The data we have from adults who stutter suggest that there are subtle differences in the brain function and anatomy of those who stutter and those who do not. There is far less known regarding cluttering, and much of what has been reported is speculation. Alm (2011) implicates the basal ganglia as being central to the difficulties seen in cluttering. He states that in those who clutter, the basal ganglia may not be providing the correct timing cues for speech – so not acting as an appropriate monitor – with the result being an accelerated rate of speech of which the speaker is not aware. This is largely speculative at this stage; however, recent work by Ward, Connally, Pliastsikas, Bretherton-Furness and Watkins (2015) does appear to corroborate Alm's (2011) theory, demonstrating over-activation of areas associated with motor planning and execution.

1.1.3.3 Auditory Processing Deficits

Deficits in auditory processing have been suggested, as those who stutter are often fluent when they read along with another person, when they sing or when they speak along to a given beat e.g. a metronome (Andrews et al., 1983; Bloodstein, 1995; Erber, 1975; Kalinowski, Armson, Stuart & Gracco 1993; Kalinowski, Stuart, Sark & Armson, 1996; Stuart, Kalinowski & Rastatter, 1997). Stuttering is also under-represented in the deaf population (Backus, 1938; Brown Sambrooks & MacCulloch, 1975; Curry & Gregory, 1969; Harms & Malone, 1939), further suggesting that there may be an audiological deficit amongst those who stutter. Fluency enhancement such as choral reading has not been investigated to the same degree in the cluttering population; however, given that those who clutter are poor at monitoring their own speech, it could be that this is due to a deficit in auditory processing. Daly (1992) recommended an altered version of Shames and Florance's (1986) Stutter-Free Speech Program in treating those who clutter. In their original program, Shames and Florance (1986) used delayed auditory feedback (DAF) in an operant conditioning manner. By using token reinforcement with DAF and continuous voicing they helped those who stutter to control their rate of speech, and they were able to improve fluency. Daly (1992) took this idea and applied it to those who clutter, using DAF in a similar way to control rate of speech. St Louis et al. (1996) used DAF with two children who cluttered to investigate if their fluency could be improved. They found that it was effective in helping one child reduce his speech rate and organise his thought but not effective for the other. As the authors themselves state, it is not possible to draw conclusions from two case studies; however, DAF did reduce the rate of speech in one participant, so further work is warranted to establish if this treatment may be effective for some who clutter. Further investigation into DAF with those who clutter will also help to establish if they have an auditory processing deficit.

1.1.3.4 Motoric deficits

Stuttering has been associated with abnormalities in the timing of respiration, phonation and articulation (Peters, Hietkamp & Boves, 1995; Viswanath & Rosenfield, 2000; Zocchi et al. 1990) and thus is often described as being characterised by deficits in motor control. Therapeutic programs such as the McGuire program focus on such difficulties by altering breathing patterns. There is little empirical evidence to support this particular program, and it is not currently recognised by the Royal College of Speech and Language Therapists (RCSLT) as a legitimate therapeutic intervention. There are, however, many anecdotal reports of success. Non-speech motor activity has also been suggested to differ between those who stutter and fluent controls. Max (2004) reviewed literature regarding the non-speech oromotor movements of those who stutter and concluded that there are marked differences between those who stutter and those who are fluent. Observation of fine motor tasks such as finger-tapping has also shown differing characteristics between those who stutter and fluent controls. Max, Caruso and Gracco (2003) found that adults who stutter differ to fluent speakers in terms of peak velocity and movement duration when completing finger-tapping tasks. Data suggests that motoric differences between those who stutter and fluent controls may not be isolated to the speech and respiratory system. Less is known about cluttering; however, it is currently described as a rate-based disorder that implicates motoric control (St Louis and Schulte 2011). Cluttered speech is described as being motorically interrupted with regard to rate, rhythm and articulation. Characteristics such as imprecise articulation and rapid rate of speech have been likened to festinant type speech seen in some who have Parkinson’s disease (Ward 2011). Ward further speculated that the anticipatory phonemic errors sometimes seen in those who clutter implicate higher-order motor programming functions, similar to those seen in verbal dyspraxia. Currently, only anecdotal evidence exists of more general motoric difficulties in cluttering; e.g. Weiss (1964) and Ward (2006) describe those who clutter as having poor handwriting.

1.1.3.5 Linguistic Deficits

As stuttering typically develops at a time when language is developing rapidly, there have been suggestions that stuttering is caused by a compromised linguistic system. It has been suggested that structures with greater grammatical complexity result in more stuttering (Kadi-Hanifi & Howell, 1992; Logan & LaSalle, 1999; Yaruss, 1999). This data comes from studies with children, and any differences between fluent speakers and stutterers appear to disappear in adulthood. There have also been suggestions that those who stutter have difficulties accessing the words they need (Gregory & Hill, 1993; Packman, Onslow, Coombes & Goodwin, 2001; Wingate, 1988). This research was also conducted with children, and there is a lack of evidence or well-controlled studies to confirm that either children or adults who stutter have difficulties with lexical access. Bretherton-Furness and Ward (2012) reported preliminary data from adults who clutter, concluding that they appear to have lexical access difficulties and difficulties planning verbal output. Van Zaalen (2009); Van Zaalen, Wijnen and Dejonckere (2011a) suggest two groups of clutterers: those who have syntactic cluttering and those who have phonological cluttering. There is a lack of additional data, but a great deal of speculative data and data from clinical experience suggests that those who clutter do have difficulties accessing needed words. There have also been many suggestions that dysfluency is a result of poor or faulty phonological encoding (Howell, 2004; Packman, Code & Onslow, 2007; Perkins, Kent and Curlee, 1991; Postma & Kolk, 1993; Wingate, 1988). Such suggestions have not been made about those who clutter, as we currently have no data.

1.1.3.6 Psychological Causes

In the 1940s and 50s it was popular for stuttering to be considered a disorder caused by bad habits, poor parenting or an operant behaviour. Whilst these views are now considered outdated and lacking in empirical evidence, there is some merit in the idea that parents may unknowingly be exacerbating a child's dysfluency. Johnson, Boehmler and Dahlstrom (1959) described parents as over-diagnosing their children with stuttering and the child then picking up on these negative feelings, with the result that their speech became less fluent. These ideas have been translated into therapies that encourage parents to create a low-demand environment for their child so that there is no pressure on their speech. Such therapeutic interventions include parent-child interaction therapy in which parents are encouraged not to correct or focus on their child's speech (Millard, Edwards & Cook, 2009; Rustin, Cook, Botterill, Hughes & Kelman, 2001). Those who clutter have not been described as having an onset caused by psychological factors, but there is anecdotal evidence to suggest that the psychological impact of cluttering is greater than originally anticipated. It is well-documented that those who clutter have poor awareness of their speech (Weiss, 1964; Daly & Burnett, 1996; Ward 2006; St Louis & Schulte 2011); however, this does not mean they are unaware of negative reactions from listeners or are not intimidated by speaking situations. This evidence comes from the Second World Congress on cluttering, from anecdotal reports in therapy and from the raise of self-help groups (Scaler Scott & St Louis, 2011). Scaler Scott and St Louis (2011) write that online forums have become a popular place for those who clutter to discuss their speech and the difficulties they face. Difficulties discussed include: negative listener reactions, frequent misunderstandings and missing out on career progression. Whilst there may not be empirical evidence to substantiate these claims, it is imperative to bear in mind the impact a communication impairment has on the lives of those affected.

1.1.4 This Thesis

The literature review that follows examines the nature of both stuttering and cluttering, from the current definitions and agreed characteristics of both disorders through to the theories of their cause and the research which both supports and refutes them. The research conducted and described in this thesis focuses on both stuttering and cluttering, examining the speaker's phonological encoding ability using phoneme monitoring and syllable detection tasks.

2 CHAPTER TWO

2.1 Defining cluttering

2.1.1 Current definitions of cluttering

What we now consider cluttering has been identified in the literature as far back as 36AD (Weiss 1964). Despite this, it has remained a neglected area with the first volume of work dedicated to cluttering not being published until 1963, one year before Weiss published his seminal work. Weiss (1964) described cluttering as embodying a central language imbalance affecting all channels of communication. He described symptoms including: *excessive speed of speech, word finding difficulties, poor articulation, unorganised thinking processes, monotone speech, poor concentration, reading disorder such as dyslexia, poor handwriting, poor spoken grammar, poor awareness of their difficulties and restlessness*. Weiss's (1964) description of cluttering, whilst helpful, was not based on empirical data but rather on his personal experiences with those who clutter. For this reason, and because subsequent research has not supported all of these characteristics, the definition of what we consider cluttering has now changed.

The World Health Organisation now distinguishes between stuttering and cluttering and in the ICD-10 version: 2015 it is stated that stuttering is:

> "*Speech that is characterized by frequent repetition or prolongation of sounds or syllables or words, or by frequent hesitations or pauses that disrupt the rhythmic flow of speech. It should be classified as a disorder only if its severity is such as to markedly disturb the fluency of speech". (WHO 2015a ICD-10 F98.5)*

Whereas cluttering is defined as:

> "*A rapid rate of speech with breakdown in fluency, but no repetitions or hesitations, of a severity to give rise to diminished speech intelligibility. Speech is erratic and dysrhythmic, with rapid jerky spurts that usually involve faulty phrasing patterns". (WHO 2015b ICD-10 F98.6)*

This is in contrast to the DSM-5 (2013), which despite being advised by ASHA (the American Speech Language and Hearing Association) to include cluttering as a distinct disorder, has continued to exclude it and only gives diagnostic criteria for stuttering. It is apparent that continued work is needed to ensure that cluttering is a well-recognised disorder with clear and consistent diagnostic criteria.

Due to insufficient data to support the inclusion of all of the characteristics described by Weiss (1964), St Louis and Schulte (2011) do not include anything to implicate concentration, language skills, or difficulties with other modalities such as reading and writing in their definition of cluttering. The 'lowest common denominator model' or LCD definition (St Louis and Schulte 2011) characterises cluttering as:

> *"…a disorder wherein segments of conversation in the speaker's native language typically are perceived as too fast, too irregular, or both. The segments of rapid and/or irregular speech rate must further be accompanied by one or more of the following: (a) excessive 'normal' disfluencies; (b) excessive collapsing or deletion of syllables; and/or abnormal pauses, syllable stress, or speech rhythm." (St. Louis and Schulte, 2011, pp 241-242).*

This definition has allowed researchers and clinicians alike to ensure that diagnosing is done consistently and with everyone using the same criteria when selecting participants for research. Having a clear definition also allows those who clutter to identify their disorder. Indeed, many reported at the Second World Conference on Cluttering in Eindhoven (2014) that having a definition allows them to understand why their speech is unintelligible; it also allows them the opportunity to explain it to others so they might understand and appreciate their difficulties.

2.1.2 The lowest common denominator (LCD) definition of cluttering

St Louis and Schulte (2011) developed their working definition through a number of studies looking at people who were considered possible clutterers and comparing their speech to that of stutterers and fluent controls. They found that the group identified as clutterers had abnormally high levels of sentence and phrase repetitions, used less complex and less complete language (e.g. used fewer sentences containing both a noun phrase and a verb phrase), and used a rapid and irregular rate of speech with a high number of articulation errors (St Louis, 1992). Also of interest is the fact that although St Louis (1992) found significant differences between his cluttering group and other groups (adults who stutter (AWS) and controls) on language measures, e.g. complexity of language used, there is no mention of a linguistic component in the current LCD definition. The definition we now have has evolved since this work in 1992 but remains broadly the same, characterising cluttering as a fluency disorder in which speech is, at times, rapid and/or irregular with a large number of normal dysfluencies and articulation errors. St Louis, Raphael, Myers and Bakker (2003) wrote that this definition is not completely satisfactory as it is reliant upon the listener's interpretation, which is highly subjective. In an ideal world we would have a more objective measure for securing a diagnosis of cluttering, but such a diagnostic tool is not currently available. Bakker, Myers, Raphael and St Louis (2011) attempted to address this by developing a software package called the cluttering severity instrument (CSI). The CSI can be used by clinicians to assess the speech of a person who clutters from a multifaceted point of view. Bakker et al. (2011) include eight different components: overall intelligibility, speech rate regularity, speech rate, articulation precision, typical disfluency, language disorganisation, discourse management and use of prosody. There is also a second component in which the therapist must listen to a passage of speech from their client three times, indicating each time they hear cluttered speech. The program then collates all of this data to give a rating of severity. At present there is no data on the reliability or validity of this tool, and there is no normative data to which to compare scores. As such, the use and interpretation of this program is reliant on clinical expertise rather than empirical data.

The LCD is not without its flaws, and its definition is given despite many researchers and clinicians including several of Weiss's (1964) symptoms in their understanding of what characterises cluttering. Van Zaalen, Wijnen, De Jonckere (2009a; 2009b) updated Daly and Cantrell's (2006) Predictive Cluttering Inventory giving a list of symptoms describing the diagnostic characteristics between cluttering and stuttering. Included in this are many of the symptoms that Weiss described in 1964. The PCI has been criticised, however, as it was found by Van Zaalen, Wijnen and Dejonckere (2009a; 2009b) that the sensitivity and specificity were both very low when used by multiple clinicians to identify cluttering.

2.1.3 Subgroups in cluttering and the cluttering spectrum

Ward (2006) posed the idea of two subgroups in cluttering; linguistics and motoric, stating that a person who clutters may be one or the other, or have symptoms of both. Ward (2006) writes that motoric cluttering is characterised by tachylalia, excessive coarticulation, articulation errors, lack of speech rhythm, monotonous speech, festinant speech and fluency disruptions (part word repetitions or phoneme repetitions with no struggle). Linguistic cluttering, on the other hand, is characterised by language formulation errors of syntax and grammar, difficulties with lexical access, excessive use of maze behaviours (stalling behaviours to allow time for the person to plan their output) and finally pragmatic level difficulties. Van Zaalen, Wijnen and Dejonckere (2009a; 2009b) support the view of two subgroups of cluttering and state that this may be why the predictive cluttering inventory fails to be a reliable means of differential diagnosis. Van Zaalen et al. (2009a; 2009b) and Van Zaalen, Wijnen and Dejonckere (2011a), whilst agreeing on there being two subgroups of people who clutter, define the groups as phonological and linguistic. Van Zaalen et al. (2011a) state that phonological cluttering should be diagnosed when "speech rate is insufficiently adjusted to the phonological encoding skills" (Van Zaalen et al., 2011a, p138). This results in reduced intelligibility secondary to excessive coarticulation, telescoping and errors in sequencing syllables. In contrast, syntactic cluttering is said by Van Zaalen et al. (2011a) to be diagnosed when "speech rate is insufficiently adjusted to the grammatical encoding skills and linguistic complexity of the message" (Van Zaalen et al., 2011a, p138). The result is speech that has excessive revisions, phrase repetitions, interjections and semantic paraphasias. The notion of subgroups of cluttering may appear attractive, especially given that there is so much disagreement regarding what characteristics are at the core of cluttering; however, at present we lack empirical data from well-controlled studies to support these views.

Ward (2006, 2011) also suggests a cluttering spectrum, enabling those who show some mild symptoms to be accounted for without a full diagnosis of cluttering. There is at present no empirical data to support such an idea. However, much as with autistic spectrum disorder (ASD), this notion would give an idea of severity with some symptoms of cluttering being present only in those who are more severely affected. Ward (2006) states that cluttering may lie on the continuum of normal speech, so that at one end you have highly fluent people who make very few errors and at the other is severe cluttering. If we are to get to the core symptoms of cluttering, we must be wary of broad definitions encompassing too many symptoms, which is what the LCD tries to avoid. Whilst a spectrum allows flexibility and can help with a measure of severity, there is a risk that we include symptoms that are not core to cluttering. More data-driven, large-scale work is needed before we can invest in ideas regarding measure of severity and symptoms that may only appear in those who are more or less severely affected.

2.1.4 Empirical data on the characteristics of cluttering

Studies are emerging investigating the characteristics of cluttering; Bakker et al. (2011) found that the DDK rates of adults who clutter (AWC) do not differ significantly from fluent speakers (FS). The authors explain this by stating that DDK rates do not represent real speech, as they are based on meaningless syllables. When the authors investigated speaking rate while reading, it was found that AWC spoke at a significantly faster rate than FS but only when participants were asked to speak at a comfortable, self-generated rate and not when they were asked to speak quickly. Bakker et al. (2011) state that results demonstrate that there is a limit to how quickly people can speak regardless of diagnosis and suggests that AWC speak at an accelerated rate under all conditions due to an internal drive to do so. Alm (2004; 2011) speculates that dysfunction in the basal ganglia's ability to produce accurate timing cues for speech results in dysfluency in people who stutter and may also explain the dysfluency seen in AWC. Van Zaalen (2009) also states that the difficulties seen in cluttering stem from 'defective language automation' along with articulation errors due to an accelerated speech rate. Van Zaalen (2009) states that it is not that AWC have a defective language system, but rather that their speech rate is such that they cannot formulate and clearly articulate their ideas. They state that this is clear because once AWC slow down, errors are not observed in semantics or syntax that may be seen when they are speaking at their normal rate. These speculations are yet to be supported by empirical data.

Myers and Bakker (2013) used the CSI (cluttering severity instrument), which they devised in 2008, to investigate the speaking characteristics of AWC. Experts in dysfluency were asked to rate the saliency of speech intelligibility, rate regularity, rate, articulation precision, normal dysfluency, language disorganisation, percentage sample duration cluttered, discourse management and prosody in samples of cluttered speech. It was found that intelligibility, rate regularity, rate, articulation precision and normal dysfluency were deemed to be the most salient characteristics. Reduced intelligibility was deemed as the most salient factor overall, which is in line with what AWC themselves report – i.e. they report that people do not understand them. Of the characteristics deemed to be most salient, four are referred to by the LCD; however, the most salient, intelligibility, is not included. This suggests experts believe that how intelligible an utterance sounds is an imperative measure of cluttering and its severity. This is despite intelligibility's lack of inclusion in the current LCD. Myers and Bakke (2013) also completed correlation analysis between the factors and found that the strongest relationships were between rate regularity and % talking time cluttered; prosody and rate regularity; normal dysfluency and rate; discourse management and language disorganisation. The authors expected % talking time cluttered to correlate more highly with more factors, as it is intended to provide a 'global measure' of the severity of cluttering, suggesting it may not be a valid measure for this purpose. Although language disorganisation did not appear in the top five in terms of saliency as rated by the experts, it did appear at number six out of nine suggesting that it is considered an important factor in the identification of and severity of cluttering. This is consistent with Daly and Cantrell's (2006) Predictive Cluttering Inventory and Van Zaalen et al.'s (2009a; 2009b) updated checklist.

Cluttering often begins in early childhood, around 3-4 years old. It is regularly undetected or misdiagnosed as parents and teachers often believe there are no difficulties because children may lack delays in language and speech or in reaching other milestones (Ward, 2006). Any delays that are identified are often so mild that they are not deemed concerning. This lack of concern appears not to be confined to the UK, with data emerging from Taiwan that teachers and parents do not deem cluttering to be a serious disorder warranting investigation and treatment (Yang, 2014). A further reason for cluttering being undiagnosed is that unlike stuttering, where the speaker is anxious and has fear associated with speaking, people who clutter (PWC) usually have less awareness of their irregular, rapid and often unintelligible speech. It is becoming clear, however, that those who clutter do have anxiety and frustration associated with their speech, and some report avoiding certain situations e.g. using the phone (Ancell, 2014; Van Zaalen, 2014), a feature typically associated with stuttering.

It can be seen that there is still great debate over what should be included within the definition of cluttering and that there is also still a poor understanding of cluttering among many professionals. Simonska (2006) described an exercise in which clinicians in Macedonia and Greece were asked about their perceptions of cluttering and their confidence in treating it. The authors concluded that speech therapists seem to be unfamiliar with how to differentially diagnose between stuttering and cluttering. Similar work has not been completed in the United Kingdom; however, St Louis et al. (2010) conducted a study in which laypeople were asked to identify both stuttering and cluttering based on simplified definitions of both disorders. Participants were from Turkey, USA, Bulgaria and Russia and were asked to identify those who stuttered and those who clutter from speech samples. The authors conclude that the public seem aware of both stuttering and cluttering and can identify them in speech. St Louis, Raphael, Myers and Bakker (2003) wrote that most speech and language therapists (SLTs) are aware of cluttering and most experienced SLTs have managed a client who clutters. They state this despite the fact that in 2014, at the Second World Conference on Cluttering, a case study was presented by Akin (2014) detailing the difficulty she faced in treating a young client diagnosed with cluttering as she had not been taught about cluttering as an undergraduate and the other clinicians she worked with had very limited knowledge of the disorder and had not treated it before. It would appear that there is some discrepancy between what is being reported regarding how well cluttering is understood amongst SLTs.

2.2 Defining Stuttering

2.2.1 Current definitions of stuttering

As stated in the previous chapter, stuttering is defined by the World Health Organisation as:

"Speech that is characterized by frequent repetition or prolongation of sounds or syllables or words, or by frequent hesitations or pauses that disrupt the rhythmic flow of speech. They should be classified as a disorder only if their severity is such as markedly to disturb the fluency of speech." (World Health organisation, ICD-10 2015a).

The ICD-10 offers greater detail than the above definition and gives specifics regarding age of onset and anxiety caused by the disorder. Ward (2006) however, warns that stuttering is extremely hard to define in an accurate and succinct manner that encompasses all aspects. The reason for this is the heterogeneous nature of the disorder, and there are many different reasons that may cause the disorder to manifest, e.g. a psychological trauma, a neurological trauma, genetic link, or neurological deficit.

Three characteristics are common in the speech of those who stutter: repetitions of parts of words or whole words; prolongations of sounds or parts of words; and blocking, a pause in which there is struggle to begin speaking. It is widely accepted that these characteristics are exaggerated when the speaker is under pressure; this pressure may be actual or perceived (Guitar, 2013; Ward, 2006). The demands and capacities model (DCM) was developed by Starkweather and colleagues (Starkweather 1987; Starkweather, Gottwald & Halfond, 1990) and was intended as a descriptive model to demonstrate that for every person (fluent or not), their speaking situation will impact upon their performance. This variability is determined by the speaker's capacity to be fluent and the demands that the speech, language and motor systems are under. If the capacity for fluent speech is undermined, e.g. there is a predisposition to stuttering, then the demands of a speaking environment may result in stuttered speech. Such demands may include: peer pressure, reactions to stuttering, teasing, expectations for 'perfect' speech, advanced language use by adults, time pressure, stressful speaking situations e.g. interviews, increased rate of adult speech, and language skills. The DCM can be used to explain why stuttering varies so much from person to person and from situation to situation. Whilst this model has been criticised for being too vague (Ingham & Cordes, 1997; Siegel, 2001) it is still a useful description of stuttering (Starkweather & Gottwald, 2001). The DCM has also been modified by some to address criticism (Yaruss, 2000) and even expanded upon to offer new theories of what causes stuttering (Packman, 2012).

2.2.2 Characteristics of stuttering

Yairi and Ambrose (2013) compiled a paper on the epidemiology of stuttering and the most recent advances made. They state that the vast majority of stuttering begins in early childhood and that most of the risk of developing stuttering is over by five years of age. They also report data suggesting that the previously reported lifespan incidence of 5% may be too conservative and that 8% may give a truer reflection. The review highlights that the differences in reported prevalence among males and females, and the differences in reporting age of onset, may in part be due to differences in methodology. Such differences include variations in the age range included, e.g. a study looking at age of onset having an upper age limit of 6 years may miss those with late stage onset of stuttering, compared to a study with an upper age limit of 12 years that may not. The authors conclude by stating that we do not, as yet, have enough data on the effects of race, ethnicity, culture, bilingualism or socioeconomic status on the incidence or prevalence of stuttering.

Stuttering begins in the preschool years (Yairi & Ambrose, 2013) when both language and motor skills are developing rapidly. One consistent finding in stuttering research is that the disorder changes over time and the manner in which it presents in the pre-school years is very different to how it presents in adulthood. One such change is that stuttering moves from function words, e.g. determiners and conjunctions, to content words e.g. nouns and adjectives (Howell, Au-Yeung & Sackin, 1999, 2000). The nature of stuttering also changes, beginning with part-word repetitions and later including blocks and repetitions (Howell, 2004; Howell & Au-Yeung, 2002). Secondary behaviours may also begin to appear as the person who stutters gets older. Guitar (2013) writes that once stuttering becomes firmly established, learned reactions (secondary behaviours) are common. These behaviours occur alongside the primary stuttering behaviours of prolongations, repetitions and blocks.

Secondary behaviours may be anything from head-jerking or hand-twitching to blinking, and they develop as a way of avoiding primary stuttering (Ward, 2006). Such avoidance behaviours may extend into a covert stutter (Gregory, 2003; Guitar, 2013). Gregory (2003) states that a vicious cycle may develop in which the increase in expected speaking difficulty leads to more fear and tension and so to more stuttering. The desire to avoid or inhibit the stutter may then follow, and a covert stutter can develop. The person who is dysfluent avoids words and/or sounds that they believe they are likely to stutter on. Guitar (2013) writes that avoidance behaviours may take many forms, e.g. avoiding speaking situations, avoiding words/phrases/sounds, and substituting hard words for easier ones and adding extra words/sounds/phrases e.g. “umm”, “err”. Although these learned behaviours may initially have developed to escape the potential of stuttering, other behaviours may not. Guitar (2013) states that these behaviours can be hard to break, as the person who stutters fears what may happen if they do not use them.

Anxiety, avoidance and obstacles to forming relationships are all described by people who stutter (Beilby, Byrnes, Meagher & Yaruss, 2013; Craig & Tran, 2006; Hayhow, Cray & Enderby, 2002; Van Borsel, Brepoels & De Coene, 2011). Beilby et al. (2013) conducted interviews with 10 PWS and their fluent partners in which they asked about how stuttering had affected their relationship and their decision to get married. They found that those who stuttered reported high levels of social anxiety, negative listener reactions and feelings of stress in social situations. Interestingly, the partners of the PWS also described feelings of stress and anxiety in social situations, possibly due to the anticipation of their partner feeling anxious or the potential for negative listener reactions. The fluent partners also described the support that they offer their spouses; this ranged from providing words when their partner was blocked to broader concepts e.g. being patient. What is clear from this work is that social anxiety is a regular occurrence for those who stutter and must be addressed in therapy.

2.3 Assessment of stuttering and cluttering

The assessment and diagnosis of these two disorders is not a straightforward process, and this complicates both clinical practice and research. As has already been mentioned, the definition that we currently have for cluttering, the LCD, has been criticised for being incomplete. Therefore, reliably identifying those who clutter is not always easy, and clinicians often need to rely upon their own clinical judgement in order to make a diagnosis (Scaler Scott & Ward, 2013).

2.3.1 Assessment of cluttering

There are currently no universally agreed assessment tools for the identification of cluttering (Scaler Scott & Ward, 2013). Daly and Burnett (1996) created a checklist of behaviours, which they stated should be used when diagnosing possible cluttering. This PCI checklist (Daly & Burnett, 1996) has been found to lack reliability and validity (Van Zaalen et al. 2009a; 2009b); however, a shortened version is being used in the Netherlands. It is used in conjunction with other diagnostic tools and is currently being translated into English by Van Zaalen Wijnen and Dejonchere (2009c). It is hoped that this will be a reliable, more sensitive method for identifying those who clutter. In their book, Scaler Scott and Ward (2013) state that a diagnosis of cluttering cannot be given unless the LCD criteria are met; however, other symptoms may also be present. They state that in order to assess for potential cluttering, assessments should be videoed so that cluttering behaviours can be identified at a later stage, and that different speaking contexts must be used, e.g. story re-telling, monologue, oral reading and conversation. From these speech samples, the clinician can objectively measure speech rate; however, the authors warn that rate may appear within normal limits only parts of speech may be too rapid. Scaler Scott and Ward (2013) state that determining what is within normal limits and how severe the clutter may be are subjective measures at present. Bakker and Myers (2008) have developed freeware called CLASP – the cluttering assessment program. This is not an assessment procedure but can be used to help the clinician count, in real time, the amount of time the speaker spends being fluent compared to time spent cluttering.

2.3.2 Assessment of stuttering

Diagnosing stuttering is a little more straightforward. Although attitudes and anxieties are central to the disorder, it is better understood and more widely recognised than cluttering. Gregory (2003) and

Ward (2006) describe the process of diagnosis as beginning with taking a full case history, followed by a variety of assessment procedures including a fluency count in different speaking situations, calculating speech rate, identifying any secondary stuttering and identifying attitudes towards fluency. Calculating a fluency count is supposedly objective; however, it can take practice before one can record consistent scores for the same patient. Fluency counts do not assess the severity of moments of stuttering, only the frequency of stuttering. This is a common criticism of fluency counts, and it is vital that the clinician also considers the severity of the moments of stuttering and the patient's feelings about their fluency. The SSI (stuttering severity instrument, Riley, 1972, 2009) is one of the most widely used assessments of stuttering (Ward, 2006). It is both an objective measure of motor speech fluency and of linguistic and nonverbal aspects of the stutter. It is, therefore, considered to be more vigorous than a fluency count alone. The SSI breaks stuttering into three main components: frequency, duration and physical concomitants. There is also a section that asks the person who stutters about the impact of their fluency.

Self-assessment should also be used to gain an insight into anxiety around speaking, attitude towards fluency and how a patient feels they are affected by their dysfluency. Such assessments include the S-24 (Andrews & Cutler, 1974) the Overall Assessment of the Speaker's Experience of Stuttering (OASES) (Yaruss & Quesal, 2004), the Wright and Ayre Stuttering Self-Rating Profile (WASSP) (Wright & Ayre, 2000), the Unhelpful Thoughts and Beliefs About Stuttering (UTBAS) (St Clare, Menzies, Onslow, Packman, Thompson & Block, 2009) and the KiddyCAT (Communication Attitude Test) (Vanryckeghem & Brutten, 2006). The assessment chosen depends upon a number of factors including the client's age and how extensive you wish the assessment to be. Each of these assessments has a scoring scale so that the clinician has an idea of severity. Scores should be taken as a baseline and can then be taken again during therapy or at the end of a block of therapy in order to measure progress. These self-assessments have not yet been validated for use with those who clutter; nevertheless, Scaler Scott and Ward (2013) state that they can be easily adapted and can offer a useful insight into the perspectives of this patient group.

2.4 Differential Diagnosis of Stuttering and Cluttering

Cluttering was not differentiated from stuttering until the nineteenth century (Weiss, 1964) due to the disorders sharing many characteristics. Arguments that cluttering leads to stuttering (Weiss 1964) also suggested that cluttering may not be distinct from stuttering. When looking at the epidemiology of stuttering and cluttering, Howell and Davis (2011) write that despite these arguments, they found that only in a minority of cases did cluttering turn into stuttering. As previously mentioned, the ICD-10 now differentiates between the two disorders, and the DSM-5 (2013) is under pressure to do the same. Ward (2007) stated at the First World Conference on Cluttering that drawing comparisons between stuttering and cluttering may not aid our understanding of cluttering and that there are clear distinctions between the disorders. Table 2.1 below details some of the distinctions between the two disorders.

Table 2.1 Characteristics of stuttering and cluttering

Differences	
Stuttering	**Cluttering**
Slow rate of speech (Johnson, 1980; Kelly and Conture, 1992; Meyers & Freeman, 1985; Pindzola, Jenkins and Lokken, 1989; Ryan, 1992; Ward 2007)	Fast rate of speech (Daly & Burnett, 1996; Daly and Cantrell, 2006; St Louis and Schulte, 2011; Ward, 2007)
Language disturbances in childhood (Anderson & Conture, 2000; Ryan, 1992) but not in adulthood (Bloodstein, 1995; Ward, 2007)	Language disturbances (Bretherton-Furness & Ward, 2012; Daly & Burnett, 1996; Van Zaalen, 2009; Weiss, 1964)
Secondary behaviours alongside persistent stuttering including tension and struggle to speak (Freeman & Ushijima, 1978; Guitar, 2013; Sheehan & Voas, 1954; Ward, 2007)	No reported secondary behaviours (Ward 2006, 2007)
Word or speech sound avoidance is common (Guitar, 2013; Van Riper, 1992; Ward 2006; Weiss 1964); the person who stutters may become a covert stutterer and avoid 'tricky' words at all times.	Those who clutter are thought to not perceive any difficulties with their speech while speaking (Daly & Burnett 1996; Daly and Cantrell, 2006; Weiss, 1964) and do not have any specific sound/word fears (Heitmann, Asbjørnsen, & Helland, 2004).
Typical frequency of normal non-fluencies	Higher than typical frequency of normal non-fluencies (Myers & Bakker, 2013; Myers, Bakker, St Louis & Raphael, 2012; St Louis & Schulte, 2011)

Around 75% of children recover naturally, normally within 2 years (Ambrose & Yairi, 1999; Yairi & Ambrose, 2013)	No reported recovery following onset
Co-morbidity with social phobia and anxiety, although this has been found to be related to stuttering itself and not a pervasive social anxiety or generalised social phobia (Blumgart, Tran & Craig, 2010; Ezrati-Vinacour & Levin, 2004; Mahr &Torosian, 1999)	High co-morbidity with other disorders such as stuttering, ASD, ADHD, dyslexia, Dows Syndrom and dyspraxia (Scaler Scott, 2011; Van Borsel, 2011; Van Zaalen, 2009; Van Zaalen, & Reichel 2015; Ward, 2006)
Delayed auditory feedback (DAF), choral reading, and prolonged speech all enhance fluency (Ingham, 1984)	Results from St Louis et al. (1996) suggest that DAF can be used to effectively slow speech in those who clutter, but effects are short-lived.

Similarities

Stuttering	**Cluttering**
Typically develops around 3-4 years old (Packman, Code & Onslow 2007; Yairi & Ambrose, 2013)	Typically develops around 3-4 years old (Ward, 2006)
Occurs more frequently in males than in females – 4:1 in adults (Yairi & Ambrose, 2013) or as high as 5:1 (Packman, Code & Onslow, 2007)	Occurs more frequently in males than in females, with a ratio of 4:1 (Arnold, 1960; St Louis & Hinzman, 1988)
The cause is not known (Buchel & Sommer, 2004)	The cause is not known (Ward, 2006)
The basal ganglia has been implicated in explaining difficulties (Alm, 2004, 2011)	It has been speculated that there may be a deficit in the basal ganglia among AWC (Alm, 2011; Ward et al., 2015).

As can be seen from the above table, there are many differences between stuttering and cluttering, making it clear that the two are separate disorders.

Ward (2007), whilst stating that drawing too many comparisons between stuttering and cluttering may be misleading, does acknowledge that comparisons are inevitable due to the high co-morbidity of cluttering with stuttering and the very fact that both are described as disorders of fluency. There has been some disagreement regarding the exact number of people who exhibit both stuttering and cluttering, but Preus (1992), Daly (1993) and Ward (2006) speculate that around a third of those who stutter may also show cluttering symptoms. The exact prevalence of cluttering remains unknown (St Louis et al., 2010), but it has been suggested that it is less prevalent than stuttering (St Louis et al. 2003). The prevalence of stuttering is far clearer, with agreement at a prevalence of between 1% and 0.75% (Andrews, 1983; Bloodstein, 1995; Craig, Hancock, Tran, Craig and Peters, 2002; Ward, 2006) in the general population.

Differential diagnosis between stuttering and cluttering is made difficult due to the two disorders regularly co-occluding. Van Zaalen et al. (2009a) described data indicating that even experienced speech and language therapists only have a 50% correspondence rate when diagnosing cluttering, with many clinicians often diagnosing stuttering without the cluttering component. Van Zaalen et al. (2009b) recommend gathering speech data in both a formal and an informal setting as PWC often demonstrate increased dysfluency when relaxed. This is in direct contrast to PWS who, typically, are increasingly dysfluent when in formal situations or under pressure. The Predictive Cluttering Inventory (PCI) (Daly and Cantrell, 2006) was updated by Van Zaalen et al. (2009a; 2009b), but found that even with the adaptations made it remained an inexact tool for differentially diagnosing between stuttering and cluttering.

Co-morbidity with stuttering and other disorders including autistic spectrum disorder (ASD), attention deficit and hyperactivity disorder (ADHD) and dyspraxia make research with this population difficult (Ward, 2006). This high degree of co-morbidity has also led to confusion when trying to define cluttering. We must guarantee that the core symptoms can account for all PWC whilst not subjecting us to a type one error in which we over diagnose or misdiagnose cluttering due to the definition being too broad. The current LCD helps prevent this to some degree; if all researchers select participants for studies using these, we can be more assured that we are not comparing apples and pears. However, as described above, the LCD is not without its flaws, and we must be cautious of discounting other possible characteristics such as a high-level language component or difficulties with concentration.

2.5 Neurological data from Stuttering and Cluttering

2.5.1 Neurological cause of cluttering

Weiss (1964) deduced that cluttering has no neurological cause e.g. trauma, but that it does appear similar to organic disorders e.g. acquired apraxia of speech. Weiss also believed that it is hereditary; however, there is little literature to support this. Drayna (2011) comments that we are no further forward in our understanding of whether cluttering runs in families or not than we were when Weiss first made his observation in 1964. By reviewing client case histories, we may find a correlation between occurrence of cluttering and frequency of occurrence in families; however, until we have well-controlled empirical evidence, we cannot state with any degree of certainly whether or not cluttering is hereditary. Stuttering has received far more scrutiny in this regard, with researchers and clinicians agreeing that stuttering runs in families. Riaz et al. (2005) believe that it has as much as a 50% hereditability rate. Given the similarities between stuttering and cluttering, it is not unreasonable to think that cluttering may be similar.

Cluttering following neurological damage to the extrapyramidal system has been reported by Lebrun (1996). Investigation of two patients with idiopathic Parkinson's disease revealed rapid bursts of speech without festination and speech that was poorly articulated and often unintelligible. This was despite patients being bradykinetic in all other voluntary actions. Lebrun (1996) states that these symptoms may be permanent or intermittent, possibly depending upon medication. The observed differences between nonverbal motor activity and motor speech activity are described by Lebrun (1996) as possibly indicating some differences in organisation between these motoric systems. This may explain why those with Parkinson's experience improvement in their non-motor symptoms but no improvement in their speech when taking medication. Leipakka and Korpijaakko-Huuhka (2014) suggest that they have identified and treated two people who had acquired cluttering. It is unclear at this stage if they used the LCD to identify these people and exactly how their speech presented, but if this is the case it provides evidence that there is a neurological basis for cluttering in at least some cases.

Cosyns et al. (2010) investigated the fluency of those who have neurofibromatosis type 1 (NF1). NF1 is an autosomal dominant disorder resulting in learning disabilities, macrocephaly, attention deficit hyperactivity disorder, short stature, headache, scoliosis, epilepsy, malignant peripheral nerve sheath tumour, hydrocephalus, pheochromocytoma, renal artery stenosis and, rarely, intracranial tumours. Cosyns et al. (2010) used 21 Dutch-speaking adults and collected speech samples including spontaneous speech, monologue, repetitions, automatic speech and reading. All 21 speakers showed evidence of dysfluent speech with interjections, revisions, prolongations and incomplete phrases being the most prevalent types. The authors conclude that dysfluencies seen were not those typical of stuttering but were more consistent with excessive normal dysfluency or what we may expect in cluttered speech. These results also suggest that cluttering may be acquired in some speakers, from a genetic disorder like NF1 or perhaps from a stroke/traumatic brain injury as suggested by Leipakka and Korpijaakko-Huuhka (2014).

2.5.2 Empirical neurological data on cluttering

We have little neurological data regarding the cause of cluttering. EEG work conducted by Luschinger and Arnold (1965) suggested that PWC have deviant traces when compared to people who stutter (PWS), who had normal traces. More work is needed to repeat these results, however, as there have been no recent studies to suggest similar findings. There is emerging fMRI data from PWC, which is discussed below. These findings are in their infancy but do offer exciting insights into the neurological correlates of cluttering.

Alm (2004) implicates basal ganglia dysfunction in his explanation of what causes dysfluency, stating that its impaired ability to produce timing cues results in stuttering. When external cues are given, e.g. when a person is singing, we normally see instant alleviation of stuttering as the basal ganglia is no longer being relied upon to provide timing cues for speech (Alm 2004). Aberrant release of dopamine has been suggested by Alm (2004) as one possible reason for this dysfunction. Langova and Moravek (1964) conducted a study using three groups: AWS, AWC and adults who stutter and clutter (AWSC) and gave half of the participants in each group a stimulant and the other half a D2-blocker. Over 80% of AWS improved on the stimulant: in contrast, 67% of AWS had worse symptoms on the D2-blocker. The opposite was found with AWC and AWSC, with 79% having worse symptoms on the stimulant but 79% improving when taking the D2-blocker. This suggests two neurochemically different groups. We must be cautious, however, when interpreting this data as it is not clear how the diagnoses were given and whether the LCD was used to identify those who are reported to be cluttering. This work is also yet to be replicated, and whilst funding was made available in the United States of America for a dopamine study, no results have been published and it appears the idea is not being pursued.

We have seen from recent fMRI research carried out at The University of Reading (Ward, Connally, Pliatsikas, Bretherton-Furness, & Watkins, 2015) that there appear to be neurological differences between PWC, PWS and the general population. This research has demonstrated that whilst there are striking similarities between the three participant groups in terms of neurology, there are also cortical and subcortical differences, and these appear to be subject to the task being completed. Cortically, images suggest that there is a greater level of activation in the pre motor cortex on the lateral and medial surfaces in people who clutter than in controls when reading and producing spontaneous speech. Subcortically, those who clutter showed greater activation in the putamen and the head of the caudate nucleus. Thus, we are seeing a picture of greater activation in PWC and recruitment of areas not used by controls when completing the same tasks. The tasks used in this research were such that they placed greater or lesser demand upon the speech processing centres. It was predicted that the spontaneous speech tasks would result in a greater level of activation in brain structures related to motor speech control. This held true for all groups; however, PWC showed the greatest level of activation and also greater recruitment of the basal ganglia, which was not seen in controls. This work has demonstrated that differences between people who clutter PWS and controls may not be isolated to motor control, planning and execution. To date this is the only published work using fMRI to examine those who clutter.

2.5.3 Empirical neurological data on stuttering

There is a far greater amount of neurological data relating to AWS. Packman, Code and Onslow (2007) stated that fMRI data from the previous 10-15 years has demonstrated that adults who stutter have unusual brain activity. In his commentary on brain imaging in stuttering, Ingham (2003) demonstrates that results have been very mixed and speculates that this is due to differing methodologies e.g. different imaging techniques used and different tasks set. Grabowski and Damasio (2000) state that using different functional imaging techniques and different tasks to try and isolate specific language processing areas means different results will likely be found. Using normal controls, Frith, Friston, and Liddle (1991) and Wood, Saling, Abbott and Jackson (2001) found that the most salient areas used in lexical access appear to be the left middle frontal gyrus (Brodmann's areas 9 and 46) and the left inferior frontal gyrus (Brodmann's areas 44 and 45). Other areas implicated in normal controls are the anterior cingulate gyrus, left inferior parietal lobule, the left supplementary motor area, the anterior insula, the pre-motor cortex and a variety of temporal lobe areas identified by Baker, Frith, & Dolan (1997); Cuenod et al. (1995); Paulesu et al. (1997); Wise et al. (1991); Yetkin et al. (1996). These areas have been identified using both PET and fMRI with a variety of lexical access tasks e.g. word generation tasks (verbal fluency) both silent and spoken, noun-noun comparison, verb-noun comparison, verb generation and lexical decision making (real vs non-word decision). With these areas well-established, we can draw comparisons with those who stutter.

A meta-analysis was completed by Brown, Ingham, Ingham, Laird and Fox (2005) and looked at eight neuroimaging studies, two fMRI and six PET. Their results support the idea that there are a set of areas that appear be to central to speech production, these include; the primary motor cortex, premotor cortex, SMA, frontal operculum, basal ganglia and quadrangular lobule of the cerebellum.

It was also found that there are three main areas of difference between those who stutter and those who do not. The authors noted increased activation in lateral vocal-motor areas, especially in the right hemisphere, and decreased activation in auditory areas. They also found a greater balance of activation in the right hemisphere with reduced activity in the primary motor cortex, auditory cortex and Rolandic operculum in the left hemisphere and increased activity in the frontal operculum and Rolandic operculum in the right hemisphere. Finally, they found over activity in the SMA, cingulate motor area and cerebellar vermis. The authors concluded that their meta-analysis gave a general picture of the phenotype of stuttering but could not give a profile of activity that was unique to stuttering. Brown et al. (2005) also state that a far larger amount of data is needed if we wish to gain a clearer picture of what activity is unique to stuttering.

Blomgren, Nagarajan, Lee, Li and Alvord (2003) report findings from an fMRI study that used a lexical access task with adults who stutter. They found striking similarities between the two groups, such as activation in Brodmann's area 22, 41, 44, 4 and 6 implicating the right and left posterior temporal gyrus, the right superior temporal gyrus, the left inferior frontal gyrus, the mid-lateral portion of the left precentral gyrus and bilateral activation of the superior precentral gyrus and anteriorly adjacent association cortex. They also found differences between the two groups, with increased right hemisphere activation found in the stuttering group. The stuttering speakers had a trend toward increased activation in the right Broca's area homologue and along the precentral gyrus in the right hemisphere. The non-stuttering groups also appeared to have less activation in the auditory association in the right hemisphere than the stuttering group. Finally, the stuttering speakers appeared to have over-activation in the right auditory association area (right Wernicke's area homologue) and over-activation in a large area along the right lateral precentral gyrus (primary motor strip). This was all seen during a silent lexical access task in which participants heard a description and then had to think of the word that would fill that description, e.g. "it's cold and you eat it from a cone". The authors state that they failed to find statistically significant differences between the two groups and that this may be due to the high variability seen in the participants' data, or the small numbers used (seven people who stutter and nine fluent speakers) or it may have been due to the stringent statistical methods used with fMRI subjecting the study to a type II error.

Smith, Sadagopan, Walsh and Weber-Fox (2010) suggest that language and motor processes are not independent and used findings from Riecker, Brendel, Ziegler, Erb and Ackermann (2008) as evidence for their multifactorial dynamic model of stuttering. Riecker et al. (2008) used fMRI to study the production of 2-syllable non-words and found that when producing non-words whose syllable onsets were more complex (based upon syllable frequency distribution in the language used here - German) there was a higher level of activation in the brain areas responsible for speech motor planning and execution. Smith et al. (2010) used non-word repetition tasks to look at accuracy in repeating non-words and articulatory precision. They found no differences in the behavioural data for AWS compared to controls, with AWS being as accurate as controls when producing non-words; however, there were significant differences found between the two groups in the kinematic data. AWS were less consistent in their inter-articulator coordination, and this increased when the length of the non-word and phonological complexity increased.

2.6 Phonological encoding and stuttering and cluttering

2.6.1 Theories

Phonological encoding is described as a process whereby a phonetic plan or articulatory plan is retrieved from each word's mental representation (Lemma) including its meaning and grammatical information (Levelt 1998). In his model of speech production, Levelt (1998) proposes that phonological encoding involves three processes: generating the segments that constitute words, the integration of sound segments in syllable frames and the assignment of stress and intonation. The result is an articulatory program which then generates a motor plan for the articulators to generate the correct coordination of movements to produce the word accurately.

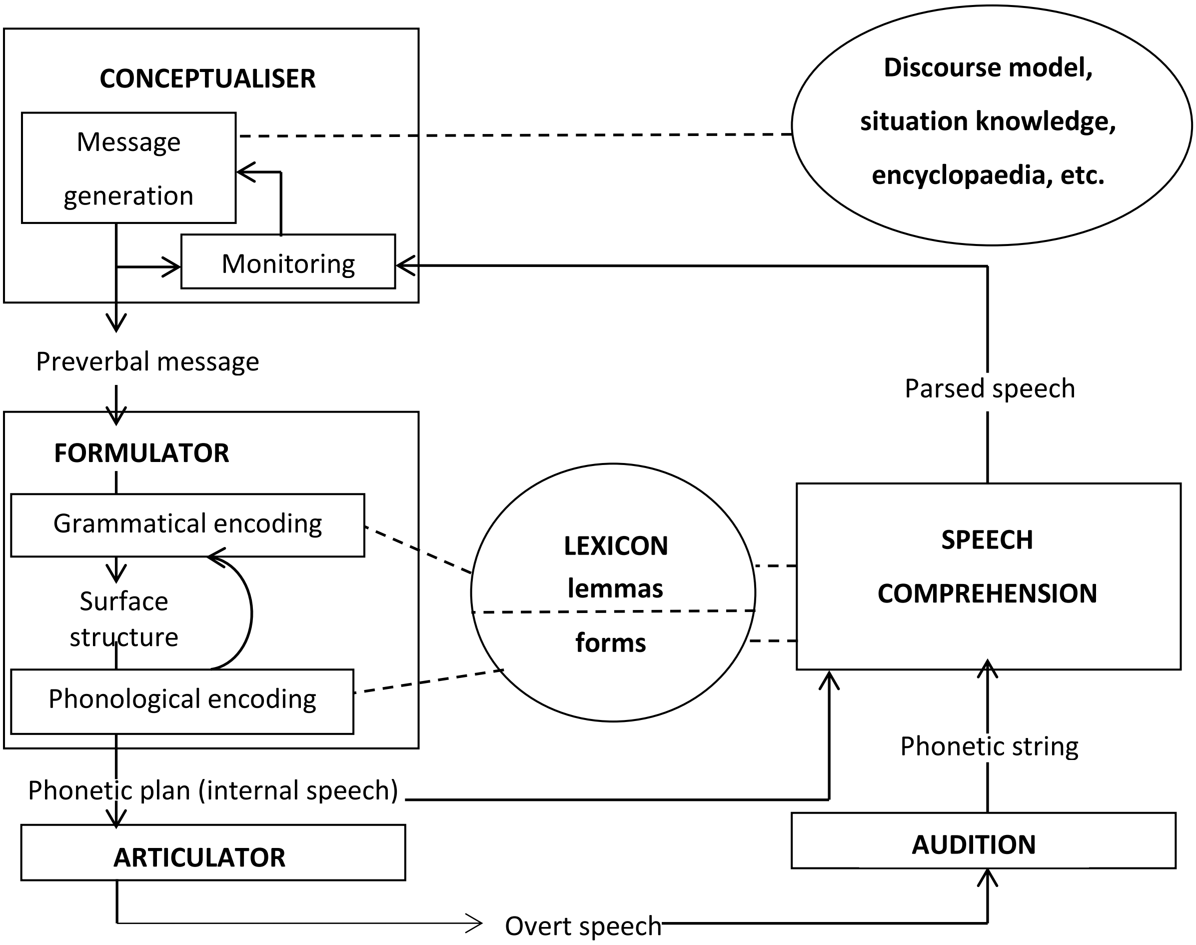

Figure 2.1 Levelt's speech production model (Levelt 1998)

production. This model has come to be a common point of reference for those researching the link between phonological encoding and dysfluency.

At least four theories have been proposed concerning the potential link between phonological encoding and stuttering.

1. EXPLAN (Howell, 2004)
2. Covert repair hypothesis (Postma and Kolk, 1993)

3. Fault line hypothesis (Wingate, 1988)
4. Syllable initiation theory (Packman, Code, and Onslow, 2007)

2.6.1.1 EXPLAN theory

EXPLAN theory, proposed by Howell (2004); Howell and Au-Yeung (2002); Howell, Au-Yeung and Sackin (1999), states that there are three core features of stuttering:

1. Stuttering occurs on content words rather than function words ('car' rather than 'can't')
2. There is an asynchrony between the motor plan and the motor execution of speech.
3. The fact that stuttering moved from function words in childhood to content words in adulthood (Bloodstein & Gantwerk, 1967; Brown, 1937) is a reflection of the different strategies used by the person who stutters.

The theory states that stuttering occurs due to the motor plan not being ready for the speech that follows. This either causes stalling or results in the speaker attempting to continue regardless (non-stalling). Stalling is characterised by the speaker repeating function word prefixes in the phonological word. If the speaker continues, and there is not enough time to complete the motor plan during stalling, then the following content words will contain dysfluencies. The authors state that as a stalling behaviour prevents a non-stalling one, the two are complementary. This model has received criticism for not considering syntactic components that may be factors in the development of stuttering and for only considering phonetic components as minor influences (Bernstein-Ratner, 2007).

2.6.1.2 The covert repair hypothesis

The covert repair hypothesis proposed by Postma and Kolk (1993) is a psycholinguistic theory of stuttering stating that errors occur due to slowed phonological encoding and a deficit in self-monitoring occurring at the prevocalisation stage of language production. This theory is based upon Levelt's 1998 model of language production and Dell's (1986) connectionist model of phonological encoding, which states that when an error is detected in the phonetic plan, speech production is stopped and a repair is made. This is a process that occurs for all of us when speaking, but Postman and Kolk (1993) state that in those who stutter, there is faulty phonological encoding resulting in a defective articulatory plan and that the moments of stuttering are overt indices of covert repairs to the articulatory plan.

2.6.1.3 The fault line hypothesis and syllable initiation theory

Wingate (1988) proposed the Fault Line Hypothesis to explain stuttering. Wingate (1988) states that stuttering occurs at syllable initial position but not syllable final, and that this is due to stuttering being a result of a delay in the retrieval and encoding of syllable rhyme during speech production. This then creates a 'fault-line' or primary stuttering behaviour at the point of integration of the syllable onset with its rhyme. Another, similar, proposal is syllable initiation theory. Suggested by Packman et al. (2007), this theory states that a difficultly initiating syllables is caused by a deficit in the SMA (supplementary motor area). The authors state that the syllable is especially important in stuttering, as those who stutter are assisted by treatment such as prolonged speech where syllabification is simplified (Packman et al. 2007). Stuttering is not seen in children when they are babbling, which Packman et al. (2007) suggest is due to syllables being evenly spaced and having equal stress. Stuttering begins, typically, when real words are put together into sentences and the child must alter the stress of words. According to the Vmodel (Packman et al., 2007) having to alter the stress of words increases linguistic and motoric demands and thus stuttering begins. Packman et al. (2007) state that the SMA is responsible for the planning of over learned movement routines that are initiated internally rather than externally and that as such it may be responsible for initiating syllables.

2.6.1.4 Neuropsycholinguistic theory

A neuropsycholinguistic theory of stuttering proposed by Perkins, Kent and Curlee (1991) aims to address stuttering from both a neurological and linguistic view point. Perkins et al. (1991) report that disruptions in speech production are a result of a dyssynchronous relationship between certain neural functions. Perkins et al. (1991) state that for fluent speech to be achieved, the paralinguistic system and the linguistic system must be integrated in synchrony. The authors suggest that the paralinguistic system and the linguistic system operate dyssynchronously in those who stutter, and that their reaction to this is what causes the moments of stuttering. Time pressure is suggested to influence whether speech will be fluent or not; that is, the speaker's need to begin, continue or accelerate an utterance increases the likelihood of the utterance being stuttered on when dyssynchrony occurs. When dysfluency occurs but is not stuttering, e.g. an inappropriate pause, or use of a filler like *umm*, this is due to a dyssynchrony between the linguistic and paralinguistic components when there is no time pressure. Both dyssynchrony between the paralinguistic system and the linguistic system and time pressure are necessary for stuttering to occur. Perkins et al. (1991) state that their theory accounts for both the disruption caused by stuttering and the experience of a loss of control, which is often described by those who stutter. At the crux of this theory is that stuttering is not only dysfluent speech but also the feeling of a loss of control. Bloodstein (1995) characterised this theory as a rewording of the idea that children are speaking faster than they are thinking.

2.6.2 Data from studies investigating phonological encoding in stuttering

Phonological encoding is said by Coles, Smid, Scheffers and Otten (1995) and Meyer (1992) to be difficult to test and manipulate directly as it is a complex process embedded within language formulation. They suggest that an appropriate way of investigating it is through processes such as phonological awareness. Phonological awareness is described by Pelczarski and Yaruss (2014) as a person's ability to "*identify, isolate and manipulate various-sized segments of speech such as words, syllables, onsets/rimes and individual phonemes*" (Pelczarski and Yaruss, 2014, p. 13).

In a recent review Sasisekaran (2014) reports that results from investigations into phonological encoding in adults and children who stutter are often ambiguous and open to a number of different interpretations. Sasisekaran (2014) reviewed studies using: rhyme judgement, phoneme monitoring, non-word repetition and priming paradigms to look at phonological encoding. It was concluded that results provide evidence that stuttering is influenced by the demands of phonological processing, specifically phonological encoding, but that studies have only focused on the word level. It is suggested that further research needs to consider tasks that constrain incremental speech planning and production. Sasisekaran (2014) criticises work that has investigated phonological encoding using overt speech, stating that it is complicating the issue with other processes such as lexical retrieval, motor planning and motor execution. Being able to assess phonological encoding without the addition of motor planning and motor execution would go some way in helping to establish if those who stutter have a motoric difficulty or a phonological one (or in fact both). Bosshardt (1990) and Postma, Kolk and Povel (1990) have found that children and adults who stutter are slower at silent reading than fluent controls, implying that phonological encoding is impaired and not just motor planning and motor execution. A further criticism raised by Sasisekaran (2014) is that studies relying upon other cognitive processes, such as working memory, are confusing the issue of phonological encoding and making it difficult to identify exactly where the area or areas of breakdown lie.

These limitations aside, phonological-encoding differences have been demonstrated in both children and adults who stutter (Anderson, 2007; Anderson & Byrd, 2008; Bakhtiar, Ali & Sadegh, 2007; Bosshardt, 1993; Byrd, Conture & Ohde, 2007; Byrd, Vallely, Anderson & Sussman 2012; Hakim & Ratner, 2004; Hennessey, Nang & Beilby, 2008; Ludlow, et al. 1997; Melnick, Conture & Ohde, 2003; Nippold, 2002; Sasisekaran & Byrd, 2013; Sasisekaran & De Nil, 2006; Sasisekaran, De

Nil, Smyth & Johnson, 2006; Vincent, Grela & Gilbert, 2012; Weber-Fox, Spencer, Spruill & Smith, 2004).

2.6.3 Non-word repetition

Non-word repetition tasks have been used extensively in the literature for investigating phonological working memory skills in children (e.g. Dollaghan, Biber, & Campbell, 1993, 1995; Dollaghan & Campbell, 1998; Gathercole & Baddeley, 1996; Pelczarski & Yaruss, 2016). These tasks assess a person's ability to store, rehearse and then produce a given non-word. The authors above have concluded that difficulties with non-word repetition are, at least in part, due to difficulties in phonological representations.

Anderson, Wagovich and Hall (2006) used a non-word repetition task to estimate phonological working memory skills in children who stutter (CWS). It is thought that a person who is able to retrieve a non-word stimulus and produce it accurately has relied upon adequate rehearsal and storage skills (Anderson et al., 2006). Therefore, if a person is unable to repeat a non-word accurately they have impaired phonological working memory, specifically due to impaired rehearsal or impaired storage skills. This would then result in impaired phonological representations leading to impaired phonological encoding. The authors do acknowledge that there is evidence to suggest that other processes are also involved in non-word repetition tasks, but these tasks remain a well-used method for accessing phonological working memory (Anderson, et al. 2006). The authors also collected language data using a range of standardised assessments including the Expressive Vocabulary Test and the Peabody Picture Vocabulary Test-III.

It was found that CWS differ from fluent controls in terms of accuracy when repeating non-words, and performance on the non-word repetition task was significantly related to performance on a test of phonology but only for CWS and not for fluent controls. On all other language measures CWS performed as did their fluent peers. The authors conclude that the difficulty with non-word repetition seen in CWS cannot be attributed to difficulties with language in general and that whilst it is interesting that CWS show a similar deficit to those who have specific language impairment (SLI) in terms of non-word repetition, they do not share characteristics beyond this. Results suggest that CWS have impaired phonological awareness skills and thus impaired phonological encoding.

Most recently Pelczarski and Yaruss (2016) conducted a study using 16 CWS and 13 fluent controls to investigate non-word repetition. They found that CWS performed significantly less accurately at the non-word repetition task (used as a measure of phonological memory). The authors explained this finding as possibly being due to a disruption in the phonological loop and a disruption in articulatory rehearsal resulting in the inaccurate rehearsal of the phonological code and then an inaccurate non-word being produced. This explanation is based upon Baddeley's (2003) four-component memory model which states that the phonological loop (one of the four components) consists of two elements: a phonological store and an articulatory rehearsal mechanism. The phonological store holds auditory information temporally but, can be 'refreshed' through rehearsal (overtly or silently) via the articulatory rehearsal mechanism. Pelczarski and Yaruss (2016) conclude that CWS appear to have an impaired ability to hold and/or rehearse phonological code for non-words and suggest that this may be due to non-words not having any lexical information. Therefore pre-existing lexical knowledge cannot be used to bolster decaying phonological code which it could be for real words (Dell, Schwartz, Martin, Saffran & Gagnon, 1997; Hoffman, Jefferies, Ehsan, Jones, & Ralph, 2009; Martin & Gupta, 2004; Thorn, Gathercole & Frankish, 2005).

This work could be criticised based upon Sasisekaran's (2014) report, as their paradigm was set up in such a way that working memory was needed due to the prime being presented followed by a 900 millisecond pause before the target was presented. Non-word repetition has also been used by Hakim and Ratner (2004), and Anderson and Wagovich (2010), to investigate phonological encoding in stuttering. Both studies showed similar findings to that of Anderson, Wagovich and Hall (2006) further supporting the notion that phonological encoding is impaired in CWS and that they have difficulty recognising and manipulating segments of speech. This data was solely collected using children, so the picture may be different in AWS. Not all work, however, has supported the findings above and Bakhtiar, Ali and Sadegh (2007) failed to support previous findings. Using 12 CWS and fluent controls, the researchers presented 40 non-words, one at a time, to children and asked them to repeat the words back immediately after hearing them. The authors concluded that there was no significant difference between CWS and fluent controls in terms of their ability to accurately repeat non-words, thus suggesting that CWS do not have impaired phonological awareness. It is worth noting that this study used children speaking Persian languages, and therefore results may not be comparable to those in English.

More recently Smith, Sadagopan, Walsh and Weber-Fox (2010) used AWS and compared them to fluent controls when performing a non-word repetition task. The authors' aim was to investigate the potential for phonological complexity manipulation to destabilise the motor system in AWS when repeating non-words. They used 17 AWS and fluent controls, giving them adapted words from the Nonword Repetition Task (Dollaghan and Campbell, 1998) and taking kinematic recordings of them repeating back these non-words. Participants also completed the full Nonword Repetition Task (Dollaghan and Campbell, 1998). It was found that there was no difference between AWS and fluent controls on the Nonword Repetition Task or on the adapted Nonword Repetition

Task words in terms of accuracy of production. However kinematic data collected did reveal a difference between the two groups. AWS had less trail-to-trail consistency in terms of the coordination of movement in the jaw and the upper and lower lip. It was also found that this difference was more pronounced when non-words were longer or more phonologically complex. The authors state that they cannot argue that phonological complexity or increased word length is operating independently from the increased demands that a longer, more complex word has on motoric planning and execution. It is concluded that at a behavioural level the data do not support any phonological deficits in AWS (they performed at ceiling in the nonwords repetition tasks in terms of accuracy of productions). Smith et al. (2010) also conclude that the greatest differences in kinematic data were found when words were longer and/or more phonologically complex. This supports the notion that longer, more complex words may slow one or all of the following processes: phonological encoding, motor planning, motor execution. Identifying exactly which of these processes is responsible is impossible from this data, and in fact it may be that all of these processes are slowed/impaired (Smith et al., 2010).

Most recently Byrd, Vallely, Anderson and Sussman (2012) criticised previous work for not containing complex enough stimuli (e.g. Smith et al. (2010) only used non-words with a maximum of four syllables). Byrd et al. (2012) also state that previous work has often only used AWS who are classed as either mild or very mild, which may result in findings being skewed. They used two-, three-, four- and seven-syllable non-words and asked 28 AWS and 28 fluent peers to repeat these. They found that when repeating two, three and four syllable non-words there were no differences in accuracy between AWS and controls. For seven-syllable words, however, AWS were significantly less accurate than controls, and controls were significantly more likely to repeat a seven-syllable word accurately on the first attempt than AWS. These findings support the idea proposed by Smith et al. (2010), that more complex words may slow one or all of the following processes: phonological encoding, motor planning, motor execution. Once again, it is not possible to identify if one or multiple processes are affected as these tasks involve overt speech.

2.6.4 Priming

Priming is used in psychology to investigate implicit memory and has been used to show that people can make faster decisions and recognise things more quickly if they are preceded by a related item. For example, ‘apple’ is recognised faster if proceeded by *orange* rather than *bungalow* (Healy & Proctor, 2003). In Dell’s (1986) model of spreading activation (or the connectionist model of speech production), he states that when we wish to produce a word all the nodes representing that word are activated. For example if we wished to say *dog*, the relevant semantic nodes would be activated

– it's an animal, it has four legs, it's a pet, it barks. The word *dog* is then chosen and activation spreads down to the nodes representing phonological structure. The model then assumes that during phonological encoding (when the phonemes for the word are being chosen) those that are most active are selected and entered into the motor plan. A priming paradigm can be used to assess phonological encoding as by priming a person with a related phoneme prior to the retrial of a target phoneme, the activation level of the target phoneme is manipulated thus making it easier to access. Priming can be used to assess phonological encoding in those who stutter. If PWS are slower than controls at recognising or retrieving a target word when they are primed with a word that has the same phonemes initially as the target word this would indicate that they have impaired phonological encoding. Wijnen and Boers (1994) used a priming paradigm to investigate phonological encoding in AWS compared to fluent controls. Expanding upon work by Meyer (1988, 1990, 1991), Wijnen and Boers (1994) used two types of priming; one where the initial consonants were primed (C-condition e.g. /p/) and one where the initial consonant and proceeding vowel were primed (CV-condition e.g. /pi/).

They found that the fluent controls responded as expected based on Meyer's (1988, 1990, 1991) original research. The priming effect appeared to reflect the size of the primed word part, i.e. retrieval was faster when more of the word was primed (in the CV-condition). With those who stutter, it was found that the priming effect for the C-condition was significantly less effective than it was for fluent speakers. In the CV-condition, however, there was no difference between those who stuttered and the fluent controls. Wijnen and Boers' (1994) results appear to support the notion that phonological encoding is impaired in AWS as those who stutter showed significantly less priming effect in the C-condition than controls, however they acknowledge that the reason for this remains speculative. Kolk (1991) suggests that in those who stutter, the activation spreading that should occur during phonological encoding for the correct phoneme to be selected is slowed. This then results in delayed phoneme section, which results in prolongations and repetitions (Kolk, 1991). The authors concluded that in AWS the encoding of the vowel in the initial stressed syllable is delayed. By priming with the initial vowel as well as the initial consonant (in CV-condition) one should see a reduction in repetitions and prolongations as the correct phonological information from the vowel has now been entered into the articulatory plan. These results support the covert repair hypothesis (Postma & Kolk, 1993), as delayed activation results in delayed or inaccurate phoneme selection resulting in a prolongation or repetition to try and repair the error detected in the articulatory plan by the internal monitoring system.

Research since this time has failed to offer the same support. Vincent, Grela and Gilbert (2012) also used phonological priming to investigate phonological encoding in AWS. In line with previous findings (Burger & Wijnen, 1999; Hennessey, Nang & Beilby, 2008) they predicted that if phonological encoding is slower in those who stutter, then the patterns of priming will differ to those who are fluent. Specifically, they said that speech onset latency should decrease from no priming to C-priming to CV-priming in those who are fluent, but that in those who stutter there should not be the same pattern. If the covert repair hypothesis is correct and as stuttering occurs at sound initial/syllable initial position, speech onset latency should only improve from no priming to CV-priming, not just C-priming, which is what was found by Wijnen and Boers (1994). Vincent, Grela and Gilbert (2012), however, found evidence to contradict this. They reported that their AWS behaved as the fluent controls, albeit significantly slower than the controls. AWS had shorter SOL (speech onset latencies) as the priming increased, in the same way as fluent speakers did. The authors concluded that these findings do not support the hypothesis or the covert repair hypothesis. It is worth noting, however, that this study did not control for the severity of stuttering. It may be that only when those with a severe stutter take part in studies can the underlying mechanics of the disorder be identified.

2.6.5 Sound blending and elision

Vincent, Grela and Gilbert's (2012) results above are interesting, as Pelczarski and Yaruss (2014) found that there are phonological encoding differences between young children who stutter and their fluent peers. Using the Comprehensive Test of Phonological Processing: Ages five to six (CTOPP; Wagner, Torgesen & Rashotte, 1999) they collected data on sound matching, sound blending and elision. The sound matching subtest involves the child listening to a target word and then a series of words in which they need to select one that matches the target's initial or final phoneme. The sound blending subtest requires the child to make real words from given segments, e.g. what word do these sounds make? *Ba-loon*. Finally, the elision test, which is the most complex, asks the child to separate spoken words to create another word by removing one phonological segment, e.g. say *greenhouse* without saying *house*. Taken together these subtests give a Phonological Awareness Composite Score, which describes a child's awareness of phonological structure and their access to it. Pelczarski and Yaruss (2014) found that those who stutter were significantly less accurate than their fluent peers at both sound blending and elision. This result was found despite there being no difference between the groups in terms of their language ability (as measured by the "Quick Test" version of the Clinical Evaluation of Language Fundamentals–Preschool (CELF-P; Wiig, Secord, & Semel, 1992)). The authors report that differences between children who stutter (CWS) and controls are subtle and may demonstrate subclinical differences between the two groups in terms of phonological awareness. One possible explanation for the results and for the contrast between children and adults who stutter is that their difficulties change. It is well-documented that stuttering moves from function words to content words as those who stutter move into adulthood (Howell, Au-Yeung & Sackin, 1999). It is possible, therefore, that difficulties with phonological encoding also change or disappear. It would however be premature to come to this conclusion now, and more work is needed to look at the difference between adults and children who stutter.

2.6.6 Rhyme Judgement

The ability to detect a rhyme between two words has been strongly linked with later literacy skills as it is related to phonological awareness (Bryant, MacLean, Bradley & Crossland, 1990). As already discussed, phonological awareness has been suggested by research, including Coles, Smid, Scheffers and Otten (1995) and Meyer (1992), as a useful and valid way in which to assess phonological encoding. Weber-Fox, Spencer, Spruill and Smith (2004) used a rhyme judgment task to investigate how phonological encoding may contribute to phonological processing differences between adults who stutter and those who are fluent. They also collected event-related potential (ERP) data and used phonologic and orthographic manipulations of word pairs to explore how additional cognitive load influences performance of the two groups. The authors used 124 rhyming and 124 non-rhyming word pairs; of the rhyming pairs, 62 were orthographically similar (*thrown, own*), and 62 were orthographically dissimilar pairs (*cone, own*). This was also the case in the non-rhyming group (e.g. *gown, own* and *cake, own*). It was found that the two groups were not significantly different in terms of accuracy in detecting rhyme. There was no overall difference for reaction time, but there was a significant difference between AWS and controls for the orthographically similar non-rhyming group, with those who stutter taking a significantly longer time to respond than fluent controls. The data from ERPs showed there were no differences between the groups in amplitude or latency of ERPs; however, there was right hemisphere asymmetry suggesting greater recruitment of the right hemisphere by AWS than by fluent controls when completing rhyme judgement.

The authors conclude that data here does not support models of stuttering which state that it is generally slowed phonologic processes and errors in phonologic planning that cause stuttering e.g. the covert repair hypothesis (Postma and Kolk, 1993). The authors also conclude that phonological encoding is vulnerable in those who stutter but only when there is increased cognitive load, such as having words that look similar but do not rhyme e.g. *cost*, *most*. This study, however, uses very small numbers, with just eleven people in each group so results should be interpreted with caution. Work prior to this by Bosshardt and Fransen (1996) and Bosshardt, Ballmer and De Nil (2002) also concluded that phonological encoding is not impaired in AWS, but rather that they have difficulties retrieving semantic information not phonological information. As Weber-Fox et al. (2004)

found, it may be that phonological encoding only breaks down with additional cognitive load, so it may be a vulnerable process rather than a deficient one.

2.6.7 Phoneme monitoring tasks

Brocklehurst (2008) describes phoneme monitoring tasks as involving similar processes to word and rhyme judgement tasks. The main difference being that rhymes are more salient than phonemes so tasks of this nature require greater concentration and cognitive resources. Brocklehurst (2008) also states that phoneme monitoring is purely dependent upon *incremental phonological processing* rather than on *more holistic phonological processing*, which is thought to underpin rhyme judgement.

Sasisekaran, De Nil, Smyth and Johnson (2006) used silent naming tasks to investigate the phonological encoding abilities of adults who stutter. Fourteen target pictures were used, which participants were familiarised with prior to beginning testing. Participants saw each picture in a random order and had to respond yes or no as to whether or not a sound was present. Participants did not need to overtly name pictures when doing this but were required to following the judgement to ensure they were using the correct name for the picture. A sound monitoring task and simple reaction time task were also completed to check general reaction times and to assess general auditory monitoring skills. It was found that AWS were significantly slower in phoneme monitoring compared to controls but there was no difference in general auditory monitoring. There were also no differences found between groups in the simple reaction time task. The authors concluded that results suggest AWS have a specific difficulty at the level of phonological monitoring, but not a general auditory monitoring deficit. Following up from this study Sasisekaran and De Nil (2006) conducted further phoneme monitoring tasks, manipulating phonological complexity. The authors used compound words e.g. *greenhouse* and noun phrases e.g. *green house*, showing participants pictures of these and asking them to monitor for the presence or absence of a given phoneme e.g. /s/. They also asked participants to monitor for phonemes given in real words heard via headphones. This allowed authors to ascertain whether participants had a general phoneme monitoring deficit or a phonological encoding deficit. It was found that AWS were significantly slower compared to controls in phoneme monitoring during silent picture naming. There were no group differences for phoneme monitoring in words heard via headphones. Findings suggest that AWS have a phonological encoding deficit and not a general monitoring deficit. Sasisekarann and De Nil (2006) stated that, surprisingly, there was no difference within groups for more or less phonologically complex words/phrases. It was expected that participants would be slower at detecting phonemes when noun phrases were used compared to when compound nouns were used. This was not found to be the case. The authors concluded that not finding a difference here may be due to there not being enough of a differentiation in the complexity between noun phrases and compound nouns.

The findings from Sasisekarann and De Nil (2006) support psycholinguistic theories of stuttering that state AWS have impaired phonological encoding abilities, specifically the covert repair hypothesis, which states that moments of dysfluency are due to faulty phonological encoding. The study is not without criticism, however; for example in Sasisekarann and De Nil (2006) there were only 10 AWS and 12 controls and their phonological complexity manipulation did not appear to be great enough to allow for a distinction between the two types of words used (compound nouns vs noun phrases). Furthermore, there may be other explanations for group differences in phoneme monitoring, for example it may be due to difficulties encoding the phonetic code rather than the phonological one (McGuire et al., 1996 and Shergill et al., 2002).

Sasisekaran, Brady and Stein (2013) used a similar paradigm to Sasisekaran et al. (2006) and found that children who stutter (CWS) were significantly slower at detecting phonemes located in bisyllabic words. The authors used nine CWS and nine age- and sex-matched controls; they were given four tasks in total. The first was a simple motor task used to ascertain reaction time to a 0.5kHz pure tone. The second was a picture familiarisation and naming task in which twelve bisyllabic nouns were used, all taken from the Snodgrass and Vandervart (1980) picture set. The third task was phoneme monitoring during silent picture naming. The same pictures used in task two were used again here to monitor for phonemes in first and second syllable onset and offset position. The fourth and final task was an auditory tone monitoring task. The authors found that CWS were significantly slower at phoneme monitoring than their fluent peers but that there was no difference in their ability to perform the auditory tone monitoring task. This suggests that difficulties lie with phonological encoding and not with mere perception of sounds. Findings also support theories such as EXPLAN (Howell, 2004), which attributes stuttering to asynchronies in the timing of encoding phonemic units when planning and producing speech. Results could also be explained by poor phonological awareness and difficulty segmenting words. The authors also found that CWS were slower at picture naming than their fluent peers. This together with delayed phoneme monitoring may mean there are also difficulties in creating a phonetic plan prior to motor execution.

2.6.8 Phonological encoding and working memory

Work from Sasisekaran and Weisberg (2014) suggests that when phonological representations are more complex (e.g. contain more consonant clusters and sounds that typically develop later in speech acquisition), AWS have greater difficulty than their fluent peers when asked to retain nonwords. Expanding upon this, Byrd, Sheng, Ratner and Gkalitsiou (2015) investigated phonological working memory by measuring the recall of word lists. They predicted that if the phonological working memory of adults who stutter is compromised, then they would be significantly less accurate at recalling words than their fluent peers and the difference would be greatest in the phonological condition. This prediction was made as words in the phonological condition only differ by individual sound segments e.g. if the critical lure word was 'rain' then the phonological word list to be recalled included words such as 'train' and 'main'. The semantic word list included words such as 'umbrella' and 'weather'. This means that the words in the phonological list put increased load on the sub-vocal rehearsal system (Baddeley, 2003) which if compromised would lead to reduced ability to re-call these words. Byrd et al. (2015) created word lists around twelve different critical lure words and for each of these words four lists of twelve words were created. Critical lure words are words that are used to make up further lists of words; for example if the critical lure word is *tree*, semantically related words would be *green, roots,* and *bark*. The lists that the authors created consisted of twelve phonological associates, twelve semantic associates and six semantic and six phonological associates for the hybrid lists. For each lure word there were two hybrid lists. Twenty-four people were used in total, 12 who stutter and 12 fluent controls all between 18 and 30 years old. Those in the stuttering group had mild – severe stuttering but no other co-morbidities. There were 48 word lists, each with twelve words (taken from Watson, Balota & Sergent-Marshall, 2001).

Participants heard twelve of the lists and were then asked to recall as many of the words as possible in any order. They found that there was no overall difference between the two groups in accuracy of recall. However, the adults who stutter recalled significantly fewer words that were presented at the beginning of the phonological condition and the hybrid condition. The researchers explain this poor recall of initial words in the phonological and hybrid lists as being due to an impairment of verbatim phonological information and sub-vocal rehearsal. These difficulties with phonological working memory in those who stutter, appear to be subtle and limited to these aspects of Baddeley's (2003) model of working memory, with no impairment in basic memory function being found.

McGill, Sussman and Byrd (2016) used a word jumble task to investigate the ability of AWS to use phonological working memory alongside lexical access. They used English words containing between three and six letters that had been jumbled up. Participants were required to silently reorder the letters to create a real word, which they then said aloud. Graphemes were given visually, therefore participants had to translate the graphemes into their corresponding phonemes retain them and access their lexicon to make a real word. The authors found that AWS were significantly less accurate than controls at reordering the letters to make words and the difference between groups became greater as the word length increased. McGill et al. (2016) concluded that results may support the idea that differences in phonological working memory, including visual-to-sound conversions, lexical access, and sub-vocal manipulations, may be compromising the ability of AWS to be fluent. Findings also suggest that with increased cognitive load (a larger number of letters to re-order) AWS became increasingly less accurate, suggesting that phonological working memory may only become compromised with additional load.

2.6.9 Syllabic stress

Martin (1972) states that for the efficient production of English, the rhythmic stress and correct execution of syllabic stress must be realised. Martin (1972) defines stress here as the perception of prominence assigned to a syllable. This prominence is based upon fundamental frequency, duration and intensity. Wingate (1976, 1979a, 1979b, 1984, 1988) states that syllabic stress is central to understanding stuttering and proposed the Fault Line Hypothesis (1988) discussed above. Prins, Hubbard and Krause (1991) state that research into the effect of syllabic stress on stuttering has been subject to methodological flaws e.g. the use of word reading tasks (Weiner, 1984) and the use of syllable “accent” only in polysyllabic words; this results in missing any evidence for an effect of phrase-level stress that occurs in monosyllabic words (Brown, 1938; Hejna, 1972). Prins et al., (1991), used connected speech to investigate whether there is a coincidence of stuttering and syllabic stress. They used ten AWS, all male and between 15-19 years old, and asked them to read the first two sentences of the Rainbow Passage (Fairbanks, 1960). They found that participants stuttered significantly more on stressed syllables as opposed to unstressed ones and concluded that this supports Wingate’s (1988) Fault Line Hypothesis. Natke, Grosser, Sandrieser and Kalveram (2002) also found evidence that stressed syllables were stuttered on significantly more frequently than unstressed syllables. These studies have only been completed asking participants to read passages and Natke et al. (2002) states that there is a need to do this work using monologues/spontaneous speech. The fact that stuttering occurs more on stressed than unstressed syllables has been called the “stress effect” (Natke et al., 2002). Explanations have been put forward ranging from the Fault Line Hypothesis (Prins, Hubbard & Krause, 1991; Weiner, 1984; Wingate, 1988) to prosodic disturbance (Bergmann, 1986).

Coalson and Byrd (2015) investigated the stress and syllable boundary assignment in AWS, using a phoneme monitoring task in nonwords with initial stress or non-initial stress. It was found that when stress was in initial position the speed at which sound monitoring occurred was comparable for AWS and adults who do not stutter (AWNS). When the stress was not in initial position, it was found that AWS took additional time to monitor for the target phoneme when it immediately followed a syllable boundary. AWS were also less accurate at phoneme monitoring when the target sound was not in initial stress position. The authors conclude that stress and syllable boundary assignment may affect the time taken by AWS during phonological encoding. They also state that without initial stress the metrical encoding of the syllable boundary in AWS could result in a delay in speech planning and subsequent stuttering.

2.6.10 Phonological encoding and cluttering

As can be seen above, there is evidence both for and against a phonological encoding deficit in AWS. In comparison, there is very little data on whether or not there is a phonological deficit in AWC. Van Zaalen (2009), Van Zaalen and Reichel (2015), Van Zaalen Wijnen and Dejonchere (2011a) and Van Zaalen, Wijnen and Dejonchere (2009d) state that there are two subtypes of cluttering: phonological cluttering and syntactical cluttering. These subgroups differ to Ward's (2006) subtypes as they are more linguistically based. The first sub-group suggested by Van Zaalen (2009), Van Zaalen and Reichel (2015) and Van Zaalen et al. (2011a, 2009d) is phonological cluttering, which they describe as being diagnosed when speech rate is too rapid for phonological encoding skills. This then causes poor intelligibility as a result of telescoping, coarticulation and syllable sequencing errors. Syntactical cluttering by comparison is diagnosed if speech rate is not slowed to account for the linguistic complexity of the message or grammatical encoding skill of the speaker. This results in sentence revisions, phrase repetitions, interjections and semantic paraphasias. These subgroup classifications are largely based upon clinical experience rather than empirical evidence, and further work is needed to test their validity. Van Zaalen, Wijnen and Dejonchere (2009d) compared Dutch-speaking children who cluttered with those who had learning difficulties and found that those who clutter had language disturbances characterised by having insufficient time to successfully structure sentences rather than having problems with language conceptualisation and formulation.

LaSalle and Wolk (2011) conducted a case study using three 14-year-old males, one who stuttered, one who cluttered and one who stuttered and cluttered. They gathered spontaneous speech samples and coded them for dysfluent words. The grammatical class, phonological complexity (as defined by the Index of Phonological complexity (ICP) Jakielski, 1998), frequency, phonological neighbourhood density and neighbourhood frequency (the mean of the word frequencies of all the targets' phonemic neighbours) of these dysfluent words was then determind. It was found that words that were dysfluent were more phonologically complex (had higher ICP scores) and had lower phonological neighbourhood density; however, there was no difference in word frequency or neighbourhood frequency. Differences were also found within the group. For the child who stuttered and the child who stuttered and cluttered, phonological neighbourhood density did affect fluency, with those words with lower phonological neighbourhood density being more likely to contain dysfluencies. The child who cluttered, however, showed no effect of phonological neighbourhood density. The authors concluded that it could be those who clutter are less affected by phonological complexity as a predictor of their speech containing dysfluencies. More work is needed, however, as this is a case study and cannot be generalised.

2.7 Self-Repair and Monitoring of Speech

Levelt (1983) discussed self-repair and monitoring in speech and describes three areas that make up repairs:

1. The original utterance
2. The editing phase
3. The repair proper

Levelt (1983) states that the reparadum (what needs repairing) occurs in the original utterance and can be anything from a single speech sound to a stretch of text. There is then a moment of interruption that stops the flow of speech, occurring within the reparadum, just after it or following a delayed interruption (of at least three syllables). The editing phase, in which there is a period of hesitation and there may be an editing phrase such as *uh*, or *well*, then begins. Finally, there is the actual repair or repair proper.

Levelt (1983) notes that for self-correction to occur in speech there must be interplay between perceptual and productive processes. The speaker must recognise that they have made an error, something that clutterers are often criticised for not doing e.g. they do not appear to notice that they have collapsed a syllable or made a phonological error as there is rarely an attempt to correct the error. Levelt (1983) states that after recognising the error the speaker must then create a correct utterance in order to express their message as intended. We know that those who clutter can reduce their speaking rate and can avoid making errors such as omitting and deleted syllables and phonological errors. To do this, however, they must pay particular attention to their speech and actively monitor what they are saying. This suggests that AWC have difficulties in recognising errors that they make as they are able to produce error-free speech when concentrating.

Two ideas have been suggested to explain how we recognise that there is an error in what we have said (Levelt, 1983). The first, *production theory of monitoring,* states that the speaker has access to components of the production process, and when criteria are not met to a sufficient degree we detect that an error has been made and can revise what has been said. The second and widely held view*, perceptual theory of monitoring*, suggests that the speaker has no access to components of the production process. Instead the speaker parses their speech via a perceptual loop; the inner or overt speech is perceived, then parsed and checked for errors, e.g. deviating from the intended message, speech sound errors or errors related to rate, prosody and volume (Levelt, 1983). At this stage the speaker can then revise any errors made.

Monitoring occurs following parsing and is a second opportunity for the speaker to correct errors made. At this stage speech has been overtly produced, and any error correction is obvious to the listener. When monitoring our own speech we are not only checking that it corresponds with our intended message, e.g. did we say *horse* when we meant *cow*, but we are also monitoring for standards of production (Levelt, 1983) e.g. syntactic flaws, voice, prosody and rate. It is clear that AWC are often not monitoring effectively, as they are not correcting errors in standards of production, speech sound errors and rate and prosody errors. The monitoring process is also responsible for creating the means for any necessary adjustment to what has been said by alerting the speaker and sending a message to the working memory (Levelt, 1983). In AWS it has been suggested that a deficit in phonological encoding results in overt examples of covert repairs to the articulatory plan (Postma & Kolk, 1993). The monitoring system is over-active in AWS, according to this theory, due to inaccurate information that is being given at the level of phonological encoding. This results in 'errors' being corrected that do not need correction.

Importantly, Levelt (1983) states that the ability to self-repair one's speech is subject to the limitations of working memory. Working memory difficulties are not implicated by the LCD for people who clutter, but there is little data available to rule out the possibility of any difficulties. Attention, however, has been implicated as affected in AWC. As discussed above, there is co-morbidity between cluttering and ADHD (Ward, 2006), and it has been speculated that those who clutter have difficulties concentrating (Daly & Burnett, 1996; Daly & Canrell, 2006; Ward, 2006; Weiss, 1964), which is suggested as one reason why they are poor at monitoring their own speech.

Blood, Blood and Tellis (2000) completed a study using children who clutter (CWC) and tested auditory processing using The Dichotic Listening Test, The Staggered Spondaic Word Test (Katz & Smith, 1991) and The Auditory Continuous Performance Test (Keith, 1994). It was found that CWC outperformed control subjects once they were given listening and concentration strategies, suggesting that attentional control is a greater difficulty than auditory processing. Molt (1996) used CWC to assess auditory processing. He found similarities between them and those with central auditory processing disorders, e.g. all CWC were found to have poor auditory memory and demonstrated high distractibility. It is important to note however that all CWC also had a diagnosis of attention deficit disorder (ADD) or attention deficit and hyperactivity disorder (ADHD), so it is likely that results are skewed and may not reflect difficulties present in those who clutter but do not have ADD/ADHD. In contradiction to these findings Heitmann, Asbjørnsen and Helland (2004) published work suggesting that CWC did not have difficulties with attention tasks (the Posner Test of

Covert Attention Shift, Conners Continuous Performance Test and The Dichotic Listening Test). The authors do note that CWC showed a significantly shorter response time in one subtest on the Posner Test of Covert Attention Shift. They state that this may demonstrate that CWC are more impulsive than children who stutter and controls but state that we cannot ascertain if this means they have poorer attentional control than the other two groups. Results should be viewed with caution as there were only eight CWC included and they were diagnosed using the Symptoms Summary Checklist (Daly & Burnett, 1996) which is not a diagnostic tool and has been shown to have low validity and reliability (Van Zaalen et al., 2009a; 2009b). It may also be that the tests used and the environment they were given in has resulted in a deficit being missed. Those who clutter can improve their fluency when they are aware they are being tested, so it is not inconceivable that when they are aware of being tested they pay particular attention and take their time responding to tasks. Further attention testing in an informal manner would improve validity of results. In the same study Heitmann, Asbjørnsen and Helland (2004) state that CWS were found to have an impaired ability to focus attention. Once again these results must be viewed with caution as they are from just nine CWS. There is little other work to support this finding so no conclusions can be drawn about how attention may or may not be implicated in cluttering.

Vasic and Wijnen (2005) proposed that stuttering occurs due to a faulty monitoring system. Whilst they do not necessarily believe that phonological encoding is disturbed in those who stutter, they do support the covert repair hypothesis (that stuttering occurs due to covert self-corrections). Levelt (1983) suggests that as an utterance proceeds less attention is needed for the planning of the utterance and the speaker has greater resources to invest in monitoring their speech. This is why errors are more likely to be corrected towards the end of an utterance (Levelt, 1983). Arends, Povel and Kolk (1988) used dual tasks in their study to suggest that excessive attention on speech correlates with stuttering. They used counting, counting backwards in threes and spontaneous speaking alongside a demanding perceptual motor task. It was found that dysfluency rate was increased when the speaking task was more complex; however, they also found that when participants were completing the dual task there were fewer moments of dysfluency in those with severe stuttering. The opposite has been found in fluent speakers with Oomen and Postma (2002) who found that when completing a spoken task alongside a complex motor task, those who are fluent use an increased number of word repetitions and more filled pauses than when speaking alone. This work supports the idea that those who stutter are excessively monitoring their own speech.

The vicious circle hypothesis was proposed by Vasic and Wijnen (2005), who state that in those who stutter the three attention parameters for monitoring, effort, focus and threshold, are inappropriately set. This means that a greater effort than is needed is used in monitoring speech, and the speaker focuses on temporal fluctuations and discontinuity. Finally, the threshold for what is deemed acceptable output by the speaker is set too high, so even normal or unavoidable temporal fluctuations are treated as dysfluencies (described as false positives). Vasic and Wijnen (2005) used 22 AWS and 10 fluent controls and gave them four tasks: speaking only (baseline) and three speaking conditions with a secondary task. Secondary tasks included: PONG – a virtual table tennis game, set either as simple or difficult, and a word monitoring task where participants had to press a button if they said a certain word. They found that when those who stutter were distracted by a demanding visual-motor task their speech contained fewer dysfluencies; this was described as a small but significant effect. No differences in terms of fluency were given for controls. The other secondary task (monitoring for a certain word) did not reallocate attention resources, as in the table tennis game, but was used to investigate the stutterer's habitual monitoring focus. It was found that this task significantly increased the number of dysfluencies used. The authors conclude that findings support the vicious circle hypothesis as when the person who stutters can focus less of their attention on monitoring their speech, they become more fluent.

Bernstein-Ratner and Wijen (2007) took the idea of a vicious cycle further. In their paper they highlight that the VCH (vicious circle hypothesis), although supportive of the covert repair hypothesis (CRH), differs in that it does not assume that each repair in speech is due to an error. The authors state that the VCH can account for why those who stutter find they are more dysfluent in more formal or stressful speaking situations e.g. giving a presentation vs speaking to friends in a bar. In a formal situation more effort/resources are required for monitoring and focus than are needed in a relaxed speaking situation. The covert repair hypothesis cannot account for this variability. The authors speculate that when in the early stages of linguistic development some children do not set their monitoring parameters correctly, which then leads to stuttering. The authors also state that the child who stutters may have precocious development of their ability to monitor.

2.8 Non-speech motor control

Once again the knowledge base surrounding stuttering is far richer than it is for cluttering. Zelaznik, Smith, Franz and Ho (1997) used finger extension and flexion to investigate differences between PWS and controls. Participants were required to keep time with a metronome using both hands. It was found that both groups produced similar rates and also adapted their rate appropriately; however, PWS did not change their peak velocity timings over trails, producing slower and smaller movements than controls. The authors conclude that this may demonstrate that motoric differences are only seen when tasks involve multiple effector systems and need precise spatiotemporal coupling, thus resembling speech. Max, Caruso and Gracco (2003) conducted similar research to Zelaznik et al. (1997) to investigate if PWS are dysfluent due to a generalised reduction in motor control and one that is not isolated to the movements of speech. Data were collected from a speech task, an orofacial non-speech task and a finger-tapping task. Results found that although orofacial non-speech movement broadly failed to reach statistical significance, finger-tapping differences were seen. PWS were found to differ in terms of peak velocity timing and movement duration, not unlike the findings described above. The authors conclude results may demonstrate that differences between the two groups are due to generalised, not speech-specific, neuromotor differences.

With the results of these studies in mind and also the knowledge that cluttering shares many traits with stuttering, we could use non-speech motor tasks to investigate if PWC differ from those who do not due to a generalised motor deficit and not one that is isolated to the speech domain. It has been well-documented that PWC often present with poor handwriting (Daly & Burnett, 1996; Ward, 2006; Weiss, 1964), and it has also been suggested that they are clumsy (Van Zaalen et al., 2009a; Weiss, 1964). However, statements regarding general personality need to be treated with caution as there is little evidence to support them. It may be due to the high co-morbidity with dyspraxia and ADHD that we see traits including restlessness, and poor attention and co-ordination.

Smits-Bandstra, De Nil and Saint-Cyr (2006) conducted two studies comparing the speech and non-speech sequence skill learning of PWS and controls. Accuracy, reaction time, sequence duration, retention and transfer skills were all measured to assess sequence skill learning. The non-speech task used was a 30-trail finger-tapping sequence, and the speech task used was a 30-trail read-aloud nonsense syllable sequence. The authors found results comparable to those previously reported that indicated that PWS do differ to controls in speech sequencing skill over practice. There was a trend towards a practice x group interaction; people who were fluent had a decreased sequence duration relative to PWS over practice, but there was no difference in accuracy. Neither group showed significant differences in reaction time improvements over practice; however, the rate of skill acquisition between the two groups in the first five trails did differ, with PWS taking longer to learn the sequences. Neither task revealed differences between participants in terms of retention or transfer. In terms of motor learning, it was found that PWS differed to controls in the early stages of learning but not in the later stages; that is, PWS were slower to learn initially as found in the speech sequencing task.

From this work Smits-Bandstra (2010) produced a paper on the methodological considerations of conducting work with PWS when measuring reaction times. Smits-Bandstra (2010) states that due to PWS showing different practice effects to controls, independent of the task being completed, certain guidelines should be followed e.g. when the study investigating practice effects is using complex tasks there must be enough trails to allow group differences to develop over practice. At present we have no data regarding whether PWC differ to controls in terms of learning or reactions times. Any research using PWC and using tasks where reactions times are collected needs to consider the possibility that reaction times may differ not due to the task but due to difference in speed of reaction time. Until there is data comparing PWC and controls on basic reaction time tasks we cannot be certain of why we see differences between these groups.

2.9 Difficulties studying fluency

Studying fluency is not a straightforward process. There are numerous reasons for this:

1. Disagreement over the definitions of both cluttering and stuttering.
2. The high number of co-morbidities, especially with cluttering, makes differentiating between what is a characteristic of cluttering and what is a characteristic of a co-morbidity very difficult.
3. Both disorders are highly heterogeneous. They vary in severity from mild to severe; the severity may also vary in individuals depending upon their environment e.g. worse under pressure in the case of stuttering. Stuttering may be covert and therefore hidden by the speaker through careful avoidance of words/phrases/situations.
4. There is a lack of an objective measure for identifying cluttering. As has been discussed, there are recommendations for assessing cluttering but no objective, reliable and valid tools that can be used for identification and measuring severity.
5. It is difficult recruiting participants. Those who clutter are often not aware that cluttering is a disorder or that they have it.

The reasons stated above may be partly to blame for little being known about cluttering, along with there being few studies into its nature, prevalence, diagnosis and treatment. Whilst off-putting, if addressed these factors should not be barriers to research in this area. To combat the issues above, it was decided that the LCD (St Louis and Schulte, 2011) would be used to define cluttering for the purposes of the study in this thesis. This is the most up-to-date definition and the one most widely accepted. It was decided that some co-morbidities would be excluded in participants, e.g. ADHA and dyspraxia, as they may have a direct impact upon the tasks being completed. It is important, however, not to discount all participants with a co-morbidity along with cluttering, as this may result in the sample not being representative of the population given the high number of those who clutter who also have other difficulties/disorders.

2.10 Directions for further research

The literature review above clearly highlights that there is a discrepancy in the amount of data we have on stuttering compared to cluttering. The lack of empirical data on cluttering has resulted in us assessing and treating it based on best practice and clinical judgement rather than on a strong evidence base. Deciding upon what area to focus on is, therefore, very difficult, as there is still so much we do not know about cluttering. Due to this the initial pilot study, using only AWC, will consist of a language battery of eight tasks. These tasks will include phoneme detection, morphological detection, rhyme detection, verbal fluency, two sentence planning tasks and a sentence production task. Tasks will be described in more detail below. They have been chosen as they all represent areas in which we have very little data about those who clutter but far more data on those who stutter.

2.11 The pilot study

2.11.1 Rationale

As has been discussed in the literature above, there is data suggesting that people who stutter have difficulties with phonological encoding (Anderson, 2007; Anderson & Byrd, 2008; Bakhtiar, Ali & Sadegh, 2007; Bosshardt, 1993; Byrd, Conture & Ohde, 2007; Byrd, Vallely, Anderson & Sussman, 2012; Hakim & Ratner, 2004; Hennessey, Nang & Beilby, 2008; Ludlow, Siren & Zikria, 1997; Melnick, Conture & Ohde, 2003; Nippold, 2002; Sasisekaran & Byrd, 2013; Sasisekaran & De Nil, 2006; Sasisekaran, de Nil, Smyth & Johnson, 2006; Vincent, Grela & Gilbert, 2012; Weber-Fox, Spencer, Spruill & Smith, 2004) but there is very little data for those who clutter. The phoneme detection and rhyme detection tasks are proposed to address this and to establish if this may be an area that warrants further investigation. A morphological detection task will also be included to investigate if detection of differing syntactic markers is affected in a similar way to detection of phonemes.

Prins, Main, and Wampler (1997) and Hennessey, Nang and Beilby (2008) found that there is no evidence of difficulties with linguistic encoding or lexical retrieval among AWS. However, Anderson and Conture (2000) found that children who stutter showed significantly poorer scores than fluent peers on tests of receptive and expressive language. One suggestion for inconsistent results with AWS compared to children who stutter is that there may be a linguistic ‘catch up’ over the course of language development into adulthood. Research completed by Bretherton-Furness and Ward (2012) gave us preliminary data to suggest that cluttering cannot merely be characterised as a motor control, planning and execution disorder and suggests that there is also a linguistic deficit. This is a view also held by many others (Daly & Burnett, 1999; Dlay and Cantrell, 2006; Myers, 1996; Teigland, 1996; Van Zaalen, 2009; Van Zaalen & Reichel 2015; Van Zaalen et al. 2011a; 2011b;

Van Zaalen et al. 2009a; 2009b; 2009d; Ward, 2006; 2011). The research conducted by Bretherton-Furness and Ward (2012) was hampered by a small sample size but did demonstrate a significant difference between PWC and controls in terms of word finding ability and ability to plan verbal output. Due to these findings, a verbal fluency task and two sentence planning tasks are to be included in the language battery.

Work completed by Tsiamtsiouris and Smith-Cairns (2013) with PWS focused on how sentence complexity affects initiation time and whether producing more complex sentences results in decreased levels of fluency. They found that PWS and controls showed slower sentences initiation when producing more complex sentences. Both groups were also more likely to produce dysfluencies with complex sentences; however, PWS were significantly less fluent with complex sentences compared to controls. The conclusion that sentence complexity has a negative impact upon fluency is supported by the capacity and demands theory. As the sentence complexity increases (the demand) the capacity for fluent speech diminishes (Starkweather and Gottwald, 1990). Conture et al. (2006) suggest that this may be due to slow and inefficient encoding of lexical material in PWS, which burdens the speech motor system resulting in temporal timing difficulties. This theory could be used to explain the results presented by Tsiamtsiouris and Smith-Cairns (2013). The work completed by Tsiamtsiouris and Smith-Cairns (2013) has not been completed with PWC; however, similar results may be seen given the parallels with stuttering and research to date that suggests that PWC have slow lexical access (Bretherton-Furness & Ward, 2012; Daly & Cantrell, 2006; Van Zaalen, et al., 2009a; 2009b). The design used by Tsiamtsiouris and Smith-Cairns (2013) will be replicated here with PWC to investigate whether sentence complexity has an impact upon the ability to recall a sentence accurately.

Finally, a sentence comprehension task will also be included in the language battery. There is currently no data to suggest that those who clutter do or do not have any difficulties with comprehending spoken or written language. Results from further research may be misinterpreted if those who clutter have difficulties with language comprehension, which remains unknown.

2.11.2 Hypotheses for pilot tasks

Phoneme detection – when compared to fluent controls, it is predicted that those who clutter will be less accurate and take a greater length of time when detecting if a given phoneme is present or not.

Morphological detection - when compared to fluent controls, it is predicted that those who clutter will be less accurate and take a greater length of time when detecting if a given morphological ending is present or not.

Rhyme detection - when compared to fluent controls, it is predicted that those who clutter will be less accurate and take a greater length of time when detecting if two written words rhyme or not.
Verbal fluency - when compared to fluent controls, it is predicted that those who clutter will name fewer words in each of the given categories.
Sentence planning: jumbled sentences – when compared to fluent controls, it is predicted that those who clutter will take a greater amount of time to re-order sentences and will also make more mistakes e.g. by creating sentences that do not make sense or do not contain all of the given words.
Sentence planning: creating sentences – when compared to fluent controls, it is predicted that those who clutter will take a greater amount of time to create sentences, and will also make a greater number of errors e.g. creating sentences that do not make sense.
Sentence comprehension – it is predicted that there will be no difference between the performance of those who clutter and those who are fluent when completing this task.
Sentence production - when compared to fluent controls, it is predicted that those who clutter will take longer to become familiar with sentences and will make a greater number of errors when producing the sentences.

3 <u>CHAPTER THREE PILOT</u>

3.1 Method

3.1.1 Participants

We used eight AWC and eight CTLs. Among the AWC the age ranged from 21 to 57, all participants were male and education level ranged from A-level equivalent up to and including PhD. Three of the eight AWC also had a stutter, and one had previously been diagnosed as dyspraxic (a diagnosis the participant felt no longer impacted upon him). Among the control group, there was no one with any formal diagnoses, their ages ranged from 22-45, all were male and educational level ranged from A-level up to and including PhD level.

3.1.2 Ethical considerations

There was no expectation of causing any distress and there was no deception involved in any tasks. Participants were informed that they could withdraw at any time without having to give reasons. All participants received an information sheet regarding the study and signed a consent form before taking part. The study was given a favourable ethical review by the School of Psychology and Clinical Language Sciences at the University of Reading. Participants were all assigned a number code so data could not be traced back to them. Any data that could identify a participant was stored on the university network and was password protected. Hard copies of information, e.g. consent forms, were locked in a secure cabinet at the university.

3.1.3 Tasks

Each task will be described individually in more detail below. They were all presented using E-prime 2.0 (Schneider, Eschman & Zuccolotto, 2012) on a PC either in a quiet room at The University of Reading or in a quiet room at the participant’s home or office. All tasks used in the pilot included a practice section with detailed instructions before the start of the task proper; participants could complete this multiple times if they wished and had the opportunity to ask any clarifying questions. The order in which tasks were presented can be seen in table 3.1 below:

Table 3.1 Task order and the main focus of each task

Task name	**No of practice items**	**Total number of trails**	**Task purpose**
Sound detection	2	80	Phonological awareness task
Morphological detection	2	30	Syntactic awareness task
Rhyme detection	2	40	Phonological awareness task
Word fluency	1	15	Lexical access (also relies upon executive functions e.g. memory)
Sentence planning – make a sentence	2	10	Lexical access, sentence planning and use of syntax
Sentence planning – jumbled sentences	2	15	Lexical access, sentence planning and use of syntax
Sentence comprehension	1	12 (6 pairs)	Language comprehension
Sentence production	2		Sentence complexity effects on recall

3.1.3.1 Sound detection

In this first task participants had to detect when a phoneme was present in a word they heard. There were 10 words for each sound used (/f, v, p, b, ʃ, dʒ, l, r/), so there were a total of 80 trails. From the 10 words used per sound five had the target phoneme present and five did not, e.g. for /f/ the words used included: *Prettified, Officiate, Censorial, Limerick, Affronting, Painterly, Stupefying, Humidify, Chortling,* and *Protrusion*. Words used had eight, nine or 10 letters and were all multisyllabic, low-frequency words (these can be found in appendix A). Participants saw the sound they had to listen for presented as a written grapheme. Graphemes used were; /f, v, p, b, sh, j, l, r/ corresponding to the phonemes; /f, v, p, b, ʃ, dʒ, l, r/. These sounds were chosen as they cover a variety of places and manners of articulation used in English. The nature of the task required participants to have grapheme to phoneme knowledge and an understanding that these graphemes result in the phonemes above. The grapheme appeared on the PC screen until the participants pressed the spacebar, and at that point a word was played (see appendix 1). Participants then had 5000 milliseconds to respond with a ‘1’ if the word contained the target sound or a ‘0’ if it did not. Data on accuracy in detecting the phonemes when present and time taken to respond was all collected by E-prime 2.0.

3.1.3.2 Morphological detection

Participants heard a simple, common word of 1-3 syllables in length e.g. *salt* or *jumped* via a set of headphones. There were a total of 30 trails, 10 for each of the endings used. Participants were instructed to press '1' if the word contained an *–s*, an *–ing* or *–ed* ending or a '0' if it did not. Of the 10 words, five had the ending present and five did not. These endings were chosen as they are common morphological markers in English, e.g. *–ed* is used as a past tense marker more frequently then *–en*. Participants had 5000 milliseconds to respond, and their response time and accuracy was collected via E-prime. Words used can be found in appendix 2.

3.1.3.3 Rhyme detection

In this task participants saw two words appear on the computer screen and had 5000 milliseconds to press '1' if they rhymed and '0' if they did not. There were 40 words in total; they were written on the screen and were common one-, two- and three-syllable words e.g. *poster* and *computer*. Words either rhymed and were semantically related (total 10) e.g. *vet* and *pet*, or rhymed but were not semantically related (total 10) e.g. *bird* and *word*, or did not rhyme and were semantically related (total 10) e.g. *sun* and *sky* or finally did not rhyme and were not semantically related (total 10) e.g. *jelly* and *light*. Appendix 3 contains the full set of words used. E-prime, again, was used to collect data on accuracy and response time.

3.1.3.4 Verbal fluency

Here participants were asked to name as many items in a given category as they could in one minute. This is a commonly used task in assessments investigating the ability to verbally produce words which are from a given category, e.g. in The Controlled Oral Word Association Test (COWAT), part of the Multilingual Aphasia Battery (Benton, Hamsher & Sivan, 1994). The task assesses lexical access but is also very reliant upon cognitive functioning e.g. memory and attention and also appears related to education level (Cahn-Weiner, Boyle & Malloy, 2002; Rodriguez-Aranda & Martinussen, 2006; Sumerall, Timmons, James, Ewing & Oehlert, 1997). There were a total of 15 trails; categories used are listed in full in appendix 4. Seven were semantic categories, e.g. *foods that we eat,* and the other eight were words beginning with a given grapheme that appeared on the computer screen. If the grapheme given was 'p' participants had words discounted if they began with that letter but not that sound e.g. *pterodactyl* which begins with the sound /t/. Words were also discounted if they were the same word as one used previously but merely had a different suffix added e.g. *police*, *policeman*, *policewoman*. For the sake of consistency, graphemes given were the same as those used in task one. E-prime 2.0 presented tasks (as previously), and responses were recorded on a digital recorder so they could be counted for data analysis.

3.1.3.5 Planning - Make a sentence

In this task participants had to make a sentence using three words that appeared on the screen e.g. *birds, together, sky*. There were a total of 10 trails, each containing three words that were presented together on the computer screen; a full list of the words used can be found in appendix 5. Words were all nouns, verbs or adjectives; no more than one verb appeared in each set of three words and it was always in the progressive tense. Participants were instructed to keep the words in the order in which they appeared on the screen and not to change the words in any way e.g. by adding a tense marker. There was no time limit on how long participants had to construct their sentences. Once they had a sentence in mind, they pressed the spacebar and then said their sentence out loud. The experimenter recorded the sentences using a digital recorder. This design allowed the time taken to come up with a sentence to be measured and also the accuracy, which was measured by whether all the words were used in the order given and whether the sentence made grammatical sense.

3.1.3.6 Planning - Jumbled sentences

Similar to the task above, participants had to construct a sentence, but this time all the words were given to make an accurate sentence and participants had to re-order the sentence to make it make sense. Participants were instructed not to change the words in any way, to add more words or to omit any words. A total of 15 jumbled sentences were used. The full sentence appeared on the computer screen, and participants had to reorder the words; they were allowed to use a pen and paper to try and reduce the load on working memory. Once they were confident that they had the sentence correct, they pressed the spacebar and said their sentence aloud. Once again this allowed us to collect data on the time taken to construct the sentence. Sentences used can be found in appendix 6.

3.1.3.7 Sentence comprehension

The seventh task we gave participants involved listening to 12 sentences via headphone and then selecting which one of four pictures best described the sentence heard. Sentences used can be found in appendix eight. Many were taken from the comprehensive aphasia test (CAT) language assessment (Swinburn, Porter, & Howard, 2004), as sentences in this assessment which differ in terms of their complexity e.g. they are either active or passive. Therefore, the ability to comprehend a sentence in AWC can be assessed as can whether sentence complexity impacts upon time taken or accuracy. Additional sentences were also added; these additions followed the same format as the ones in the CAT, with one sentence being simple (active) and the second sentence being more complex e.g. containing embedding with or without negation e.g. *the fluffy rat is next to the bin* v.s *the rat that is fluffy is next to the bin*. A total of twelve sentences were presented in pairs, with one in the pair being active and the other passive, or one being active and the other having embedding, or finally one being active and the other with embedding and negation. Participants had to select one of four pictures which depicted the sentence that they heard; pictures were all drawn and coloured in before being entered into the E-prime program. Time taken to make a selection and the accuracy of the decision were collected by E-prime. Of the four pictures used, one was the correct selection and the other three were similar but different in at least one way. For example, if participants heard the sentence the *the doctor shot the policeman* they would see a picture of this alongside a picture of a policeman shooting a doctor and a picture of a doctor punching a policeman and finally a picture of a cheerleader shooting the policeman (see appendix 8).

3.1.3.8 Sentence production

Finally, task eight was a sentence production task in which participants saw a total of 36 complex or simple sentences (18 complex and 18 simple). Once they thought they could remember the sentence they pressed the spacebar and then said the sentence aloud. Low complexity sentences included: no clause in the noun phrase (six sentences), sentences with object- subject relatives (three sentences), sentences with the structure main-subordinate (three sentences), active sentences (three sentences) and sentences with verb phrase complement (three sentences). High complexity sentences included: relative clause in the noun phrase (six sentences), sentences with subject-object relatives (three sentences), sentences with the structure subordinate-main (three sentences), passive sentences (three sentences), and sentences with an adjunct clause (three sentences). We used this design to investigate if the complexity of the sentences affected how well participants recalled them and how long it took participants to be confident that they could recall them accurately. Sentences used can be found in appendix 9.

3.1.4 Analysis

The accuracy and time taken data for tasks one, two, three, five, six and seven were taken and compared across the two groups in SPSS. A further analysis was run in which the time taken data was excluded in all cases when the answer given was incorrect, to see if this altered the time taken by participants, i.e. were those who clutter slower when their incorrect responses were excluded, or were they faster than CTLs or did they perform as CTLs? In task two data was separated into four different morphological endings; none, -ing, -s and –ed; to investigate whether there was a difference in performance based on the ending being detected. Similarly, in task 3 data was separated to investigate whether or not there was a difference in speed and accuracy in detecting rhyme when words did rhyme vs when they did not and when words were semantically related vs when they were not. In task four a total for the number of items named in a semantic category, e.g. things you find in a kitchen, and a phonological category was created and the two groups were compared. In task seven sentences were categorised as either simple or complex and analysis was completed to assess whether there were between or within group differences in response time when responding to simple or complex sentences (data on accuracy was not compared as there was a ceiling effect in this task with most participants achieving 100%). Finally, in task eight we scored each sentence from 0-5, with zero being recorded if no mistakes were made and five being recorded if there was no attempt at the sentence or the meaning was significantly changed – see appendix 10 for full scoring details. We then compared the total scores for each participant across groups.

3.2 Results

3.2.1 Sound detection: accuracy and response times

Table 3.2 shows the mean, standard deviation and effect size for both groups. As can be seen, AWC are slower and less accurate than CTLs in sound detection.

Table 3.2 Mean, standard deviation and effect size for both groups for response time and accuracy when detecting a sound.

	Group	**Mean**	**SD**	**Effect Size (*d*)**
Correct answers	AWC	69.5	8.19	0.9
	CTLs	74.63	2.62	
Response time (seconds)	AWC	1.46	0.19	2.03
	CTLs	1.12	0.16	

A t-test revealed that AWC were significantly slower to respond than CTLs, $t(14) = 3.791$, $p < 0.001$ (one-tailed) $d = 2.03$. AWC were approaching significantly less accurate at detecting the sounds, $t(14) = 1.685$, $p = 0.057$ (one-tailed) $d = 0.9$. Effect sizes are large for both response time and accuracy (Cohen, 1988) suggesting that results show a large magnitude of difference between the two groups. Despite the *p* value of 0.057 for accuracy the effect size of 0.9 suggests that this warrants further investigation with a larger sample size.

3.2.1.1 Sound detection without incorrect responses: response times

Table 3.3 shows the mean and standard deviation for both groups. In this table the response time for incorrect responses has been excluded. As can be seen, AWC remain slower and less accurate than CTLs in sound detection. Means and standard deviations are almost identical, highlighting that whether responses are correct or not does not appear to be affecting response time.

Table 3.3 Mean, standard deviation and effect size for response time of both groups when incorrect responses are excluded in sound detection.

	Group	**Mean**	**SD**	**Effect Size (*d*)**
Response time (seconds)	AWC	1.46	0.17	2.17
	CTLs	1.12	0.16	

With incorrect responses excluded AWC were still found to be significantly slower than CTLs when detecting sounds, $t(14) = 4.069$, $p < 0.001$ (one-tailed) $d = 2.17$.

3.2.1.2 Sound detection – individual sounds: Response times

In order to see whether certain sounds took longer to detect than others for AWC, the total time taken for each sound was calculated and the mean and standard deviation are displayed in table 3.4.

Table 3.4 Mean, standard deviation and effect size for the response time of both groups for each sound.

	Group	**Mean**	**SD**	**Effect size (*d*)**
Response time /b/	AWC	1.44	0.70	1.67
(seconds)	CTLs	1.14	0.22	
Response time /f/	AWC	1.31	0.15	1.49
(seconds)	CTLs	1.06	0.21	
Response time /dʒ/	AWC	1.28	0.24	1.60
(seconds)	CTLs	0.98	0.15	
Response time /l/	AWC	1.45	0.33	1.54
(seconds)	CTLs	1.07	0.17	
Response time /p/	AWC	1.65	0.38	1.49
(seconds)	CTLs	1.22	0.20	
Response time /r/	AWC	1.70	0.33	1.85
(seconds)	CTLs	1.21	0.23	
Response time / ʃ /	AWC	1.41	0.12	1.90
(seconds)	CTLs	1.158	0.16	
Response time /v/	AWC	1.42	0.18	2.12
(seconds)	CTLs	1.13	0.11	

Using t-tests it was found that AWC were significantly slower than CTLs at detecting the presence or absence of each of the sounds: $t(14) = 3.128$, $p = 0.004$ (one-tailed), $d = 1.67$ for /b/, $t(14) = 2.791$, $p = 0.007$ (one-tailed), $d = 1.49$ for /f/, $t(14) = 2.994$, $p = 0.005$ (one-tailed), $d = 1.60$ for /dʒ/, $t(14) = 2.889$, $p = 0.006$ (one-tailed), $d = 1.54$ for /l/, $t(14) = 2.783$, $p = 0.008$ (one-tailed), $d = 1.49$ for /p/, $t(14) = 3.457$, $p = 0.002$ (one-tailed), $d = 1.85$ for /r/, $t(14)$ 3.558, $p = 0.002$ (one-tailed), $d = 1.90$ for /ʃ/ and $t(14) = 3.965$, $p < 0.001$ (one-tailed), $d = 2.12$ for /v/. Once Bonferroni correction is applied the significance drops to 0.0125 as we must divide our original p by 8 (the number of sounds). This results in all sounds remaining significant as $p < 0.0125$ with AWC being slower to detect all sounds. The effect size for all sounds is also very large so results suggest a large magnitude of difference between groups.

3.2.1.3 Sound detection – individual sounds: accuracy

As above in order to see whether certain sounds were harder to detect than others for AWC, accuracy for each sound was calculated and the mean and standard deviation are displayed in table 3.5.

Table 3.5 Mean, standard deviation and effect size for the accuracy of both groups for each sound.

	Group	**Mean**	**SD**	**Effect size (*d*)**
Accuracy /b/	AWC	8.63	2.13	0.69
(seconds)	CTLs	9.63	0.52	
Accuracy /f/	AWC	8.75	1.17	1.04
(seconds)	CTLs	9.63	0.52	
Accuracy /dʒ/	AWC	8.88	1.64	0.78
(seconds)	CTLs	9.75	0.46	
Accuracy /l/	AWC	8.00	1.69	0.53
(seconds)	CTLs	8.75	1.28	
Accuracy /p/	AWC	8.50	1.31	0.35
(seconds)	CTLs	8.13	0.99	
Accuracy /r/	AWC	8.75	1.28	0.31
(seconds)	CTLs	9.38	0.74	
Accuracy / ʃ /	AWC	9.38	1.19	4.64
(seconds)	CTLs	9.38	0.35	
Accuracy /v/	AWC	8.63	0.74	0.37
(seconds)	CTLs	9.50	0.54	

T-tests found that once Bonferroni correction was applied only /v/ remained significant, with AWC being significantly less accurate when asked to detect /v/, $t(14) = 2.701$, $p = 0.0085$ (one-tailed) which is significant as $p < 0.0125$. Before Bonferroni correction /f/ was the only other sound that was detected significantly less accurately by AWC than controls $t(14) = 1.94$, $p = 0.041$ (this did not withstand a Bonferroni correction as $p > 0.0125$).

3.2.2 Morphological detection

Table 3.6 shows the mean, standard deviation and effect size for both groups when responding to whether the ending –ing, -s or –ed is present or not. Means indicate that AWC are both less accurate and slower at detecting the presence or absence of morphological endings.

Table 3.6 Mean, standard deviation and effect size for both groups for response time and accuracy when detecting a morphological ending.

	Group	**Mean**	**SD**	**Effect Size (*d*)**
Correct answers	AWC	28.25	2.66	0.84
	CTLs	29.75	0.46	
Response time (seconds)	AWC	1.43	0.23	2.06
	CTLs	1.10	0.08	

T-test revealed that AWC were significantly slower that CTLs at detecting a morphological ending with $t(14)$ 3.847, $p = 0.001$ (one-tailed), $d = 2.06$. There was also a trend towards AWC being less accurate $t(14) = 1.572$, $p = 0.069$ (one-tailed,) $d = 0.84$. Effect sizes also are large for both response time and accuracy.

3.2.2.1 Morphological detection – without incorrect responses

Table 3.7 shows the mean and standard deviation for both groups when responding to whether the morphological endings –ing, -s or –ed are present or not. In this table the response time for incorrect responses has been excluded. The mean shows that AWC remained slower at detecting the presence or absence of morphological markers with response times for incorrect responses removed. There is no difference between the mean and standard deviation for CTLs when response times for both correct and incorrect responses are included and for when response times for incorrect responses are excluded. There is also very little difference between these for AWC, with the effect size remaining the same for both.

Table 3.7 Mean, standard deviation and effect size for response time of both groups when incorrect responses are excluded when detecting a morphological ending.

	Group	**Mean**	**SD**	**Effect Size (*d*)**
Response time (seconds)	AWC	1.42	0.22	2.06
	CTLs	1.10	0.08	

As with sound detection when response times for incorrect responses are excluded there is very little difference in means and standard deviations suggesting that participants are taking the same time to respond regardless of whether they get the answer right or not.

A t-test with response times excluded for incorrect responses revealed that there was still a significant difference with AWC taking longer to respond than CTLs, $t(14) = 3.847$, $p < 0.001$ (one-tailed) $d = 2.06$.

3.2.2.2 Morphological detection - individual morphological endings: response times and accuracy.

Table 3.8 shows the mean, standard deviation and effect size for each group when detecting the presence or absence of a morphological ending (-ing, -s or –ed). It is apparent from the mean that AWC are consistently slower than CTLs for each morphological ending.

Table 3.8 Mean, standard deviation and effect size for both groups for response time and accuracy when detecting each different morphological ending.

	Group	**Mean**	**SD**	**Effect Size (*d*)**
Response time: no ending (seconds)	AWC	1.43	0.25	1.77
	CTLs	1.12	0.08	
Response time: -ing (seconds)	AWC	1.32	0.32	1.35
	CTLs	1.02	0.11	
Response time: -s (seconds)	AWC	1.48	0.31	1.52
	CTLs	1.16	0.1	
Response time: -ed (seconds)	AWC	1.47	1.9	2.69
	CTLs	1.09	0.09	

A t-test found a significant difference between the two groups when there was no morphological ending on a word with AWC taking longer to respond yes or no than CTLs; $t(14) = 3.325$, $p = 0.0025$ (one-tailed) $d = 1.77$. There was also a significant difference between the two groups when detecting the presence or absence of each of the morphological markers –ing, -s or -ed with AWC taking longer than CTLs. For an –ing ending $t(14) = 2.527$, $p = 0.012$ (one-tailed) $d = 1.35$, for an –s ending $t(14) = 2.835$, $p = 0.007$ (one-tailed) $d= 1.52$ and for an –ed ending $t(14) = 5.032$, $p < 0.001$ (one-tailed) $d = 2.69$. Once a Bonferroni correction is applied, significance changes to $p < 0.025$ as there are four possible endings (non, -ing, -s, and –ed); AWC remain significantly slower than CTLs when detecting that there is no ending or that there is an –ing, -s or –ed ending. The effect size for each of these is also large suggesting we have a large magnitude of difference.

3.2.3 Rhyme detection

Table 3.9 shows the mean and standard deviation for both groups when the total response time over all 40 trails is taken and compared across the two groups. As can be seen AWC are slower and less accurate than CTLs in rhyme detection.

Table 3.9 Mean, standard deviation and effect size for both groups when detecting if two words rhyme or not.

	Group	**Mean**	**SD**	**Effect Size (*d*)**
Correct answers	AWC	37.5	1.77	1.42
	CTLs	39.38	0.92	
Response time (seconds)	AWC	1.22	0.24	1.64
	CTLs	0.91	0.15	

A t-tests revealed that AWC were significantly slower at detecting whether words rhymed or not with $t(14) = 3.067$, $p = 0.004$ (one-tailed) $d = 1.42$.
Data for accuracy were not normally distributed so a Mann Whitney U Test was carried out, which found that AWC were significantly less accurate than CTLs, $U = 11.5$, $p = 0.014$ (1-tailed) $d = 1.64$. Effect sizes are large suggesting a large magnitude of difference between groups for both response times and accuracy.

3.2.3.1 Rhyme detection without incorrect responses

Table 3.10 shows the mean, standard deviation and effect size for both groups when detecting if words that appeared on the screen rhymed or not. In this table the response time for incorrect responses has been excluded.

Table 3.10 Mean, standard deviation and effect size for both groups when incorrect responses are excluded.

	Group	**Mean**	**SD**	**Effect Size (*d*)**
Response time (seconds)	AWC	1.13	0.07	1.44
	CTLs	0.89	0.05	

A t-test revealed that there was still a significant difference between AWC and CTLs with response time for incorrect answers excluded, $t(14) = 2.686$, $p = 0.009$ (one-tailed) $d = 1.44$. Response time, again, does not appear related to whether the participant got the answer correct or not. Effect size remains large.

3.2.3.2 Rhyme detection – sematic relatedness and rhyme detection

In order to investigate if semantic relatedness affected ability to detect rhyme, each group's performance was compared for the following: when words rhymed and were semantically related (R_S), when they rhymed but were not semantically related (R_NS), when they did not rhyme and were semantically related (NR_S) and finally when they did not rhyme and were not semantically related (NR_NS).

Table 3.11 Mean, standard deviation and effect size for both groups for semantically related and not related words in rhyme detection.

	Group	**Mean**	**SD**	**Effect Size (*d*)**
Correct answers	AWC	0.92	0.08	1.2
R_NS	CTLs	0.99	0.04	
Correct answers	AWC	0.97	0.05	0.27
NR_NS	CTLs	0.98	0.04	
Correct answers	AWC	0.93	0.08	0.76
R_S	CTLs	0.98	0.04	
Correct answers	AWC	0.84	0.11	0.89
NR_S	CTLs	0.9	0.00	
Response time	AWC	1.30	0.27	1.63
R_NS (seconds)	CTLs	0.95	0.18	
Response time	AWC	1.22	0.26	1.58
NR_NS (seconds)	CTLs	0.91	0.15	
Response time	AWC	1.11	0.25	1.12
R_S (seconds)	CTLs	0.9	0.14	
Response time	AWC	1.26	0.3	1.52
NR_S (seconds)	CTLs	0.9	0.18	

For accuracy in detecting rhyme t-tests found that R_NS was $t(14) = 2.236$, $p = 0.021$ (one-tailed) $d = 1.2$, NR_NS was $t(14) = 0.509$, $p = 0.31$ (one-tailed) $d = 0.27$. Data for R_S and NR_S were not

normally distributed, so a Mann Whitney U test was used and it was found that for R_S, $U = 22.00$, $p = 0.11$ (one-tailed) $d = 0.76$ and for NR_S, $U = 20.00$, $p = 0.032$ (one-tailed) $d = 0.89$. Once a Bonferroni correction was applied there was only a significant difference between AWC and CTLs for R_NS with $p < 0.025$. There were no longer any significant differences between AWC and CTLs for NR_NS, R_S or NR_S as all $p > 0.025$.
There were large effect sizes for R_NS, R_S and NR_S with each $d > 0.7$; however, there was a small effect size for NR_NS suggesting a small magnitude of difference between the two groups' ability to detect rhyme in this condition.

Paired sampled t-tests showed that for accuracy there was a significant difference between NR_NS and NR_S for AWC $t(7) = 3.537$, $p = 0.010$, $d = 0.6$ and this withstands a Bonferroni correction as $p < 0.025$. There were no other significant differences for AWC. For CTLs there was a significant difference between R_NS and NR_S t(7) = 6.200, p < 0.001, d = 2.20, between NR_NS and NR_S $t(7) = 5.194$, $p = 0.001$, and between R_S and NR_S $t(7) = 5.194$, $p = 0.001$. These significant differences also withstand a Bonferroni correction as all $p < 0.025$. There are no effect sizes for NR_NS and NR_S or R_S and NR_S as the standard deviation for CTLs in the NR_S condition is 0, therefore *d* cannot be calculated.

For response time t-tests found that R_NS was $t(14) = 3.055$, $p = 0.0045$ (one-tailed) $d = 1.63$, NR_NS was $t(14) = 2.956$, $p = 0.005$ (one-tailed) $d = 1.58$, R_S was $t(14) = 2.098$, $p = 0.0275$ (one-tailed) $d = 1.12$ and NR_S was $t(14) = 2.847$, $p = 0.0065$ (one-tailed) $d = 1.52$. With Bonferroni correction applied significance drops to 0.025 as four comparisons have been calculated. This results in R_NS, NR_NS and NR_S showing a significant difference between AWC and CTLs, with AWC being significantly slower at detecting rhyme in these conditions. R_S is no longer significant as $p > 0.025$ in this condition. Table 3.11 shows that the effect size for each of these is large ($d > 0.7$).

Paired sample t-tests were also completed for response time to assess whether there were within group differences in terms of which conditions were easier to detect rhyme in. There were no significant differences between each condition for CTLs with all $p > 0.05$. For AWC there was a significant difference for time taken to react between NR_S and R_S with AWC being slower to react in the NR_S condition than in R_S, $t(7) = 3.217$, $p = 0.015$, $d = 4.36$.

3.2.4 Verbal fluency

Table 3.12 shows the mean, standard deviation and effect size for both groups when naming items in a given category e.g. clothes or when given a grapheme e.g. /p/. The means suggest that AWC name fewer items than CTLs both when given a grapheme and when given a category; however, the standard deviations are large suggesting heterogeneous data and large variation within the groups.

Table 3.12 Mean, standard deviation and effect size for each group when naming items in a given category or beginning with a given phoneme.

	Group	**Mean**	**SD**	**Effect Size (*d*)**
Graphemes (8 in total)	AWC	93.38	37.4	0.96
	CTLs	125.88	34.46	
Categories (8 in total)	AWC	108.63	33.1	1.26
	CTLs	145.13	28.65	

A t-test found that AWC named significantly fewer words beginning with a given grapheme $t(14) = 1.808$, $p = 0.046$, (one-tailed) $d = 0.96$ and they also named significantly fewer words in a given category $t(14) = 2.358$ $p = 0.017$ (one-tailed) $d = 1.26$.

3.2.5 Planning - Make a sentence

Table 3.13 shows the mean, standard deviation and effect size for both groups for accuracy in creating a sentence and time taken to plan the sentence. Based upon the mean AWC appear to take longer than CTLs and are also less accurate in creating sentences.

Table 3.13 Mean, standard deviation and effect size for both groups when planning a sentence.

	Group	**Mean**	**SD**	**Effect Size (*d*)**
Incorrect responses	AWC	2.25	1.67	1.64
	CTLs	0.38	0.52	
Time taken to think of a sentence over 10 trails (seconds)	AWC	16.17	25.1	0.45
	CTLs	8.58	4.0	

A t-test found that there was no significant difference between the two groups for the time taken to create a sentence; $t(14) = 0.842$, $p = 0.207$ (one tailed) $d = 0.45$. A Mann Whitney U test found that there was a significant difference between the groups in terms of accuracy with AWC being significantly less accurate at creating a sentence than CTLs; $U = 8.5$, $p = 0.005$ (1-tailed) $d = 1.64$.

3.2.5.1 Planning – make a sentence: incorrect responses excluded

Table 3.14 shows the mean and standard deviation for time taken by each group to plan a sentence when given three words to use. CTL's mean and standard deviation remains the same as when incorrect response times are included (table 13), for AWC both the mean and standard deviation have decreased slightly.

Table 3.14 Mean, standard deviation and effect size for both groups when planning a sentence with incorrect responses excluded.

	Group	**Mean**	**SD**	**Effect Size (*d*)**
Time taken to think of a sentence	AWC	12.1	14.4	0.35
(seconds)	CTLs	8.58	4.0	

A t-test found that with incorrect responses excluded, there was still no significant difference between AWC and CTLs for time taken to plan sentences $t(14) = 0.659$, $p = 0.261$ (one-tailed) $d = 0.35$. The small effect size also suggests that there is no difference between groups.

3.2.6 Planning - Jumbled sentences

Table 3.15 shows the mean and standard deviation for both groups when re-ordering a sentence to make grammatical and semantic sense. The means suggest that AWC were less accurate than CTLs when completing this task; however, there is only a very small difference in time taken to complete the task. Time taken to give an answer, even if it was incorrect, is given and time taken to give a correct answer is also given.

Table 3.15 Mean, standard deviation and effect size for both groups when re-ordering jumbled sentences.

	Group	Mean	SD	Effect Size (*d*)
Incorrect responses	AWC	7.38	3.29	1.55
	CTLs	3.25	2.32	
Time taken for all (seconds)	AWC	25.78	10.04	0.08
	CTLs	25.12	7.61	
Time taken, correct responses only (seconds)	AWC	23.36	10.77	0.07
	CTLs	22.78	8.23	

A t-test revealed that AWC were significantly less accurate than CTLs when re-ordering sentences; $t(14) = 2.9$, $p = 0.006$ (one-tailed) $d = 1.55$. This also has a large effect size suggesting a large magnitude of difference between AWC and CTLs.

Further t-tests showed no significant difference between the time taken to give a response and the time taken to give a correct response for the two groups both for when all responses were included; $t(14) = 0.146$, $p = 0.443$ (one-tailed) $d = 0.08$ or for when incorrect responses were excluded; $t(14) = 0.123$, $p = 0.452$ (one-tailed) $d = 0.07$.

3.2.7 Sentence comprehension

Table 3.16 shows the means, standard deviation and effect size for sentence comprehension. Interestingly CTLs can be seen to have made slightly more errors than AWC, although means show that there is very little difference and standard deviation shows there is very little variation in the data. For time taken to select a picture that corresponded to the sentence heard, it can be seen that there is a large mean and standard deviation for AWC, this was due to one outlier with one participant taking a long time over 1 trail. Once correct responses only are selected, it can be seen that there is far less variation in the data as the standard deviation drops from 14.65 seconds to 0.37 seconds.

Table 3.16 Mean, standard deviation and effect size for both groups for sentence comprehension.

	Group	Mean	SD	Effect Size (*d*)
Incorrect responses	AWC	11.88	0.35	0.88
	CTLs	11.5	0.54	
Time taken (seconds)	AWC	8.87	14.65	0.6
	CTLs	2.92	0.39	
Time taken correct responses only	AWC	3.74	0.37	1.64
(seconds)	CTLs	3.06	0.51	

A Mann Whitney U test found that there was no significant difference between AWC and CTLs regarding accuracy; *U* = 20.0, *p* = 0.0585 (one-tailed) *d* = 0.88. The effect size is large.
A further Mann Whitney U test showed that there was a significant difference between AWC and CTLs for response time *U* = 5.0, *p* = 0.0025 (one-tailed) *d* = 0.6 there was also a significant difference between AWC and CTLs when incorrect responses were excluded *t*(14) = 3.064, *p* = 0.004 (one-tailed) *d* = 1.64. The effect size is medium for total time taken but large for when incorrect responses are excluded.

3.2.7.1 Sentence comprehension – simple vs complex sentences between and within groups

Table 3.17 shows the mean, standard deviation and effect size for each group for the simple and the complex sentences. As can be seen the mean for AWC is larger for both simple and complex sentences than it is for CTLs. There is also very little variation in the data as can be seen by the small standard deviations for both groups.

Table 3.17 Mean, standard deviation and effect size for both groups for sentence comprehension, simple and complex sentences.

	Group	Mean	SD	Effect Size (*d*)
Time taken (seconds) simple	AWC	2.75	0.23	2.12
	CTLs	2.27	0.25	
Time taken (seconds) complex	AWC	3.45	0.55	1.7
	CTLs	2.66	0.43	

A t-test found that AWC were significantly slower at selecting the correct picture than CTLs for both simple sentences $t(14) = 3.975$, $p < 0.001$ (one-tailed) $d = 2.12$ and complex sentences $t(14) = 3.177$, $p = 0.0045$ (one-tailed) $d = 1.7$. Effect sizes are large for both suggesting a large magnitude of difference between the groups.

To look at the within group differences a paired sample t-test was completed. It was found that both CTLs $t(14) = 3.132$, $p = 0.0085$ (one-tailed) $d= 1.67$ and AWC $t(14) = 3.919$, $p = 0.003$ (one-tailed) $d = 2.09$ were significantly slower to respond to complex sentences than simple ones (as would be expected). As with previous tasks the effect size for both groups is large.

3.2.8 Sentence production

Table 3.18 shows the mean, standard deviation and effect size for both groups when completing the sentence production task. The higher the score a participant received the more errors they made when recalling the sentences. The means suggest that AWC made a larger number of errors than CTLs overall and for simple and complex sentences. Interestingly both groups made more errors on simple sentences than complex ones (as suggested by the means). The standard deviations for AWC are larger than they are for CTLs and this is consistent across simple and complex sentences.

Table 3.18 Mean, standard deviation and effect size for both groups for number of errors made when completing sentence production.

	Group	**Mean**	**SD**	**Effect Size (*d*)**
Sentence error score	AWC	47.75	30.59	1.41
	CTLs	16.88	12.82	
Sentence error score - simple	AWC	25.5	17.55	1.23
	CTLs	9.75	8.1	
Sentence error score - complex	AWC	22.25	14.76	1.47
	CTLs	7.13	5.06	

A Mann Whitney U test found an overall significant difference between the number of errors made by AWC and CTLs $U = 10.5$, $p = 0.0105$ (one-tailed) $d = 1.41$ with AWC making significantly more errors than CTLs with a large effect size.

For simple sentences AWC were significantly less accurate than CTLs as found by a t-test, $t(14) = 2.305$, $p = 0.0185$ (one-tailed) $d = 1.23$. A Mann Whitney U test found that for complex sentences AWC were significantly less accurate than CTLs, $U = 11.5$, $p = 0.014$ (one-tailed) $d = 1.47$. The effect sizes for both of these are large suggesting a large magnitude of difference between the two groups.

A paired sample t-test found that there was no difference between accuracy on simple vs complex sentences for AWC $t(14) = 0.853$, $p = 0.21$ (one-tailed) $d = 0.46$ or for controls $t(14) = 1.751$, $p = 0.062$ (one-tailed) $d = 0.94$.

3.2.8.1 Sentence production – time taken to recall sentences

Table 3.19 shows the mean, standard deviation and effect size for AWC and CTLs for the time taken for participants to feel confident that they can recall the sentences given. The means suggest that AWC are taking less time than controls to feel confident in recalling sentences, there is also greater variability in data from CTLs with a standard deviation of 10.37 seconds verses 2.6 seconds for AWC.

Table 3.19 Mean, standard deviation and effect size for both groups for time taken to feel confident to recall sentences in sentence production.

	Group	**Mean**	**SD**	**Effect Size (d)**
Thinking time	AWC	10.95	2.6	0.96
(seconds)	CTLs	17.77	10.37	

A Mann Whitney U test was also completed to investigate if there was a difference between the time taken to feel confident that the sentence could be recalled. It was found that there was no significant difference between the two groups, $U = 19.0$, p = 0.0975 (one-tailed) $d = 0.96$. The large effect size suggests that there was a large difference between the groups but not a significant one.

3.3 Discussion

Given the current LCD definition of cluttering, we would expect a similar performance between AWC and CTLs on all the tasks used. However, AWC were significantly slower at sound detection and morphological detection with an additional trend noted toward reduced accuracy (p = 0.057 and p = 0.069 respectively). In order to ascertain that slower response times were not just due to a difference between whether responses were correct or not, analysis was completed excluding all incorrect response times. For both sound detection and morphological detection AWC were still found to be significantly slower at responding than controls. This is in contrast to AWS who have been found to be comparable to CTLs when doing this type of task (Sasisekaran & De Nil, 2006). Initially, this might seem to suggest that AWS do not have a general monitoring deficit but AWC might. It is equally possible, however, that AWC have a general auditory discrimination deficit which impacts on both sound detection and morphological detection abilities. At present this cannot be ruled out as an explanation as we have not used a non-word sound detection task. This is planned for the main study to follow.

In the sound detection task each sound was analysed individually to establish if any of the sounds were more difficult to perceive for AWC than CTLs. It was found that AWC were significantly slower than controls regardless of the sound; however, only /f/ and /v/ were detected significantly less accurately by AWC (although /f/ did not withstand Bonferroni correction). These results suggest that the deficit is more likely a general monitoring one rather than a sound specific one. Although AWC were significantly less accurate at detecting /v/ than CTLs the effect size was only d = 0.37 suggesting the magnitude of difference is small. As above, results appear to suggest that AWC have a generalised monitoring deficit. Blood, Blood and Tellis (2000) found evidence to suggest that rather than an auditory processing difficulty, CWC have difficulties controlling their attention and need cues to enable them to perform as controls. We cannot know at this stage if attention alone is the reason for the difference between our groups or whether difficulties with attention merely contribute to the differences.

Rhyme detection findings show that AWC were both less accurate and slower than CTLs when detecting if words rhymed or not. This level of phonological awareness is described by Gillon (2004) as the intrasyllable level, where syllable segmentation is a pre-requisite to onset-rime awareness. We did not include a syllable detection task here so we cannot conclude whether difficulties are at the onset-rime level or at the syllable awareness level. Deficits in phonological awareness have been associated with reading difficulties (Bryant, MacLean, Bradley, & Crossland, 1990; Swan & Goswami 1997), and while we do not have any data suggesting that AWC (who do not have a learning disability) have reading difficulties results here support the notion of further investigation. It is also worth noting that many clients who clutter report a history of dyslexia when presenting at assessment.

Results regarding response times must be viewed with caution, as at present we cannot rule out the possibility of a generalised motor deficit resulting in slower response times than controls. (Although such an eventual finding could, in itself, provide telling insights into the aetiology of cluttering).Tasks addressing this possibility are planned for the main study.

Verbal fluency findings are consistent with those of Bretherton-Furness and Ward (2012) in supporting the notion that AWC may have difficulties with lexical access. However, verbal fluency tasks of this nature are reliant upon working memory attention and vocabulary size; it is therefore vital that tasks are completed which address lexical access with fewer other demands to enable us to conclude whether AWC have word finding difficulties or potentially, other cognitive impairments, for example, in working memory.

Also consistent with previous research (Bretherton-Furness & Ward, 2012) is the finding that AWC were less accurate at sentence planning – specifically, correctly reordering sentences - and this group also experienced problems creating sentences from words already given to them. Demands upon working memory were minimised as words/sentences were left on screen for participants to see until they were ready to give an answer. Participants also had a pen and paper to assist with re-ordering jumbled sentences. Interestingly, seven out of eight AWC did not use the pen and paper compared to three out of eight controls who did not.

It is important to note that this data is for a pilot only and therefore the number of participants is small. There are also further controls that would be put in place if these tasks were to be used in the main study to follow. For example, in the phoneme detection task the position of the target phoneme in the word should be controlled for. Some tasks used also contain a small number of trails, e.g. the sentence comprehension task has only six pairs of sentences which limits the amount of data available. Finally, it is important to note that three AWC also had a stutter, this is a common co-morbidity with cluttering but may skew results as these three participants are not *pure* clutterers. As has already been discussed it is important not to discount anyone with any co-morbidity along with cluttering as this may result in the sample not being representative of AWC. That being said, it is also important that we consider the influence that any co-morbidities may have on the results of those who clutter.

Taken together, and alongside recent findings (Bretherton-Furness & Ward, 2012), these data provide preliminary evidence that those who clutter show evidence of subtle language disturbances at lexical and phonological levels. Van Zaalen, Wijnen and Dejonckere (2011a) and Ward (2006) had already offered opinions on this very possibility, albeit with slightly different interpretations of the data available. Of course, this is a preliminary interpretation, taken from a small experimental cohort, and the potential significance awaits findings from our ongoing and larger-scale research at Reading. If verified with larger numbers (and subsequently across different laboratories) there are potential ramifications, both for cluttering definition and cluttering therapy.

3.4 Going forward

The following chapter lays out the rationale and hypothesis for the main study. It was decided to progress by investigating phonological encoding by assessing phonological awareness in both AWC and AWS. This decision was made due to the phoneme detection and rhyme detection tasks above suggesting that AWC may have difficulties in this area. As described in the literature review, it is well-documented that AWS have difficulties with phonological encoding but we are lacking in data regarding those who clutter. The aim for the main study is to establish if those who clutter have difficulties with phonological encoding and if so how they compare to those who stutter. Tasks used to do this, the rationale for using them and hypotheses can be found in the following chapter.

4 CHAPTER FOUR MAIN STUDY

4.1 Reaction time tasks

In order to control for the possibility that any differences between AWC, AWS and fluent controls are not just merely down to differences in reaction times (RT); two RT tasks will be given to participants. It has been found that practice effects differ in adults who stutter (AWS) compared to fluent controls and these differences are dependent upon task complexity (Smits- Bandstra, De Nil & Saint-Cyr, 2006). RT differences between AWS and controls for simple tasks are largest immediately and RT differences between the groups for simple tasks are much smaller after practice, the opposite has been found for complex tasks (Smits-Bandstra, 2010). Following her paper on potential methodological difficulties using reaction time data with AWS, Smits-Bandstra (2010) gave an RT study guide which will be followed in the design used here, e.g. ensuring that for our simple reaction time task there are enough trials to ensure we do not just get differences in practice effects.

4.1.1 Reaction time task one

In the first RT task participants will only have to respond to the presence of a cross on the right or left of a computer screen with either a left or right key press, depending upon where the cross appears.

4.1.1.1 Hypothesis

It is predicted that there will be no overall difference between AWS and controls in terms of accuracy or reaction time. This is based upon findings by Smits-Bandstra (2010), who found that whilst there are practice effect differences between AWS and fluent speakers, these initial differences in simple RT tasks do not hold with sufficient trails. It is also predicted that there will be no difference between AWC and controls in terms of accuracy or RT as there is no evidence to date to suggest that there will be a difference.

4.1.2 Reaction time task two

The second task is more complex. Participants will be presented with a 10-number string which they will have to type out numerically as quickly as possible. A 10-number string was chosen as Smits-Bandstra, De Nil, & Saint-Cyr (2006) found that using fewer numbers, e.g. six or eight, resulted in a ceiling effect being reached after just a few trials.

4.1.2.1 Hypothesis

It is predicted that there will be no difference between AWC, AWS and controls in terms of accuracy or reaction time. Smits-Brandstra et al. (2006) found that while practice effects differ between AWS and controls their accuracy and over-all reaction time for this task did not differ. To date there is no evidence to suggest that AWC show any differences in reaction times or practice effects compared to fluent speakers.

4.2 Phoneme monitoring tasks

In all phoneme monitoring tasks phonemes to be monitored for include; /p, d, m, s, k, n, t, l, b, f, r, ʃ/. No vowels will be used. There are a number of reasons for this, previous research has always focused on consonants (Sasisekaran & De Nil, 2006; Sasisekaran, De Nil, Smyth & Johnson, 2006) and the following tasks are a rough replication of the methods used by these authors. A further reason is that vowel sounds vary a great deal based upon regional dialect, which could impact upon the validity of the study.

4.2.1 Real word phoneme monitoring (RWPM)

The third task, phoneme monitoring across real words is being used as in our pilot we used low frequency words between two and four syllables long and asked adults who clutter (AWC) to indicate if a speech sound was present or not. In the pilot study it was found that AWC were significantly slower at sound detection and were approaching significantly less accurate ($p = 0.057$). We know that AWS have been found to be similar to controls in terms of accuracy when doing this type of task but they are slower to respond than controls (Sasisekaran & De Nil, 2006; Sasisekaran, De Nil, Smyth & Johnson, 2006). This initially suggests that those who stutter do not have a general monitoring deficit, however, those who clutter may. This needs to be repeated with more participants as in the pilot we only had eight AWC. There were also methodological differences in the pilot e.g. we used the letter to indicate which sound to listen for, here we will use the speech sound presented via headphones e.g. /s/ followed by *basket*. We also want to see if we can replicate previous findings from adults who stutter (AWS) that they are similar to fluent speakers when just asked to monitor for the presence or absence of speech sounds.

4.2.1.1 Hypotheses

Based on what we know already, our hypothesis for task three is that AWS will perform as controls in terms of accuracy of responses but they will be significantly slower than controls (consistent with

Sasisekaran & De Nil, 2006). It is predicted that AWC will also perform significantly more slowly than controls and significantly less accurately then the other two groups as was suggested in our pilot.

4.2.2 Non-word phoneme monitoring (NWPM)

In the fourth task, participants will repeat the task described above but with non-words rather than real words. The non-word monitoring task was chosen in order to establish whether there is a general auditory processing deficit we need to use non-words as the participants do not need to access the meaning of the word (as they have no meaning), to decide if a sound is present or not.

4.2.2.1 Hypothesis

Based on the findings and hypotheses described in section 4.2.1.1 (above) it is predicted that AWS will perform as controls in terms of accuracy of responses. It is also predicted that AWS will be significantly slower than controls, as they have been found to be when real words are used (Sasisekaran & De Nil, 2006; Sasisekaran, De Nil, Smyth & Johnson, 2006). There is some suggestion that those who clutter may have a general auditory processing deficit (Molt, 1996), however, there is also evidence to the contrary (Blood, Blood & Tellis, 2000) it is predicted that AWC will be significantly less accurate than AWS and controls, and significantly slower to respond than controls, based on findings from the pilot study.

4.2.3 Phoneme monitoring in silent reading (PMSR)

The next task, phoneme monitoring when silently reading, will involve participants being presented with a written word and being asked to indicate if the target sound is in the word or not. Once again the target sound will be played over headphones and then the word will appear on the screen.

4.2.3.1 Hypothesis

It is predicted that AWC and AWS will be no different to controls in terms of accuracy in this task. This prediction is made as there is no evidence to suggest that AWC or AWS have any difficulties with grapheme to phoneme representation. Those who stutter have also been found to only have difficulties with phonological encoding when tasks have increased difficulty e.g. are linguistically complex (Sasisekaran & De Nil, 2006; Sasisekaran, De Nil, Smyth & Johnson, 2006). In terms of time taken to respond, we expect there to be no difference between controls and those who stutter due to the reasons given above. Those who clutter are expected to take significantly longer than controls in this task. This is driven by the pilot study findings and the knowledge that whilst those who clutter have not been found to have difficulties with reading or with grapheme to phoneme correspondence they have been predicted to have a generalised deficit with phonological encoding.

4.2.4 Phoneme monitoring in silent picture naming (SPN)

Task six, monitoring in silent picture naming, addresses phonological encoding skills which have been implicated as being impaired in AWS (Howell, 2004; Packman, Code & Onslow, 2007; Perkins, Kent and Curlees, 1991; Postma & Kolk, 1993; Sasisekaran & De Nil, 2006; Sasisekaran, De Nil, Smyth & Johnson, 2006; Wingate, 1988). Sasisekaran and De Nil (2006) found that AWS were significantly slower than controls in monitoring for a speech sound when they were silently naming pictures at the same time. We have no data on AWC at present.

4.2.4.1 Hypothesis

AWC and AWS will be significantly slower at responding to whether the sound is present or not and AWC will also be significantly less accurate compared to controls. This hypothesis is made based on the pilot study findings that indicated AWC may have a general monitoring deficit and also on Sasisekaran and De Nil's (2006) finding that AWS appear to have a deficit in phonological encoding.

4.3 Syllable detection tasks

A further component of phonological encoding involves the generation of syllabic structure (Indefrey & Levelt, 2000). In order to fully understand whether AWC and AWS have difficulties with phonological encoding we need to look at all the processes involved, as laid out by Levelt (1998). It has been found that adults who stutter have difficulty initiating syllables with suggestions that the syllable is key to the development of stuttering (e.g. Packman et al., 2007). In order to establish if difficulties are limited to initiating syllables when speaking we need to investigate whether there is a difficulty perceiving syllables. The evidence for AWC is far less enlightening, there has not been any data or speculation that AWC have difficulties initiating syllables; as their difficulties are not with initiating speech but with speaking at an appropriate rate or rhythm. However, AWC have been found to have difficulties with phonological encoding (from our pilot) therefore, we must look at all components of phonological encoding to establish if there is a generalised deficit or one that is specific to just one aspect of the process.

4.3.1 Syllable detection in real words (SDRW)

In the seventh task participants will hear real words containing two, three and four syllables and will be required to identify how many syllables the words have.

4.3.1.1 Hypothesis:

It is predicted that both AWS and AWC will perform significantly more slowly and significantly less accurately than controls. This is based on findings from the pilot study that suggest AWC may have a general phonological encoding deficit, and that AWS have difficulties that may not be limited to just initiating syllables but also to identifying them in spoken words.

4.3.2 Syllable detection in non-words (SDNW)

In the eighth and final task participants will be presented with non-words of two, three or four syllables. As before, participants will be asked to identify how many syllables each word has.

4.3.2.1 Hypothesis

As in task seven it is predicted that both AWS and AWC will perform significantly more slowly and significantly less accurately than controls.

4.4 Methods in the main study

The chapter that follows gives details of exactly how each task has been carried out, the participants who took part, the materials and stimuli used, and how data has been analysed. There is an additional chapter (chapter six) which gives specific detail of how non-words were created. (Also see Bretherton-Furness, Ward & Saddy, 2016).

5 CHAPTER FIVE METHOD and PROCEDURE

5.1 Participants

5.1.1 Inclusion criteria

A total of 43 people took part in the study; 14 who stutter, 14 who clutter and 15 control subjects. Participants in the experimental groups (AWC & AWS) were all between 19 and 55 years of age and had a formal diagnosis of cluttering and/or stuttering. The average age of those who clutter was 34 years old and the average age of those who stutter was 40 years old. There was one female and 14 males in the cluttering group and two females and 13 males in the stuttering group. All diagnoses were given by an experienced, specialist speech and language therapist. In the case of cluttering this was via the lowest common denominator definition (St Louis & Schulte, 2011) and for those who stutter the DSM-5 diagnostic criteria (APA, 2013) was used (details of which can be found in chapters one & two). The stuttering severity instrument fourth edition (Riley, 2009) questionnaire and syllables stuttered (SSI-IV) was also used in deciding upon inclusion of AWS.

The control group consisted of 15 fluent speakers, one female and 14 males all between 19 and 55 years with an average age of 34 years old. Participants had an education level of A-level (or equivalent) or above and all stated that they had no neurological impairments e.g. had never been treated for stroke, traumatic brain injury or treated for a progressive neurological condition prior to or during the study.

Participants were recruited through an advertisement placed on the British Stammering Association website, though SLTs and though social contacts.

5.1.2 Participant screening

All participants completed a set of screening of questions (appendix 11). Questions were designed to ask about possible developmental disorders e.g. dyspraxia, previous speech therapy intervention, and possible speech/language disorders. This was all based on self-report but participants were advised that all information was confidential and it may affect results if they did not disclose something which may impact upon the study. All participants reported no known co-occurring language deficits e.g. history of specific language impairment. All of the participants' first language was English; they had no hearing deficits, or co-occurring diagnosis of attention deficit and hyperactivity disorder (ADHD), dyspraxia (verbal or general) or dyslexia.

As additional screening, each participant completed four subtests (picture naming, onset segmentation, offset segmentation, and word rhyme judgement) from the Psycholinguistic Assessment of Language Processing in Aphasia (PALPA; Kay, Lesser, & Coltheart, 1992). These tests are designed to assess differences in vocabulary and phonological knowledge, both of which are focii in our study. These subtests have been used in previous studies of a similar nature to control for any differences in the attributes listed above e.g. Sasisekaran and De Nil (2006). There are of course limitations in using tests of this nature; as they were designed to identify language and processing difficulties following a stroke. However, as already discussed in the introduction there are no tests currently available that can be reliably used to differentiate between those who are dysfluent and those who are fluent in terms of their language ability. These tests do, however, allow identification of any large differences between our groups. Participants had to achieve scores in the normal range to be included in the study (as defined by the PALPA subtests, Kay, Lesser, & Coltheart (1992)). Table 5.1, below, gives a breakdown of scores on all subtests, for each group of participants. No individual scored below 40 in the Spoken Picture Naming task (a mean correct of 39.80 is required by the PALPA to be within normal limits (WNL)). In phonological segmentation of initial sounds (real words) no individual had a score of less than 29/30, with two AWC getting 29/30, giving a mean of 29.85 which is larger than the mean of 29.36 required for participants to be WNL. In phonological segmentation of final sounds (real words) no individual scored below 30/30, (a mean correct of 29.29 is required to be WNL). The Rhyme judgement task does not have norms currently available; however, as no experimental participants scored less than 59/60 they did not differ significantly from the control group so no one was excluded from the study.

Table 5.1 Mean correct for each group on subtests used from the PALPA.

Participant group	**Spoken Picture Naming (out of 40)**	**Word Rhyme Judgement (Out of 60)**	**Phonological Segmentation of Initial Sounds (real and made up word) (Out of 30)**	**Phonological Segmentation of Final Sounds (real and made up word) (Out of 30)**
AWC	40	59.93	29.85	30
AWS	40	60	30	30
Controls	40	60	30	30

Additional screening data that was collected included completion of the Edinburgh handedness assessment (revised version; Williams, 2010) and the stuttering severity instrument fourth edition (Riley, 2009) questionnaire and syllables stuttered (SSI-IV), where appropriate. The handedness score for each participant can be found in appendix 12. The Edinburgh handedness assessment was completed to check for outliers (of which there were none) based upon dominant hand.

5.1.3 Stuttering severity

The percentage of syllables stuttered for each participant in the stuttering group can be found in appendix 13, this percentage was based on reading 209 syllables from the Rainbow Passage (Fairbanks, 1960) and from between 203 and 217 syllables of conversation with the experimenter. It was found that all AWS were considered to be mild to moderate in severity (as measured by the SSI-IV).

5.1.4 Cluttering severity

AWC were all deemed to be mild to moderate in severity. Whilst cluttering can be identified by the presence of features in the LCD definition, the measurement and classification of cluttering severity currently defies objective measurement. Judgments were therefore, based upon clinical impression at assessment. In the absence of a standardised, reliable and valid way to assess severity in cluttering this was deemed to be the most robust form of assessing severity. Table 5.2 below details how mild, moderate and severe have been characterised.

Table 5.2 Definitions used for assigning mild, moderate or severe to AWC

Mild	**Moderate**	**Severe**
Few moments of rapid and/or irregular speech rate which are infrequent but result in moments of unintelligibility. Occurring less than 10% of the time. Infrequent occurrences of 'normal' disfluencies; collapsing or deletion of syllables; and/or abnormal pauses, syllable stress, or speech rhythm (not all three need to be present).	Rapid and/or irregular speech rate. Occurring between 10% and 25% of the time and resulting in speech being unintelligible. Occurrences of one or more of the following; excessive 'normal' disfluencies; collapsing or deletion of syllables; and/or abnormal pauses, syllable stress, or speech rhythm.	Rapid and/or irregular speech rate. Occurring between 25% and 100% of the time, resulting in large sections of speech being unintelligible. Noticeable occurrences of one or more of the following; excessive 'normal' disfluencies; collapsing or deletion of syllables; and/or abnormal pauses, syllable stress, or speech rhythm.

5.2 Ethical considerations

The study was given a favourable ethical review by the University of Reading ethical committee and the NHS Research Ethics Committee. There was no expectation of any tasks causing any distress and there was no deception involved in any tasks. Participants were informed that they could withdraw at any time without having to give reasons. Clinical participants were also informed that participation would not affect access to therapy now or in the future and tasks did not have a therapeutic nature. All participants received an information sheet regarding the study and signed a consent form before taking part. Participants were all assigned a number code so data could not be traced back to them. Any data that could identify a participant was stored on the university network and was password protected. Hard copies of information e.g. consent forms were locked in a secure cabinet at the university.

5.3 Data collection

All data collection occurred at the University of Reading, in a participant's own home or at their place of work depending on what was most convenient for them. Participants were seated in front of a laptop computer and were instructed to use the keyboard to respond to tasks.

All tasks used were presented using E-prime 2.0 (Schneider, Eschman & Zuccolotto, 2012) and reaction time data and data on accuracy were collected via E-prime 2.0. There was a practice section before each task consisting of four to five trails, this gave participants a chance to familiarise themselves with each task that would follow. Participants were informed that they could complete practice items multiple times if they wished and were given the opportunity to ask any clarifying questions before and after the practice trails.

5.4 Tasks

5.4.1 Reaction time tasks

<u>Simple reaction time experiment</u> – participants were asked to press either a '1' or '0' key depending on whether a cross was on the left (1) or right (0) of a vertical line dividing the computer screen in half. An example of the stimulus E-Prime screen can be found in the appendix 14. In this task a small black cross appeared on one side of a black vertical line down the middle of the screen separating the page in two. The cross appeared on either side of the screen 20 times giving a total of 40 trials with four practice trails. Each cross appeared for 1.5 seconds. If there was no response in this time a 'no response' result was collected and they were deemed to have not responded.

Complex reaction time experiment – participants were asked to type out a 10 digit number sequence as quickly and as accurately as possible. There were 20 trails in total with four practice trails. A full list of the number combinations used can be found in appendix 15. This task also used E-Prime 2.0 to present the trials. Participants were presented with a horizontal 10-number string (comprising numbers 1-4) on the computer screen and were asked to type it out as quickly and as accurately as possible. They were instructed to use their dominant hand and to type out the numbers on four horizontal buttons (1-4) on the computer keyboard (also see Smits-Bandstra, De Nil & Saint-Cyr, 2006). Participants were instructed to keep going even if they made a mistake as the screen would not change until 10 digits had been pressed. In both of these reaction time tasks stimuli were randomised so each participant saw crosses and number strings in different orders.

5.4.2 Task 3: Real word phoneme monitoring task (RWPM)

Participants were instructed to monitor for the presence of selected phonemes appearing in spoken real words. They saw the instructions:

> *"In this task you will hear a sound that you need to listen out for. You will then hear a word and you must press 1 if the target sound is present or 0 if the target sound is not present".*

The first thing presented was the individual phoneme that participants needed to monitor for e.g. /p/. They then heard a word (e.g. lamp) and had to press a 1 key if the sound was present or a 0 key if it was not. Participants heard all words via headphones while sitting in front of the computer screen. A total of 226 words were used which had been taken from the Snodgrass picture set (Snodgrass & Vanderwart, 1980) these pictures were also used in later tasks. A full list of Snodgrass words used, including phonological transcription, can be found in the appendix 16. This picture set is standardised and there is data as to word familiarity, typical age of acquisition and picture to name agreement. There is also standardised data showing that the pictures match the target name, this was especially important in the silent picture naming task. Words that are less commonly used in English e.g. *wrench* (picture of a *spanner*) were excluded as participants may not be familiar with them. Other exclusions were made when a word was a noun phrase e.g. *wine glass*, as only nouns were used in these tasks. Full details of all words excluded and why they were excluded, can be found in the appendix 17.

The target sounds which were monitored for included; /p, d, m, s, k, n, t, l, b, f, r, ʃ/. These sounds were selected as they occur in the Snodgrass word set at least six times at either syllable initial or syllable final position (but not including word initial position). There were 18 or 19 words in each sound set and the target sounds appeared between six and 10 times in each set. Full details of the occurrence of words in sound sets can be found in the appendix 18. In each sound set there was a total of between 29-33 syllables with each word having between one and four syllables. Reaction time data and data on accuracy were collected via E-Prime 2.0.

5.4.3 Task 4: Phoneme monitoring across non-words (NWPM)

Full details of how a non-word list was created to match the 226 Snodgrass pictures can be found in the following chapter. In this task, as before, participants saw the instructions:

> "*In this task you will hear a sound to listen for followed by a made up word. You need to press 1 if the sound is present or 0 if the sound is not present*".

The difference to task 2.3.2 is that non-words were used in place of real words. Using the ARC NON-WORD DATABASE (Rastle, Harrington, & Coltheart, 2002) and Wuggy software (Keuleers & Brybaert, 2010) non-words were created which were matched to real words phoneme length, syllable length, presence or absence of the target sound, place in which the target sound occurred when it occurred and stress pattern. A full list of non-words can be found in the appendix 19. Bigram frequency data was calculated for real and non-words. A Wilcoxon signed rank test found that there was not a significant difference between bigram frequencies ($z = -0.123$, $p = 0.902$). (A full list of bigram frequencies and differences can be found in appendix 20.) None of the non-words differed to the real words by more than two standard deviations (more than five bigrams) and the greatest difference was six occurrences of a bigram vs one occurrence of it. This ensures that whilst the words varied they did not do so to an extent that can no longer be considered similar.

Non-words were presented via headphones and, as in RWPM, each word was preceded by the sound that needed to be monitored for, e.g. /s/. Participants heard 226 non-words in a random order and had to press a '1' key if the sound was present and a '0' key if it was not. The target sounds which were monitored for were identical to those used in the real word phoneme monitoring task Also consistent with the earlier task, there were eighteen or nineteen words in each sound set and the target sound appeared between six and ten times. Full details of the occurrence of words in sound sets can be sound in the appendix 21. In each sound set there was a total of between 29-33 syllables with each word containing between one and four syllables.

5.4.4 Task 5: Phoneme monitoring in silent reading (PMSR)

The following instructions appeared on the screen at the start of this task:

> *"In a moment you will hear a sound that you have to listen out for. You will then see a selection of words and you must indicate if the target sound is present or not by pressing 1 for YES and 0 for NO. Do not focus on the spelling but rather on how the word sounds if you were to say it".*

The same 226 Snodgrass words used in the phoneme monitoring in real words were used for this task. Participants first heard a target sound e.g. /f/, they then saw a written word e.g. *car*. Participants were instructed to silently read the word and then press the '1' key if the sound was in the word or the '0' key if it was not. The sounds monitored for were the same as in previous tasks RWPM, NWPM and PMSPN.

5.4.5 Task 6: Phoneme monitoring in silent picture naming (PMSPN)

In this task, the following instructions were presented on the screen:

> *"In a moment you will hear a sound that you have to listen out for. You will then see a picture and you must indicate if the target sound is present or not by pressing 1 for YES or 0 for NO. Focus on how the word sounds rather than its spelling. Do not say anything out loud at this point. After you have indicated if the sound is present or not you must say the name of the picture aloud."*

Participants saw pictures of the Snodgrass words used in the phoneme monitoring in real words task and the phoneme monitoring in silent reading task. The Snodgrass pictures have been standardised (when they were created to ensure high picture to name correspondence) and were presented here in colour. A full set of the pictures can be found in the appendix 22. Participants heard a target sound, as before, and without naming the picture they were presented with had to press a '1' key if the sound was present and a '0' if it was not. Participants were told to say the word in their head and to think about the way the word sounded in order to inform their judgment. They then overtly named the picture to check that the right name was used. Any pictures named incorrectly were excluded from analysis. A familiarisation period preceded this task; participants were shown a booklet containing all 226 Snodgrass pictures. Participants saw these pictures and their corresponding names and were told that these were the names that should be used for these pictures. Participants were then asked to name each of the pictures with the experimenter giving corrections if any errors were made. Consistent with previous tasks the sounds monitored for were /p, d, m, s, k, n, t, l, b, f, r, ʃ/ and they appeared in the words as they did for in the real word monitoring task (see appendix 18 for a full list of words and where target sound occurred).

5.4.6 Task 7: Syllable detection in words (SDW)

In this task participants had to respond to multisyllabic words by indicating on a keyboard how many syllables the word has. Before beginning this task participants saw the following instructions:

> *"In this task you will hear real words and you need to press 2, 3 or 4 on the keyboard to indicate how many syllables the word has. The first 4 words will be practice. Ask any questions now."*

In this task words used had two, three or four syllables. Snodgrass word were used, however, additional words were needed as there were too few three and four syllable words in the Snodgrass picture set. In order to decide upon additional words to add we kept words as similar to Snodgrass words as possible. All additional words used were nouns and were not statistically less frequent than the Snodgrass words. In order to gain data on the frequency of the Snodgrass words used and words that were added the English Lexicon Project Web Site (Balota et al., 2007) was used. The goal of this project was to provide researchers with descriptive characteristics of words that could be used in research projects, including the frequency with which a word is used. Balota et al. (2007) suggest that researchers use data on word frequency from the HAL study. Balota et al. (2007) describe HAL frequency as:

> *"Freq_HAL refers to the Hyperspace Analogue to Language (HAL) frequency norms (Lund & Burgess, 1996), based on the HAL corpus, which consists of approximately 131 million words gathered across 3,000 Usenet newsgroups during February 1995. Log_Freq_HAL refers to log-transformed HAL frequency norms." (*Balota et al., 2007 pp. 450).

A list of the words used here and their frequency scores can be found in appendix 23. Descriptive statistics showed that the mean frequency of all words was 7.31. Only 3/100 of the words used were greater than two standard deviations more frequent than this mean. It was also found that three percent of the words used could not be computed by the software (*origami*, *mozzarella* and *margarita*). Due to this, five monolingual speech and language therapy undergraduate students aged

25-30 years old were asked to rate how familiar they found these words together with the other 97 words chosen. Each word was rated out of 10 for how familiar it was, with 10 being highly familiar and one being not at all familiar. It was found that none of the words scored less than 46/50 from five raters for familiarity.

When completing the task participants heard a word which was presented via headphones, they were then asked to press two, three, or four on the keyboard to indicate how many syllables they believed the word contained. There were a total of 100 trails and reaction time data and data on accuracy was collected via E-Prime 2.0.

5.4.7 Task 8: Syllable detection in non-words (SDNW)

In this task participants heard non-words and had to indicate how many syllables the word has. Instructions appeared on the computer screen prior to beginning:

> *"In this task you will hear made up words and you need to press 2, 3 or 4 on the keyboard to indicate how many syllables the word has. The first 4 words will be practice. Ask any questions now."*

In-order to present this task a non-word list had to be created to match the real words used in the previous task. The Wuggy software (Keuleers & Brybaert, 2010) was used to do this. Words were matched to real words in terms of; phoneme length, syllable length and stress pattern. Letter bigram frequency data was calculated for real and non-words. A Wilcoxon signed rank test found that there was not a significant difference between letter bigram frequencies ($z < 0.001$, $p = 1.000$). Bigrams for real words and non-words were also all within two SDs of each other. A full list of phonologically transcribed non-words, letter bigrams and the difference between real and non-words can be found in the appendix 24 and 25 respectively.

As in the task above, participants heard words via headphones and had to indicate whether they contained either two, three or four syllables by pressing keys on the keyboard. There were a total of 100 trails and data on accuracy and response time was collected by E-prime 2.0.

5.5 Data Analysis

5.5.1 Main analysis

All data was analysed using IBM SPSS Statistics 22. The simple and complex reaction time tasks were analysed using a one way ANOVA to ascertain if there was a difference between all three groups in terms of accuracy and response times. No further analysis was completed on this data as these tasks were included merely to ascertain whether there was a difference between AWS, AWC and controls in terms of ability to react to a stimulus.

All data from the phoneme monitoring tasks (RWPM, NWPM, PMSPN & PMSR) and syllable detection tasks (SDW & SDNW) was first analysed using a one-way ANOVA to establish if there was a main effect in terms of accuracy and response time between each group. Post hoc analysis was then used to establish where any differences lay. If significant differences were found generalised estimating equations was used which showed which if any of the variables were driving the differences.

5.5.2 Rational for further analysis

Generalised models came about to allow regression type modelling to be run on data that is not normally distributed or with a dependent variable which is binary (as we do with correct or incorrect responses) (IBM Knowledge Centre, 2013). As our question here is about whether there are differences between the three groups in terms of accuracy and/or response time, and then to investigate if any of our predictors are driving this difference, a regression would be the most effective way of addressing this. A standard generalised linear model cannot be used with our data however; as data collected are not independent. Our data contains contextual variables; the participants within their groups are not independent as they're members of the same clinical or non-clinical group. This means there may be correlations between residuals as the groups' participants are similar to each other. Due to this non-independence we either have to use a generalised linear mixed model or generalised estimating equations. Generalised estimating equations were deemed most suitable as they are used when modelling the mean of a population's responses of non-independent binary data as a function of covariates. As there are three groups in this study (AWS, AWC and controls) there are three different populations and what is of interest is the difference between these three populations.

A final reason for the use of generalised estimating equation modelling rather than generalised linear mixed modelling is that due to the number of predictors and the number of levels within those predictors e.g. eight in number of phoneme and four in number of syllables, it would not be possible for the model to reach convergence. What this would mean is that the model would either never finish running or it would partially run before giving an error message stating that convergence (or a result) could not be completed.

In order to establish if any of the potential predictors do in fact predict differences between the groups, each predictor has been entered into SPSS and subsequently the GEE model. The number of syllables in a word (range one to four), the number of phonemes each word has (range one to nine), the position of the stressed syllable in each word (0 for initial stress, 1 for stress on the second syllable, 2 for stress on the second syllable, and 3 if the stress was on the final syllable), whether the target was present or not (1 for yes, 0 for no); and finally the location of the target phoneme in the word (0 target not present, 1 for the end of the first syllable, 2 for within the word and 3 for the end of the word). For example, the word *accordion* had a 4 for number of syllables, a 7 for number of phonemes, a 2 for the position of the stressed syllable, a 1 as the target /d/ was present, and finally a 2 for the location of the target sound in the word.

All predictors consisted of nominal data. Data was entered numerically in this manner so that distinction could be made as to whether there was a difference in accuracy or response time in each group depending upon where a target sound was within a word, or how long the word was e.g. is it easier to detect a /p/ in *cap* as opposed to *apple*? As the words used were bound by the Snodgrass picture set (due to pictures being used in the silent picture naming task) it was not possible to have an equal number of sounds occurring in an equal number of positions, see appendix 26 for full details.

6 CHAPTER SIX CREATING THE NON-WORD LISTS

Creating a Non-Word List to Match 226 of the Snodgrass Standardised Picture Set.

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Creating non-word lists is a necessary but time consuming exercise often needed when conducting behavioural language tasks such as lexical decisions or non-word reading. The following article describes the process whereby we created a list of 226 non-words matching 226 of the Snodgrass picture set (Snodgrass & Vanderwart, 1980). In order to examine phoneme monitoring in fluent and non-fluent speakers we used the Snodgrass pictures created by Snodgrass and Vanderwart (1980). We also wished to look at phoneme monitoring in non-words so began creating a list of words that were matched to the Snodgrass pictures. The non-words created were matched on the following dimensions; number of syllables, stress pattern, number of phonemes, bigram count and presence and location of the target sound when relevant. These properties were chosen as they have been found to influence how easy or difficult it is to detect a target phoneme.

6.1 Rationale for creating a non-word list

The nature of non-words used in experimental work has been shown to be extremely important to the results of the study they're used for. For example, the more or less similar a non-word is to a real word affects the speed at which a lexical decision is made (Borowsky & Masson, 1996; Gerhand & Barry, 1999; Gibbs & Van Orden, 1998; Ghyselinck, Lewis, & Brysbaert, 2004). Gibbs and Van Orden (1998) found that lexical decisions were fastest when the non-words used contained illegal letter strings – strings of letters that do not appear together in the language used e.g. /gtf/. Keuleers and Brysbaert (2010) state that due to the impact non-words have on lexical decisions, they should only contain legal letter strings thus more closely approximating real words.

Phonotatic probability is the frequency with which different sound segments and segment sequences occur in the lexicon Jusczyk & Luce (1994); Storkel (2001, 2003); Vitevitch (2002); Vitevitch, Armbrüster, & Chu (2004). For example, /bl/ occurs commonly in English and is therefore thought to have a high phonotactic probability. It has been found that sensitivity to phonotactic probability develops in childhood and becomes increasingly sensitive as our lexicon grows (Coady & Aslin, 2004; Edwards, Beckman, & Munson, 2004; Munson, Kurtz, & Windsor, 2005; Storkel, 2001). Munson and Bable (2005) suggested that this increase in sensitivity is reflective of our lexical representations becoming more segmental. As our lexicon expands, so too do the phonotactic possibilities and we become more sensitive to those segments which appear most often e.g. /bl/.

Coady and Aslin (2004), Storkel (2001) and Zamuner, Gerken and Hammond (2004) have found that phonotactic probability is reflected in the accuracy of speech in young children e.g. the lower the phonotactic probability the less accurate the speech. This finding, when applied to the two-step model of lexical access (Dell, Schwartz, Martin, Saffran, & Gagnon, 1997) can be explained in terms of the level of activation. When a speaker attempts to access a word in their lexicon this model proposes two steps, lemma retrieval and phonological retrieval. These two steps are not sequential and activation spreads throughout the retrieval network from semantic features to phonological features and back again. The most active phoneme units are then selected and positioned into the phonological frame. The model would suggest that those units with higher phonological probability have higher activation and are, therefore, more readily retrieved. For this reason it may be easier to detect /l/ when it is in a /bl/ combination rather than a /nl/ combination as /bl/ occurs more often in English than /nl/. As our list was created for a phoneme monitoring task controlling for the number of letter bigrams was especially important.

In Levelt, Roelofs, & Meyer (1999) model of speech production it is noted that we have the ability to monitor phonological code that is generated in the syllabification process which occurs before word production. Tasks such as phoneme monitoring can be used to test our ability to monitor phonological code which is what Schiller (2005) did. Adult Dutch speakers were given a silent phoneme monitoring task in which the phoneme they had to monitor for occurred in the syllable initial and stress initial position and was compared to when it occurred in syllable initial but not stress initial position. It was found that phoneme monitoring occurs fastest when the phoneme occurs in the initial stress position. Dutch like English is a language in which the majority of multisyllabic words have their syllable stress on the initial syllable so results can be generalised to English. Coalson and Byrd (2015) conducted a study asking participants to monitor for a phoneme in non-words. They found similar results to Schiller (2005), and also suggest that fluent adults monitor for phonemes more slowly in non-words as opposed to real words. It can be seen from this work that controlling for the position of the phoneme within the word and whether it occurs in the stressed syllable is important as it affects speed of monitoring.

6.2 Purpose of the list – current study

We created this non-word list as in our subsequent study we wished to examine phoneme monitoring in real and non-words in adult who are fluent vs. adults who are dysfluent. As we also wished to do this in a silent picture phoneme monitoring paradigm we chose to use the Snodgrass picture set (Snodgrass & Vanderwart, 1980). Snodgrass and Vanderwart created their set of 260 line drawings which they standardised on four variables; familiarity, image agreement, name agreement and visual complexity. These variables must be controlled for as they affect cognitive processing in pictorial and verbal form. More familiar items are more easily named as are words learnt at a younger age, those with higher name and image agreement, and less visual complexity, are also more easily named (Ellis & Catriona, 1998; Funnrell & Sheridan, 1992; Gilhooly and Gilhooly, 1979).

6.3 Generating the non-words

Initially we excluded some of the Snodgrass words e.g. those which are not regularly used in British English e.g. *wrench* (in English we would use *spanner*). Noun phrases were also excluded e.g. *wine glass*. We then transcribed each word orthographically and phonologically detailing position of primary stress, total number of syllables and the total number of phonemes. A letter bigram count was also calculated by hand. This count, taking account of phonological transcription, was vital as English orthographic transcription does not consistently agree with phonological transaction. Once we had all of this information we could begin creating our non-words.

In order to create the non-words we used two software programs. The first was the ARC Nonword Database (Rastle, Harrington, & Coltheart, 2002). This database was created so that researchers could access monosyllabic non-words or pseudo-homophones, chosen on the basis of a number of properties including; the number of letters, the neighbourhood size, summed frequency of neighbours, number of body neighbours, summed frequency of body neighbours, number of body friends, number of body enemies, number of onset neighbours, summed frequency of onset neighbours, number of phonological neighbours, summed frequency of onset neighbours, bigram frequency – type, bigram frequency – token (both position specific and position non-specific), trigram frequency – type, trigram frequency – token (both position specific and position non-specific) and the number of phonemes. Values for each of these can be set (upper and lower limits) and the fields you wish to have output for can also be selected. Non-words and pseudo-homophones can be chosen to be only orthographically existing onsets, be only orthographically existing bodies, only legal bigrams, monomorphemic only syllables, polymorphemic only syllables and morphologically ambiguous syllables. The ARC software, whilst extensive, could only be used to create non-words for all of the monosyllabic words in the Snodgrass set (121 words of the 226 total). Each word was chosen from a list of possible options given by the ARC database, when the target sound needed to be present non-words had to be selected that also had the target sound in the same position. It was not possible to ask the software to do this for us so added additional workload.

For the remaining 105 multisyllabic words we used the Wuggy software (Keuleers & Brysbaert, 2010) to create the non-words. Once again words were matched to real words in terms of phoneme length, syllable length, presence or absence of the target sound, place in which the target sound occurred when it occurred and stress pattern. Wuggy is a multilingual pseudo-word generator designed to elicit non-words in Basque, Dutch, English, French, German, Serbian (Cyrillic and Latin), Spanish, and Vietnamese. This software was developed to expand upon what ARC offers as it can generate multisyllabic words. A word or non-word can be inputted and the algorithm can generate pseudo-words which are matched in sub-syllabic structure and transition frequencies. In the Wuggy software, after the language has been selected, it is possible to select whether real or pseudo-words are required. Output restrictions can then be applied including: match length of sub-syllabic segments, match letter length, match transition frequencies (concentric search) and match sub-syllabic segments e.g. two out of three. There are also output options similar to ARC, including; syllables, lexicality, OLD20, neighbours at edit distance, number of overlapping segments and deviation statistics. Each of the remaining 105 words were put into Wuggy and one of the options generated was chosen based upon whether it had the target sound (when applicable) in the correct location.

Once each non-word had been chosen and transcribed orthographically and phonologically a manual bigram count was taken. To ensure no bigrams were missed the total number of phonemes was calculated (980 phonemes in each list – words and non-words) following this the total number of possible bigrams was calculated (754 bigrams in each list – words and non-words). Bigram frequency data was calculated for real and non-words and a Wilcoxon signed rank test similar frequencies across the two word lists ($z = -0.123$, $p = 0.902$). None of the non-words differed to the real words by more than two standard deviations (more than five bigrams) and the greatest difference was six occurrences of a bigram vs one occurrence of it. By ensuring that the lists are as similar as possible we have minimised the chance of any differences in performance on each list being down to factors other than the word/non-word distinction.

6.4 Outcome

The completed non-word list with corresponding Snodgrass words can be found in appendix 19. The target phonemes that we used in the subsequent phoneme monitoring task are highlighted in bold (where applicable). It should be noted that whilst this list is matched and the bigram frequencies are such that there is no significant difference between the two lists, this is only the case when all 226 words are used. If exclusions are made in any work using them then a new bigram count must be taken to ensure that lists remain well matched.

7 CHAPTER SEVEN RESULTS

7.1 Results

The procedure and models used to analyse results have been outlined at the end of chapter five. For all response times results are given in milliseconds, for accuracy of response data in the reaction time tasks a score is given out of the number of trails (out of 40 for the simple reaction time task and out of 20 for the complex reaction time task). For accuracy in all other tasks (phoneme monitoring tasks and syllable detection tasks) a score is given of between zero and one. At the end of this section a summary table can be found which gives an overview of the main findings in this section (table 7.2).

7.1.1 Simple reaction time (SRT)

Before analysing results, any data points associated with reaction times under 200 milliseconds were excluded. This cut off is well established (Ratcliff, 1993; Whelan, 2008) and used to avoid the inclusion of outliers due to mistakes, lack of inhibition or guessing. This resulted in very few data points being disregarded: 2/600 for controls, 0/560 for AWC and 2/560 for AWS. Total data points were calculated as number of participants x number of trails e.g. for AWC, 14 participants x 40 trails each).

7.1.1.1 Accuracy of responses (out of 40)

AWC mean correct 39.14, SD = 0.86, mean for incorrect responses 0.86

AWS mean correct 38.86, SD = 1.29, mean for incorrect responses 1.14

Controls mean correct 39.40, SD = 0.81, mean for incorrect responses 0.6

The means and standard deviations clearly demonstrate that there is very little difference between all three groups and they are all performing and near ceiling rate (ceiling would have been 40).

A one-way ANOVA found there was no main effect of accuracy between the three groups $F(2, 40) = 1.04$ $p = 0.363$.

7.1.1.2 Response time (RT in milliseconds)

Response times for incorrect responses were excluded and have been reported separately (see below).

AWC mean RT 383.8, SD = 53.63, mean for RT incorrect 322.31, SD = 64.88

AWS mean RT 416.1, SD = 62.01, mean for RT incorrect 372.85, SD = 70.0

Controls mean RT 356.89, SD = 42.4, mean for RT incorrect 313.1, SD = 67.5

These figures, for correct responses, are shown in graph 7.1 below. It can be seen that AWS take longer than the other two groups in this task with a mean that is 59.21 milliseconds slower than controls and 26.91 milliseconds slower than AWC.

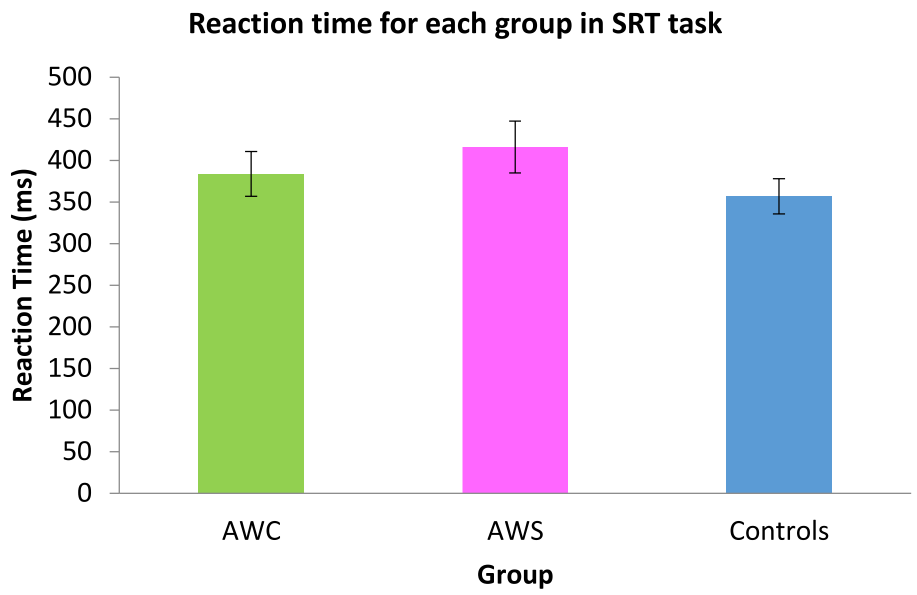

Figure 7.1 A graph showing the means and standard deviations for all groups' RT in SRT task.

A one-way ANOVA showed there was a main effect of reaction time between the three groups $F(2, 40) = 4.525$ $p = 0.017$.

Post Hoc analysis using a Bonferroni test revealed a significant difference between controls and AWS; $p = 0.014$ with an associated effect size of $d = 1.11$. There was no significant difference between AWS and AWC $p = 0.345$ or controls and AWC $p = 0.539$.

Using a one-way ANOVA it was also found that there was no difference in reaction time when just analysing incorrect responses $F(2, 18) = 1.723$ $p = 0.207$.

7.1.2 Complex Reaction time (CRT)

7.1.2.1 Accuracy (out of 20)

AWC mean correct 16.57, SD = 3.85, mean for incorrect responses 3.43

AWS mean correct 16.93, SD = 2.67, mean for incorrect responses 3.07

Controls mean correct 17.3,3 SD = 1.11, mean for incorrect responses 2.67

A one-way ANOVA found there was no main effect of accuracy between the three groups. $F(2, 40) = 0.310$, $p = 0.735$.

7.1.2.2 Response time (RT in milliseconds)

Response times for incorrect responses were excluded and have been reported separately below.

AWC mean RT 5691.17, SD = 799.0, mean RT for incorrect responses 6935.07, SD = 371.95

AWS mean RT 6225.89, SD = 1236.76, mean RT for incorrect responses 6837.08, SD = 1632.77

Controls mean RT 5176.39, SD = 773.83, mean RT for incorrect responses 6225.65, SD = 1046.91

These figures, for correct responses, are shown in graph 7.2 below. It can be seen that AWS are taking longer than the other two groups in this task with a mean RT that is 1049.5 milliseconds slower than controls and 534.72 milliseconds slower than AWC.

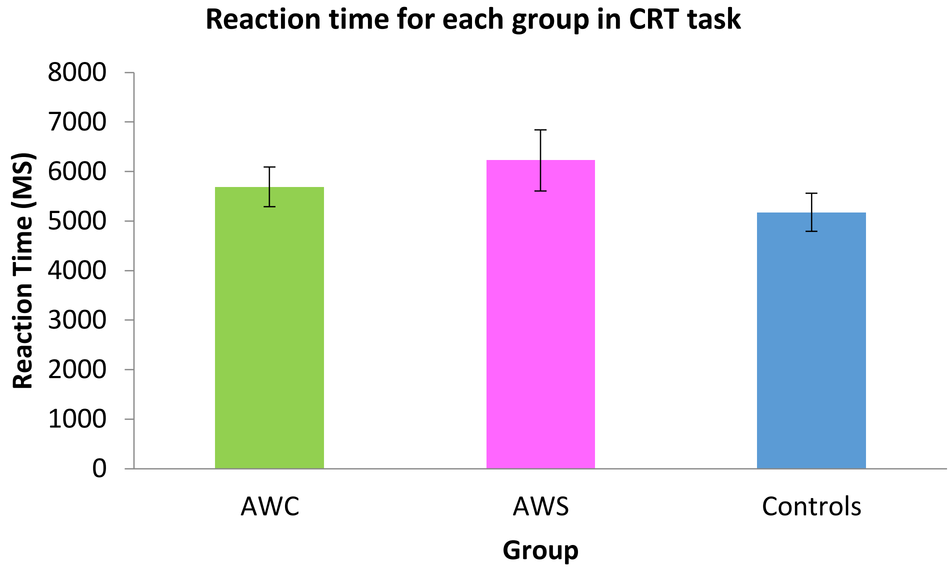

Figure 7.2 A graph showing the means and standard deviations for all groups' RT in CRT task.

A one-way ANOVA found there was a main effect of reaction time between the three groups $F(2, 40) = 4.363$, $p = 0.019$.

Post Hoc analysis using a Bonferroni test revealed a significant difference between controls and AWS $p = 0.016$ with an associated effect size of $d = 1.02$. There was no significant difference between AWS and AWC, $p = 0.440$ or controls and AWC, $p = 0.466$.

Using a one-way ANOVA also found that there was no difference in reaction time when just analysing incorrect responses $F(2, 35) = 1.175$, $p = 0.321$.

7.1.3 Phoneme monitoring

The data collected in this task and the following four is complex as there are numerous independent variable such as the number of phonemes, whether the target phoneme was present or not and where in the word the target phoneme was. Prior to investigating the effect that these may have had on response time and accuracy, a broader analysis using one way ANOVAs was done to see if there was a difference in response time and accuracy between the three groups. If there was not a difference at this level further analysis would not be completed.

7.1.3.1 Real word phoneme monitoring (RWPM)

1.1.4.1.1 Response time (RT in milliseconds)

AWC mean RT 1350.26, SD = 432.07

AWS mean RT 1459.39, SD = 399.62

Controls mean RT 1184.58, SD = 242.14

A one way ANOVA revealed that there was no difference between each of the groups in terms of response time. $F(2, 40) = 2.093$, $p = 0.137$.

7.1.3.1.1 Accuracy (out of one)

AWC mean accuracy 0.86, SD = 0.11

AWS mean accuracy 0.86, SD = 0.09

Controls mean accuracy 0.94, SD = 0.03

AWS and AWC are performing in almost exactly the same way in this task but they are both less accurate than controls. Graph 7.3 below illustrates this.

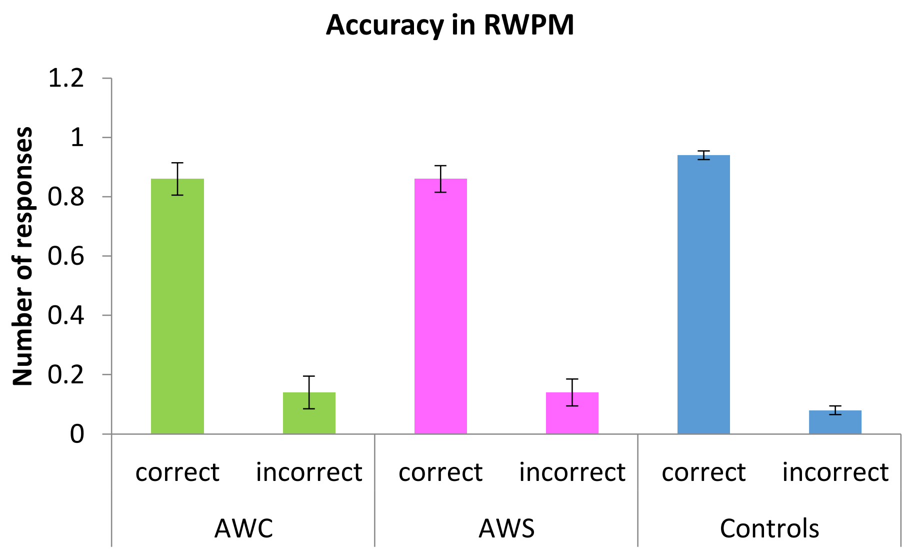

Figure 7.3 A graph showing the means and standard deviations for all groups' accuracy in the real word phoneme monitoring task.

A one way ANOVA found that there was a significant main effect of accuracy between the three groups $F(2,40)=4.334$, $p = 0.020$. Post hoc analysis was then completed using a Bonferroni test which found that there was a significant difference between controls and AWC $p = 0.045$ with an associated effect size of $d = 0.99$. There was also a significant difference between controls and AWS $p = 0.046$ with an associated effect size of $d = 1.2$. There was no difference between AWC or AWS $p = 1.00$.

A Generalised estimating equation (GEE) was then run to establish which if any of the predictors were having an effect on each group. The syntax for running this process in SPSS can be found in appendix 27. The test of the model's effects was calculated for each group with each predictor included within the model (target sound, number of syllables, number of phonemes, position of the stress, position of the target sound and whether the target is present or not). It is worth noting that when running this analysis the following warning message was given:

> *The Hessian matrix is singular. Some convergence criteria are not satisfied for split file Group = Controls.*

This message was given as there is so little variation in the control data, as seen in the small standard deviation for accuracy for controls (0.03). Due to this small variation the mean of 0.94 is enough to explain the data. The model still runs regardless of this message but results from the GEE for the control group must be interpreted with caution e.g. there may be redundant predictors on certain factors in predictors.

A Wald Chi-Square found that for AWC there was a significant effect of target sound on ability to accurately detect a sound in a real words; $p < 0.001$. The number of phonemes, $p = 0.044$ and the location of the target sound, $p = 0.013$ were also found to have a significant effect on accuracy in RWPM for AWC.

For AWS there was only a significant effect for target sound on accuracy in RWPM $p < 0.001$. Finally for controls there was a significant effect for target sound $p < 0.001$, number of phonemes $p = 0.005$ and the location of the target sound $p = 0.001$ on accuracy in RWPM. The model then gives details of how each factor (e.g. specific sounds, exact location of the target sound in the word) in each predictor affects the accuracy of RWPM.

For AWC there was a significant difference for /r/ and /s/ (Wald Chi-Square 4.001, $p = 0.045$ and Wald Chi-Square 4.720, $p = 0.030$ respectively). AWC were significantly less accurate at detecting /r/ and /s/ than other phonemes with a mean accuracy for /r/ of 0.82 and for /s/ a mean accuracy of 0.84 compared to a mean accuracy of 0.89 for /b/, for example. For location of the target it was found that for AWC if the target was not present they were significantly more accurate than when it occurred in any other location *p* = 0.010. The effect for the number of phonemes did not hold with further analysis.

For AWS the only predictor having an effect was target sound and it was found that the phoneme /n/ was responded to significantly less accurately than any other phoneme, Wald Chi-Square = 7.302, *p* = 0.007.

Finally, for controls each phoneme other than /t/ was significantly different from the mean with /b, d, f, n, p/ being responded to significantly more accurately than /k, l, m, r, s, ʃ/. Corresponding Wald Chi-Square and p values are given in table 7.1 below.

Table 7.1 Wald Chi-Square and p values for each phoneme in the control group.

Phoneme	**Wald Chi-Square**	***p* value**
/b/	4.514	0.034
/d/	5.847	0.016
/f/	20.396	<0.001
/n/	10.214	0.001
/p/	5.269	0.022
/k/	8.668	0.003
/l/	22.140	<0.001
/m/	5.553	0.018
/r/	24.575	<0.001
/s/	(not calculated due to no variation in the data – all participants scored the same)	<0.001
/ʃ/	27.979	<0.001
/t/	Set to zero because this parameter is redundant (this is due to insufficient variation in the data for this phoneme).	

For controls, like AWC, the significant effect of number of phonemes did not hold with further analysis. This was also true for the significant effect of the location of the target sound in the word. This is due to the model first identifying if there is an overall effect of a predictor like the number of phonemes a word has and then separating out each level (or factor) within this predictor e.g. if it has four, five or eight phonemes and then testing to see if any of these are what is driving the significant overall effect. It is possible for there to be an overall effect without any one factor being solely responsible. This can be likened to the analogy of coming into a room and finding a broken plate, you can see that a plate has been broke (there is a main effect) but a combination of things has caused it – the dog barked at the postman, which made the cat jump off the table which made the glass of water fall over and knock the plate onto the floor. So it is impossible to say that any of the factors the postman, the dog, the cat or the glass of water were responsible for the broken plate.

7.1.3.2 Non-word phoneme monitoring (NWPM)

7.1.3.2.1 Response time (RT in milliseconds)

AWC mean RT 1452.6, SD = 448.09

AWS mean RT 1527.66, SD = 316.61

Controls mean RT 1351.12, SD = 224.83

A one way ANOVA was carried out which revealed that there was no difference between each of the groups in terms of response time. $F(2, 40) = 0.988$, $p = 0.381$.

7.1.3.2.2 Accuracy (out of one)

AWC mean accuracy 0.82, SD = 0.15

AWS mean accuracy 0.85, SD = 0.08

Controls mean accuracy 0.91, SD = 0.08

Despite a difference in the means of 0.086 (the same difference as in the previous task – RWPM) between AWC and controls a one way ANOVA revealed there was no significant difference between groups. $F(2, 40) = 2.476$, $p = 0.097$. The standard deviations are larger in this task than in RWPM which may contribute to the lack of statistically significant difference. No further analysis was conducted on the data as no differences were found by the ANOVA.

7.1.3.3 Phoneme monitoring in silent reading (PMSR)

7.1.3.3.1 Response time (RT in milliseconds)

AWC mean RT 932.49, SD = 321.78

AWS mean RT 1107.58, SD = 272.58

Controls mean RT 782.45, SD = 102.65

Graph 7.4 below shows that AWS are taking longer than both AWC and controls in this task.

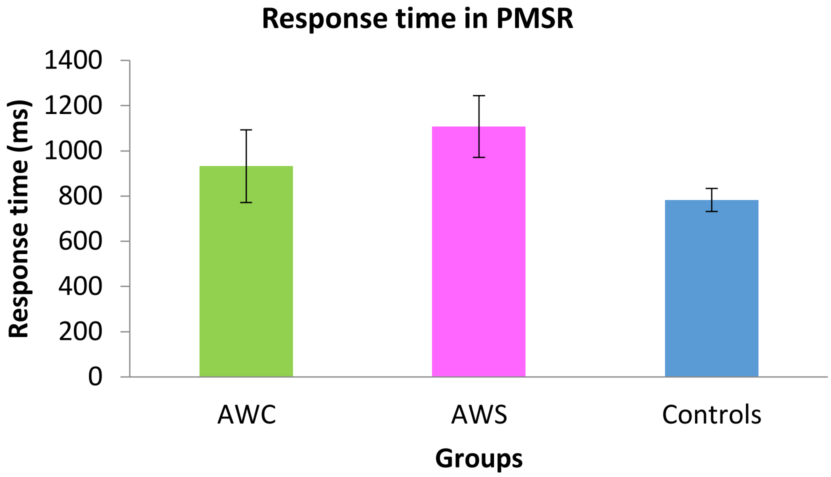

Figure 7.4 A graph showing the means and standard deviations for all each groups for RT in the phoneme monitoring in silent reading task.

A one-way ANOVA was used which found that there was a significant main effect of response between the three groups $F(2, 10) = 0.004$. Post hoc testing with a Bonferroni test found that there was a significant difference between AWS and controls $p = 0.003$ with an associated effect size of $d = 1.6$. There were no other significant interactions found, AWC and controls $p = 0.334$ and AWC and AWS $p = 0.207$.

A GEE model was run with all groups to establish which if any predictors were impacting upon group differences. The syntax for this GEE can be found in appendix 28. The predictors, target sound, position of stress and whether the target was present or not were included in the GEE. The number of phonemes, number of syllables and position of the target phoneme were not included as differences here may be misleading as taking longer to detect a sound in a longer word is likely only due to longer processing time. The model effect found there was a significant effect in all three groups for target sound and the position of the stress in the word p < 0.001 for both predictors in all three groups.

Further analysis found that for AWC were significantly slower at detecting /f/ and /ʃ/ than any other phoneme (Wald Chi-Square 16.261, $p < 0.001$ and Wald Chi-Square 17.508, $p < 0.001$ respectively). They also took significantly longer at detecting phonemes when they occurred in a word with the stress on the second syllable as opposed to any other position (Wald Chi-Square 4.716, $p = 0.030$) rather than any other position (either in a single syllable word, a word with initial stress or a word with a final stress). Controls also took significantly longer at detecting phonemes when they occurred in a word with the stress on the second syllable (Wald Chi-Square 4.532, $p = 0.033$) rather than any other position but no effect of target sound held under further analysis. For AWS no differences held under further analysis.

7.1.3.3.2 Accuracy (out of one)

AWC mean accuracy 0.93, SD = 0.08

AWS mean accuracy 0.93, SD = 0.06

Controls mean accuracy 0.98, SD = 0.02

A one-way ANOVA revealed that there was no significant main effect for accuracy between the three groups $F(2,40)=3.023$, $p = 0.06$.

7.1.3.4 Phoneme monitoring in silent picture naming (SPN)

7.1.3.4.1 Response time (RT in milliseconds)

Prior to data analysis, all words that had been named incorrectly were excluded for each participant. This resulted in between 0 and 11 words being excluded per participant. The exclusion was undertaken as if words were named incorrectly then the target phoneme was not being monitored for in the correct word, which may skew results.

AWC mean RT 1911.72, SD = 773.12

AWS mean RT 1900.63, SD = 565.57

Controls mean RT 1247.76, SD = 338.51

The means for each group demonstrate that AWC and AWS are performing this task within a similar time but that controls are far faster. Graph 7.5, below, shows how each compares.

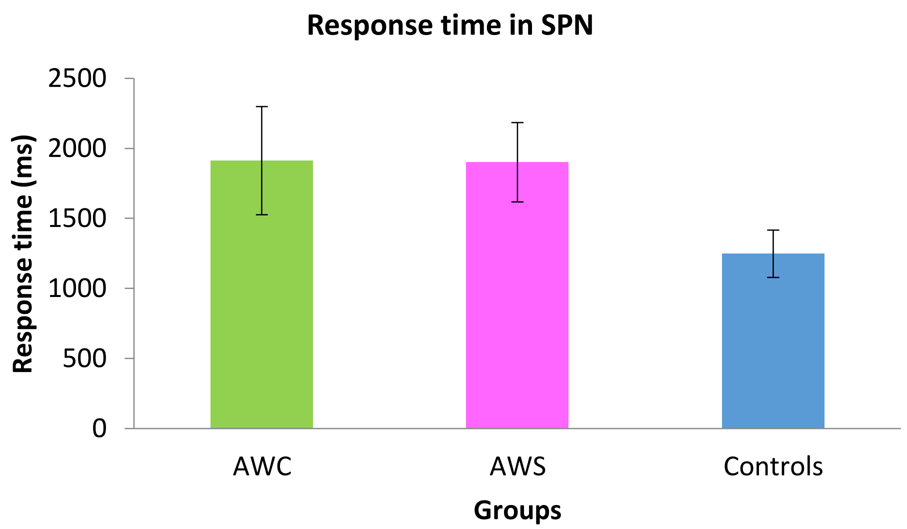

Figure 7.5 A graph showing the mean response time and the standard deviations for AWC, AWS and controls when completing the silent picture naming task.

A one-way ANOVA was completed which found that there was a significant main effect for response time between the three groups $F(2,40)=6.258$, $p = 0.004$. Post hoc analysis was then completed using a Bonferroni correct which found that there was a significant difference between controls and AWC $p = 0.011$ with an associated effect size of $d = 1.11$. There was also a significant difference between controls and AWS $p = 0.013$ with an associated effect size of $d = 1.4$. There was no difference between AWS and AWC, $p = 1.00$.

A GEE model was run including each group and the predictors, as before in SR task, target sound, position of stress and whether the target was present or not. Once again the number of phonemes, number of syllables and position of the target phoneme were not included as differences here may be misleading as taking longer to detect a sound in a longer word is likely only due to longer processing time.

The model found there was a significant effect in all three groups for target sound and the position of the stress in the word. Following further analysis it was found that no factor held as significant in any group for the main effect of target sound or for the location of the stress in the target.

7.1.3.4.2 Accuracy (out of one)

AWC mean accuracy 0.89, SD = 0.08

AWS mean accuracy 0.88, SD = 0.09

Controls mean accuracy 0.97, SD = 0.02

In graph 7.6 below it can be seen that those in the control group are performing more accurately than both AWS and AWC who are performing in a very similar way.

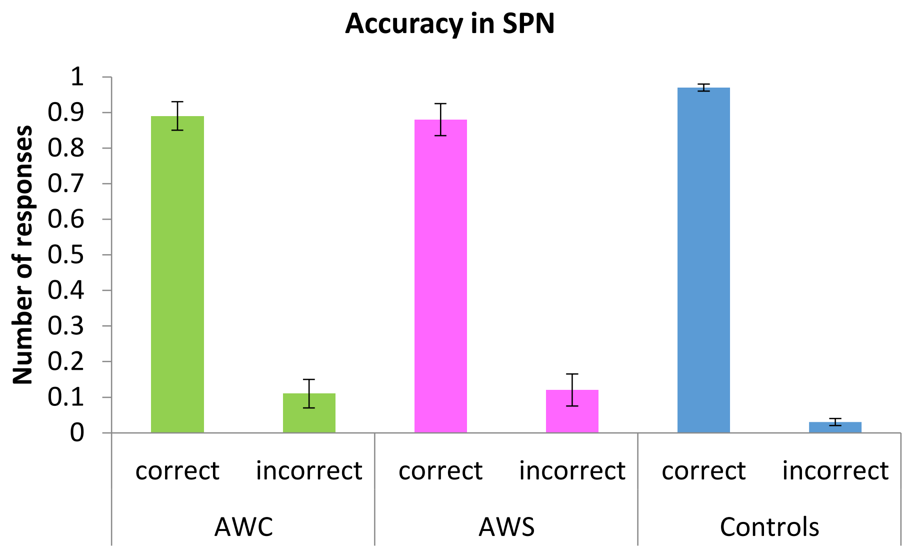

Figure 7.6 A graph showing the mean and standard deviation for accuracy for each group in silent picture naming.

A one-way ANOVA revealed that there was a significant main effect for accuracy between the three groups $F(2,42)= 8.865$ $p = 0.001$. Post hoc analysis using a Bonferroni correction found that there was a significant difference between the accuracy of responses for AWC and controls $p = 0.004$ with an associated effect size of $d = 1.37$. There was also a significant difference between AWS and controls $p = 0.001$ with an associated effect size of $d = 1.38$. There was no difference between AWC or AWS $p = 1.00$.

A GEE model was run in SPSS using the same syntax as was used previously (appendix 27). The test of the model's effects was calculated for each group with each predictor included within the model (target sound, number of syllables, number of phonemes, position of the stress, position of the target sound and whether the target is present or not). Once again, it is worth noting that SPSS gave the same warning as previously regarding the limited variation in the data due to groups performing in such a consistent manner (see above pp. 96). The result of this is some predictors being redundant or significant differences of the model effect not holding when analysed further.

A Wald Chi-Square found that for AWC there was a significant effect of target sound $p < 0.001$ and for the number of phonemes $p = 0.001$. For AWS there was a significant effect for target sound $p < 0.001$, for the number of syllables $p = 0.015$, for the number of phonemes and the location of the target sound within the word $p < 0.001$. Finally for controls there was a significant effect for target sound $p < 0.001$, number of phonemes $p < 0.001$ and the number of syllables $p = 0.042$. The model then gives details of how each factor in each predictor affects the accuracy.

For AWC there was a significant difference for /l/ and /ʃ/ (Wald Chi-Square 3.942, $p = 0.047$ and Wald Chi-Square 4.443, $p = 0.035$ respectively). /l/ was detected significantly less accurately by AWC compared to the other phonemes and /ʃ/ was detected significantly more accurately than the other phonemes. For AWS /ʃ/ was detected significantly more accurately than other phonemes (Wald Chi-Square 7.202, $p = 0.007$). When the target word had three syllables sound detection was significantly less accurate than in one or two syllable words, four syllable words was a redundant factor due to there being insufficient variation in the data. The significant effect for the number of phonemes and location of the target sound did not hold with further analysis. Finally, for controls only the difference for target sound held with further analysis. /k, p/ and /s/ were detected significantly less accurately than other phonemes (Wald Chi-Square 7.370, $p = 0.007$, Wald Chi-Square 4.191, $p = 0.041$ and Wald Chi-Square 6.561, $p = 0.010$ respectively.

7.1.4 Syllable detection

7.1.4.1 Syllable detection in real words (SDRW)

7.1.4.1.1 Response time (RT in milliseconds)

AWC mean RT 1908.3, SD = 434.55

AWS mean RT 2096.28, SD = 565.57

Controls mean RT 1845.29, SD = 279.26

A one-way ANOVA revealed that there was no significant main effect for response time between the three groups $F(2,40) = 1.312$, $p = 0.281$.

7.1.4.1.2 Accuracy (out of one)

AWC mean accuracy 0.81, SD = 0.2

AWS mean accuracy 0.89, SD = 0.16

Controls mean accuracy 0.94, SD = 0.03

Despite the large difference in means between AWC and controls, a one-way ANOVA revealed that there was no significant main effect for accuracy between the three groups $F(2,40) = 2.799$, $p = 0.073$. Graph 7.7 below shows more clearly that AWC are performing the most poorly in this task with controls performing close to ceiling level.

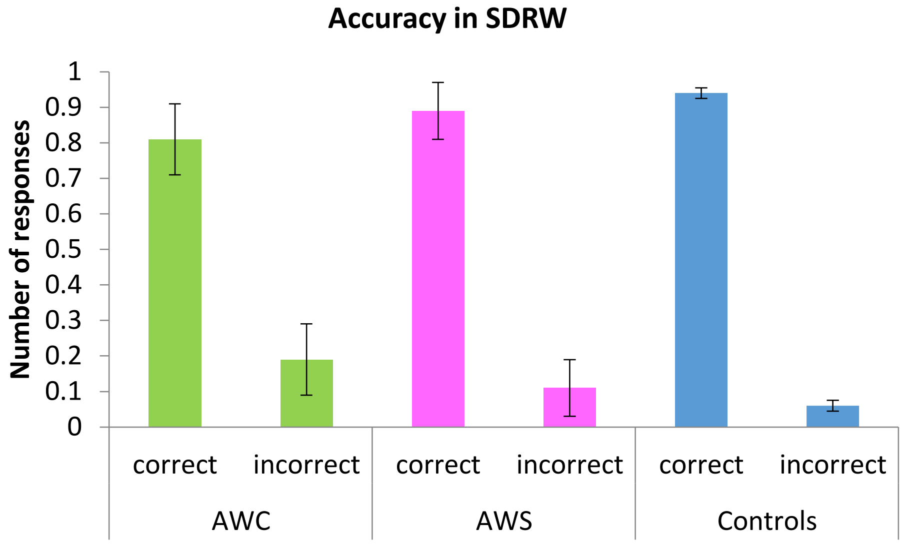

Figure 7.7 A graph showing each group's mean accuracy with standard deviations in the SDRW task.

7.1.4.2 Syllable detection in non-words (SDNW)

7.1.4.2.1 Response time (RT in milliseconds)

AWC mean RT 2014.65, SD = 434.55

AWS mean RT 2132.27, SD = 502.36

Controls mean RT 1930.14, SD = 384.05

A one-way ANOVA revealed that there was no significant main effect for response time between the three groups $F(2,40)= 0.762$, $p = 0.474$.

7.1.4.2.2 Accuracy (out of one)

AWC mean accuracy 0.84, SD = 0.19

AWS mean accuracy 0.89, SD = 0.17

Controls mean accuracy 0.96, SD = 0.04

Once again despite the large difference in mean between AWC and controls a one-way ANOVA revealed that there was no significant main effect for accuracy between the three groups $F(2,40)=2.465$, $p = 0.098$.

Graph 7.8 below shows that as in SDNW those who clutter are performing with the least accuracy and controls are performing at near ceiling level.

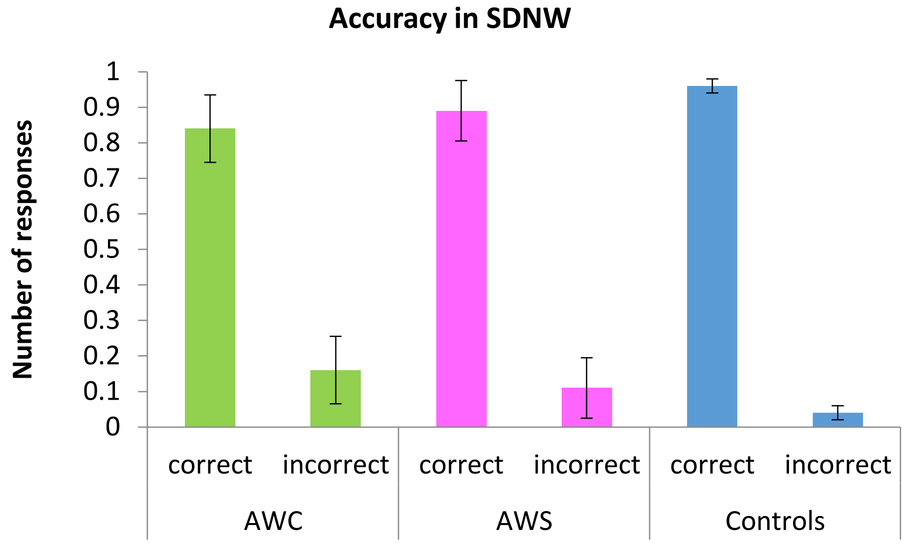

Figure 7.8 A graph showing each group's mean accuracy with standard deviations in the SDNW task.

7.2 Summary of main findings

Table 7.2 below gives a summary of what has been found. Explanations for these results and possible implications will be discussed in the following chapter.

Table 7.2 Summary of main findings

Task completed	**Significant effects**	
	Accuracy	**Response time (RT)**
Simple reaction time (SRT)	No significant differences	AWS took significantly longer than AWC and controls.
Complex reaction time (CRT)	No significant differences	AWS took significantly longer than AWC and controls.
RWPM	AWC and AWS were significantly less accurate than controls	No significant differences
NWPM	No significant differences	No significant differences
PMSR	No significant differences	AWS took significantly longer than controls
SPN	AWC and AWS were significant less accurate than controls	No significant differences
Syllable detection in real words (SDRW)	No significant differences	No significant differences
Syllable detection in non-words (SDNW)	No significant differences	No significant differences

In the phoneme monitoring tasks in which there was a significant difference between groups it was found that in RWPM:

- AWC were significantly less accurate at detecting /r/ and /s/ than any other phoneme and they were significantly more accurate when there was no target sound to monitor for than when it occurred in any other position.
- For AWS /n/ was responded to significantly less accurately than any other phoneme.
- For controls each phoneme other than /t/ was significantly different from the mean with /b, d, f, n, p/ being responded to significantly more accurately than /k, l, m, r, s, ʃ/.

In the PMSR task it was found that:

- AWC were significantly slower at detecting /f/ and /ʃ/ than any other phoneme.
- AWC took significantly longer at detecting phonemes when they occurred in a word with the stress on the second syllable rather than any other position.
- Controls also took significantly longer at detecting phonemes when they occurred in a word with the stress on the second syllable rather than any other position.
- AWS were not significantly faster or slower on any factors.

In the SPN task it was found that:

- The model effect found there was a significant effect in all three groups for target sound and the position of the stress in the word. Following further analysis it was found that no factor held as significant in any group.

8 CHAPTER EIGHT DISCUSSION

8.1 Orientation to discussion

In the following section results will be explored, first in terms of how they compare to the hypotheses made in chapter four, then each task will be discussed in greater depth. There is a focus on the work completed by Sasisekaran and De Nil (2006) as the methodology used by them has been roughly replicated in this study. Data from those who stutter and those who clutter will be reported separately for ease and continuity. As with previous chapters, reaction time tasks will be reviewed first, followed by the phoneme monitoring tasks and concluding with the syllable detection tasks. Finally, the implications of results, limitations of the research and the potential for further work will be discussed.

8.2 Summary of findings in terms of hypotheses

8.2.1 Reaction time tasks

It was predicted that there would be no differences between the three groups (AWS, AWC and controls) for accuracy or response times in the simple reaction time task. It was found that this was the case for accuracy, but unexpectedly AWS were significantly slower at this task, thus not supporting the experimental hypothesis.

This same prediction was also given for the complex reaction time task and the same outcome was found. AWS were no different to controls or AWC in terms of accuracy but once again they were significantly slower in terms of response time.

8.2.2 Real and non-word phoneme monitoring

For the real word phoneme monitoring task (RWPM) it was predicted that AWS would perform as controls in terms of accuracy of responses but they would be significantly slower than controls (consistent with Sasisekaran & De Nil, 2006 findings). It was also predicted that AWC would perform significantly more slowly than controls and significantly less accurately then the other two groups (as was suggested in the pilot study – chapter three). However, no differences were found between the three groups for response time thus not supporting our hypothesis that AWC and AWS would respond significantly more slowly than controls. In terms of accuracy our hypothesis that AWC would be significantly less accurate than controls was supported, it was also found that AWS were significantly less accurate than controls. This was not expected and contradicts what was found by Sasisekaran and De Nil (2006). Exploratory analysis using GEE found that AWC were significantly less accurate at detecting /r/ and /s/ compared to other phonemes and they were significantly more accurate when there was no target sound to monitor for than when it occurred in any other position. For AWS /n/ was responded to significantly less accurately than any other phoneme. For controls each phoneme other than /t/ was significantly different from the mean with /b, d, f, n, p/ being responded to significantly more accurately than /k, l, m, r, s, ʃ/.

In the non-word phoneme monitoring task (NWPM) it was hypothesised that AWS would perform as controls in terms of accuracy of responses but they would be significantly slower than controls as predicted by Sasisekaran and De Nil (2006); it was also hypothesised that AWC would be significantly less accurate than AWS and controls and significantly slower to respond than controls, based on findings from the pilot study. Hypotheses were only partially supported, as there were no significant differences between AWS or controls for accuracy of responses in NWPM. It was also found that there were no differences between the three groups in terms of response times and AWC also performed as controls in terms of accuracy of responses.

8.2.3 Phoneme monitoring in silent reading

When completing the phoneme monitoring in silent reading (PMSR) task it was predicted that AWC and AWS would be no different to controls in terms of accuracy. This prediction was made as there is no evidence to suggest that AWC or AWS have any difficulties with grapheme to phoneme representation or with reading ability. For those who clutter it was expected that they would take significantly longer than controls in this task. Findings demonstrated that as predicted there were no differences between the three groups in terms of accuracy but unexpectedly AWS took significantly longer than controls and AWC when completing this task. There was no difference between AWC and controls in terms of time taken to respond, thus not supporting the experimental hypothesis. Exploratory analysis to look at the potential impact of predictors such as target sound found that for AWS, no factors held as significant in the GEE model. For AWC and controls there was no main effect in the one way-ANOVA, therefore, further reporting on the potential impact of predictors on results is redundant.

8.2.4 Phoneme monitoring in silent picture naming

It was predicted that when completing the silent picture naming task that AWC and AWS would be significantly slower at responding to whether the sound is present or not and AWC would also be significantly less accurate compared to controls. This hypothesis was made based on the pilot's findings, suggesting that AWC may have a general monitoring deficit as they had difficulty detecting sounds and morphological endings and there did not appear to be a difference depending on the sound being monitored for. For AWS it was made due to Sasisekaran and De Nil's (2006), findings that AWS appear to have a deficit in phonological encoding. Results show that the hypothesis regarding AWS and AWC taking significantly longer was not supported as there were no differences between the groups for response time. AWC were significantly less accurate than controls, supporting our experimental hypothesis. AWS were also significantly less accurate than controls and performed in an almost identical way to AWC. This was not expected based upon previous findings.

8.2.5 Syllable detection tasks

For syllable detection in real words (SDRW) and non-words (SDNW) it was predicted that both AWS and AWC would perform significantly more slowly and significantly less accurately than controls. This prediction was made due to the findings from the pilot that AWC had difficulty with rhyme detection. They may, therefore, have a general phonological encoding deficit not limited to generating the segments that constitute words but also affecting the integration of sound segments in syllable frames (Levelt, 1989). The same prediction was made for AWS as it has been suggested that they have difficulties that may not be limited to just initiating syllables (Packman et al., 2007) but also in identifying them in spoken words. It was found, however, that there were no significant differences between the three groups in terms of accuracy or response time.

In the following sections possible interpretations of results and further discussion regarding what has been found will be given for each task completed.

8.3 Reaction time tasks

These tasks were included to control for the possibility that any differences between AWC, AWS and fluent controls are not just merely down to differences in reaction times. As expected there were no differences between the three groups in terms of accuracy in either the simple or the complex reaction time tasks. Also, as expected, there was no difference between AWC and controls for response time in either task, simple or complex. It was also predicted that there would be no overall difference between AWS and controls on the simple reaction time task in terms of time taken to respond. This was based upon findings by Smits-Bandstra (2010), who found that when performing simple reaction time tasks any group differences between AWS and controls disappeared as trails continued; this was because initial differences between AWS and controls were due to differences in practice effects and not due to differences in reaction times. There were a total of 40 trails in the simple reaction time task used in this study but it may have been that this was not sufficient for any group differences to disappear. Smits-Bandstra (2010), gives details of best practice when completing reaction time tasks with AWS but she does not state how many trails should be used to ensure that differences in practice effects do not impact upon overall response time differences between groups. There were no outliers in the data from AWS and the standard deviation was also small, suggesting all AWS were performing in a similar way to each other and at a similar speed.

The result is in direct contradiction to findings from Hennessey, Nang and Beilby (2008), Smits- Bandstra, De Nil and Saint-Cyr (2006) and Till, Goldsmith and Reich (1981) who found that there were no differences in simple reaction times between AWS and controls. This may, in part, be due to methodological differences: e.g. Hennessey et al. (2008) used a verbal response to being shown a basic shape to measure simple reaction time whereas in this study there was just a button press used. Using a verbal response to measure reaction time is likely to disadvantage AWS due to the pressure of having to verbalise under pressure but that was not found by Hennessey et al. (2008). Till et al. (1981) also used a simple button press measure of reaction times and found no overall differences in the time taken by AWS and fluent controls. Their task required participants to press a key with their left or right index finger in response to the offset of a 1000-Hz pure tone. It is, therefore, methodologically different to the task used in this study as participants were responding to the presence of a cross on a computer screen. It is also possible that this finding is actually a type 1 error; hypothesis testing leaves us open to the possibility that there is always a percentage chance that our result is a false positive (we have found a difference where there is actually no difference to find).

Results in this area have not been altogether consistent. For example Starkweather, Kranklin and Smigo (1984), found that AWS were significantly slower in both a simple button press task in response to the offset of a tone and to a simple speech reaction time task. The authors note that differences were largest for the speech reaction time task but were also present for the simple task. Bishop, Williams and Cooper (1991) used children between three years and 10 years 11 months giving them simple manual and verbal reaction time tasks of varying difficulty. They found significant improvements with age for both those who stutter and fluent controls when completing both kinds of task but that for children who stutter they were consistently slower in reaction times on all tasks than their fluent peers. These differences were greatest with increased task complexity but only for vocal reaction time tasks. It may be misleading to compare results from children who stutter (CWS) to adults who do as we know from linguistic research that CWS may appear to lag behind peers but then ‘catch up’. Specifically CWS have been found to score more poorly than their age matched peers on the Peabody Picture Vocabulary Test (Dunn & Dunn, 1997), a test of receptive vocabulary (Meyers & Freeman, 1985; Murray & Reed, 1977; Ryan, 1992). AWS do not show the same differences to controls in receptive and expressive language abilities (Anderson & Conture, 2000; Hennessey, Nang & Beilby, 2008; Prins, Main, & Wampler, 1997). This may also be the case here and slower reaction times in CWS compared to fluent controls may disappear as they become older. The differences in results may also, in part, be down to the differences in sample size used in these studies. For example Starkweather, Kranklin and Smigo (1984) only used 14 AWS whereas Bishop, Williams and Cooper (1991) used 40 CWS. However we interpret our finding here, that AWS were slower than controls on the simple reaction time task, it is clear that they are not supportive of the most recent literature and should, therefore, be viewed with caution.

The same unexpected finding occurred with the complex reaction time task with AWS being significantly slower to respond than controls and AWC. Once again this difference is in direct contradiction to findings from Smits-Bandstra, De Nil and Rochon (2006), who used this same paradigm and found no overall differences in reaction times between the two groups. They did, however, report greater variability in performance of those who stutter compared to fluent controls and note that, whilst control subjects get faster and more accurate at this task with practice, those who stutter do not show the same practice effects. It could be, therefore, that our results are merely showing differences in practice effects and whilst there were no outliers in the data AWS did show more variability in their data with a far larger standard deviation than either of the other groups. Further analysis of these results investigating practice effects is outside the focus of this thesis. These results do, however, suggest that further investigation is needed into how we conduct the fairest and most accurate research with AWS when looking at reaction times.

The prediction that there would be no differences between AWC and controls was supported as they were neither slower nor less accurate. There are currently no published data on whether there are any differences between AWC and controls when completing reaction time tasks, simple or complex. The results here would suggest that AWC perform as controls in terms of accuracy and time taken to respond when completing tasks of this nature. There are only 14 AWC in this study and results would need to be replicated before any firm conclusions can be drawn.

8.4 Phoneme monitoring tasks

8.4.1 Real word and non-word phoneme monitoring – Results for AWS

Phoneme monitoring tasks were used in this study to investigate the process whereby the phonetic plan is retrieved from the word's lemma (mental representation). Levelt (1989) dubbed this phonological encoding and, as has been described in chapter two, it is thought to consist of three processes. Testing phonological encoding directly has been deemed extremely difficult (Coles, Smid, Scheffers & Otten, 1995 and Meyer, 1992) as it is a complex process that occurs within language formulation. Testing phonological awareness using tasks such as rhyme judgement and non-word repetition have been suggested as the most effective way of investigating phonological encoding

(Coles, Smid, Scheffers & Otten, 1995; Meyer, 1992). In order to gain a full picture of phonological encoding abilities both real and non-word tasks were used here and tasks covered auditory presented stimuli, written stimuli and pictorial stimuli.

In the real word phoneme monitoring task (RWPM), AWS were significantly less accurate than controls. As has been stated above the significant difference in accuracy between AWS and controls was not expected. Sasisekaran and De Nil (2006) used a similar task in their investigation of perceptual monitoring of phonemic segments and found that AWS were not significantly different to controls in terms of accuracy but were for speed of response. The finding here that AWS were not significantly slower than controls at RWPM is, at first glance, in direct contradiction to Sasisekaran and De Nil (2006). Results that AWS were less accurate than controls at detecting phonemes in real words are also not supportive of Sasisekaran and De Nil's (2006) findings. However, like Sasisekaran and De Nil (2006) and Sasisekaran, De Nil, Smyth and Johnson (2006), our results do suggest that AWS differ from controls when completing phoneme monitoring tasks. The difference between results here and previous findings could be down to a number of factors, e.g. the difference in stuttering severity between AWS used here and those used by the authors above. In the study here all AWS were considered to be mild (13) to moderate (one) in severity (as measured by the SSI-IV). Sasisekaran, De Nil, Smyth, and Johnson (2006), used 11 AWS one severe, two moderate, two mild, and six very mild and Sasisekaran and De Nil (2006), used 10 AWS two moderate, two mild, and six very mild. These differences in severity of stuttering in participants may impact upon results and ideally research should be conducted with a range of different severities to enable us to have a complete picture of any differences between AWS and controls.

Differences in results may also be due to differences in the stimuli used by the researchers or by the breadth of data collected. For example, Sasisekaran, De Nil, Smyth, and Johnson (2006) used 14 bisyllabic words and Sasisekaran and De Nil (2006) used just seven bisyllabic words whereas in this study there were a total of 226 monosyllabic and multisyllabic words. Finally, differences may be due to research relying on small numbers of participants.

Evidence from phoneme monitoring tasks is consistent as it suggests that AWS do not perform as controls; be that due to them being slower (Sasisekaran & De Nil, 2006; and Sasisekaran, De Nil, Smyth & Johnson, 2006) or less accurate (as here). This is in contrast to what has been found in rhyme judgement tasks which have, for the most part, found that there are no differences between AWS and controls (Bosshardt, Ballmer & De Nil, 2002; Bosshardt & Fransen, 1996; Weber-Fox, Spencer, Spruill & Smith, 2004). Brocklehurst (2008) states that differences in results, between rhyme judgement and phoneme monitoring tasks may be down to phoneme monitoring tasks being more cognitively demanding than rhyme judgement tasks. Weber-Fox et al. (2004) also suggested this, concluding that increased cognitive load is needed in rhyme judgement tasks in order to see any vulnerability in the functioning of phonological encoding e.g. using words that look similar but do not rhyme – *cost, most*.

Sasisekaran & De Nil (2006) report, from their study into phoneme monitoring in silent picture naming, that AWS difficulties completing this task are due to either difficulties monitoring their output or difficulties activating and then encoding phonemes. As discussed in chapter two, work completed by Postma and Kolk (1992) has suggested that AWS have a phonological encoding deficit and not a self-monitoring one. Postma and Kolk (1992) used AWS and fluent controls and asked them to detect self-produced speech errors. They found that AWS and controls did not differ in terms of accuracy of error detection or speed of error detection. They concluded that this demonstrates that AWS do not have a generalised monitoring deficit and that self-monitoring is not impaired in AWS. Postma and Kolk (1992) also asked AWS and controls to listen to pre-recorded speech from other speakers and had to detect any errors. They found that AWS detected fewer errors than fluent controls when listening to the tapes and that these difficulties are likely due to a generalised phonological deficit not a specific self-monitoring one. These results as well as findings from this study are supportive of the covert repair hypothesis (CRH) which states that a person who stutters does so due to slowed or faulty activation of phonological segment nodes. As was discussed in chapter two the CRH, developed by Postma and Kolk (1993), is based on Dell's (1986) spreading activation model which can be used to explain errors we all make in our speech. In the spreading activation model when we want to say something we create a metrical frame for what we plan to say and then fill this frame with phonological nodes (phonemes). Phonemes are selected as they become the most active for the speaker; Postma and Kolk (1993) suggest that this activation is slowed in AWS, which then leads to appropriate phoneme choice taking longer and being more susceptible to error. This then leads to an abnormally high number of errors in the phonetic plan that is then detected by the person who stutters and repairs (which interrupt speech) are required. It is the process of trying to repair all of these errors which leads to blocks, prolongations and repetitions. Findings in this study suggest AWS have difficulty recognising phonemes, therefore suggesting they have poor phonological encoding which will impact upon their ability to select the correct phonemes for speech resulting in dysfluent overt speech.

Despite Postmas and Kolk (1992) suggesting that AWS do not have a self-monitoring deficit the result here may also support Vasic and Wijnen's (2005) vicious circle hypothesis (VCH) that AWS have defective or rigid monitoring skills. Vasic and Wijnen (2005) subscribe to Levelt's (1983, 1998) notion of self-monitoring (as described in chapter two) that there are two components to monitoring: attending to the output of the speech-programmer and comparing this output with what was intended. This is said to be done using two channels; the inner loop and the outer loop (speech is internally parsed and checked for errors and then checked again once it has been realised). The VCH does not suggest that AWS have a phonological encoding deficit but rather that the parameters for monitoring speech are inappropriately set. The three parameters for monitoring speech are described as: effort, focus and threshold. If applied to the task used here this theory would state that AWS use a great amount of effort to over focus on the monitoring that is needed and that their threshold for what they are monitoring for is set too high – i.e. they too readily respond that a target is or is not present. In the case here AWS responded that a target was present when it was not in 91% of the cases when they were incorrect. So when they were incorrect in monitoring for a phoneme it was due to believing that the target sound was present when it was not. This suggests that their threshold is inappropriately set but that it is set too low, rather than too high which is what the authors of the VCH suggested. Vasic and Wijnen (2005) conclude that when the person who stutters has less attention that can be used to monitor their speech, they became more fluent. They state that under normal speaking circumstances the AWS set their threshold for error detection too high and over repair their speech leading to stuttering behaviours (not unlike the covert repair hypothesis, Postma and Kolk, 1993). Results from this RWPM task therefore only partially support the VCH, as AWS appear to have their parameters for monitoring for phonemes set too low rather than too high.

In the non-word phoneme monitoring task (NWPM) there were no significant differences between AWS or controls for accuracy or response time. In RWPM AWS were significantly less accurate than controls but once they are monitoring in non-words this difference disappeared. As the non-words were created to match the real words as far as possible (see chapter six for more details) the difference in accuracy is likely down to the difference in words being real vs. made up. When completing tasks using real words the semantics system is active (Indefrey & Levely, 2000; Levelt, 1998) the person looks into their semantic system and establishes that a word is a real word and information about that word is activated e.g. for *ball* information such as: *toy*, *round*, *used in games* becomes active in the person's mind. For non-words this process is far simpler, e.g. the person only has to establish whether the word they heard is real or not (Levelt, 1998). The results here suggest that AWS have no difficulties with phonological encoding when phoneme monitoring occurs in non-word vs when monitoring for phonemes in real words. This may be due to difficulties with phonological encoding in monitoring tasks only becoming apparent when real words are used. This may be due to the additional cognitive/linguistic load of using real words vs non-words. As has been stated above when presented with a real word we activate semantics information or semantic nodes (Levelt, 1998) which tell us about the word, when presented with a non-word we do not go through this process; thus making it, a potentially, more simple process.

Packman, Onslow, Coombes and Goodwin (2001) describe findings that when reading non-words aloud AWS still stutter despite there being no semantic or syntactic demands in this task. It is important to note that reading aloud requires motor planning and motor execution whereas in this task no overt speech was needed. This may mean that whilst phonological encoding is not slowed or impaired by the presence of semantic information in non-speech tasks it may be impaired when overt speech is required (as in reading non-words aloud). It may also be that it is just motor planning and motor execution that are impaired in AWS when working with non-words. This will be discussed further below.

Data from AWS and any difficulties they may have with non-word repetition tasks have not been consistent (Byrd, Vallely, Anderson & Sussman, 2012; Smith, Sadogopan, Walsh & Weber-Fox, 2010). Byrd et al. (2012) criticised previous work stating that stimuli have not been sufficiently complex in past studies and recommend that in order for differences to be seen between AWS and controls tasks must be high level e.g. using seven syllable non-word repetition tasks. The tasks used in this study did not contain any non-words with more than four syllables so it may be that tasks were not challenging enough to show any differences between AWS and controls. The findings here may also be due to the difference between tasks used e.g. phoneme monitoring in non-words does not require any overt speech. This results in motor planning and motor execution not being required to complete the task accurately as opposed to non-word repetition tasks that do require these. Smith et al. (2010) suggested that more complex words may slow one or all of the following processes: phonological encoding, motor planning, motor execution. The results here suggest that, for non-words, it is not phonological encoding that is slowed in AWS. Instead, it may be that in the non-word repetition tasks used in previous research (Bryd et al., 2012; Smith et al., 2010) it is just motor planning and/or motor execution that are implicated. As the same non-words used in previous research were not used here it would be premature to conclude that when working with non-words AWS may only have difficulties with long non-words and/or difficulties may be isolated to motor planning and/or motor execution. Further work using phoneme monitoring in longer, multi-syllabic non-words should be conducted to try and establish if it is motor planning and/or execution alone that are impaired when AWS complete phonological awareness tasks with non-words.

From the GEE modelling that was used to investigate if any of the predictors that were controlled for (target sound, presence of target sound, position of target sound, position of stress within the word, number of syllables a word has and number of phonemes a word has) influenced participant’s accuracy in RWPM it was found that, for AWS, /n/ was responded to significantly less

accurately than any other phoneme. This was in contrast to controls who responded to /n/ significantly more accurately than /k, l, m, r, s, ʃ/. Howell, Au-Yeung, Yaruss and Eldridge (2006) used the index of phonetic complexity (IPC) developed by Jakielski (1998) to investigate if the fluency of children, teenagers and adults who stutter is affected by how phonetically complex a word is.
The IPC is a scoring scheme that can be applied to words and is based on English child sound and language development. Each phone/word is given a score based on the scoring scheme in table 8.1 below.

Table 8.1 IPC scoring scheme (Jakielski, 1998)

Factor	**No Score (0)**	**One point each (1)**
Consonant by place	Labials, coronals, glottals	Dorsals
Consonant by manner	Stops, nasals, glides	Fricatives, affricates, approximates
Singleton consonant by place	Reduplicated	Variegated
Vowel by class	Monophthongs, diphthongs	Rhotics
Word shape	Ends with a vowel	Ends with a consonant
Word length (syllables)	Monosyllables, disyllables	Multisyllabic
Contiguous consonants	No clusters	Consonant clusters
Cluster by place	Homorganic	Heterorganic

Howell et al. (2006) found that for teens and adults who stutter, stuttered content words had higher IPC scores than fluent content words. There was no such difference for function words and there were no differences in fluency rates for children who stutter regardless of IPC score or word class. The authors then wished to examine which of the factors above best predicted occurrences of stuttering. They found that consonant by manner, consonant by place, word length and contiguous consonants were the largest contributory factors in predicting dysfluency and consonant by manner was the overall best predictor. This means that for adults who stutter and teenagers who stutter they are more likely to do so on words containing fricatives, affricates and approximants; containing dorsals (postalveolar, velar), are multisyllabic and contain consonant clusters. As manner had the most predictive value Howell et al. (2006) describe it as an effective way of classifying motoric difficulty. In this study AWS performed most poorly on /n/ which is in contrast to the findings above as it is in a low scoring place of articulation – alveolar, and has a low scoring manner of articulation – nasal. It is important to note, however, that this was a perception task not a spoken one, so sounds that are more difficult to produce, due to motoric difficultly, may not be harder to perceive. It may be interesting to look back at the data presented here and score the words used in the above manner to see if, like in production tasks, the same factors predict accuracy in terms of perception.

8.4.2 Real word and non-word phoneme monitoring – Results for AWC

As with AWS, those who clutter performed in a very similar way in both real and non-word phoneme monitoring tasks. AWC (like AWS) were less accurate than controls at detecting phonemes amongst real words. This suggests that those who clutter have very similar difficulties to those who stutter in terms of phonological encoding. Unlike the stuttering literature there has been very little written about cluttering and phonological encoding. Van Zaalen (2009) describes cluttering as being due to defective language automatization and that the speech plan is not ready for overt speech. Van Zaalen (2009), Van Zaalen and Reichel (2015) and Van Zaalen, Wijnen, and Dejonckere (2011a) have suggested that there are two sub groups of cluttering, phonological and linguistic. In phonological cluttering the authors suggest that the rate of speech in AWC is too great for their ineffective phonological encoding skills to enable them to produce fluent speech. When this occurs, due to the phonological plan not being correctly complete, the message cannot be produced fluently (Van Zaalen, 2009; Van Zaalen & Reichel, 2015). This suggestion may help explain the difficulties seen in the speech of AWC as the authors make a case that due to poor phonological encoding the speech contains excessive coarticulation, telescoping and errors in sequencing syllables. Van Zaalen (2009) and Van Zaalen and Reichel (2015) suggest that the differences in error patterns seen in AWC is evidence for there being two subgroups e.g.

> *"Defective automatisation of lexical (lemma) retrieval and grammatical encoding problems can result in word and phrase repetitions, interjections, hesitations and revisions". –* Syntactic cluttering

vs.

> *"Errors in phonological encoding are not detected by the monitor, resulting in word structure errors ('motoric effects': coarticulation, telescoping or syllable sequencing errors) in multi-syllabic words". –* Phonological cluttering *(Van Zaalen, 2009 pp 144)*

There is, however, very little data to support this idea and it is more of an interpretation of error patterns and clinical experience, than being based on findings from work such as that conducted here. Work completed by Van Zaalen (2009), which underpins the notion of these two subgroups, involved the analysis of errors in a variety of speaking situations and the ability of AWC to complete speech motor control tasks. These errors were then analysed and divided into two separate groups (described above). The findings in this study suggest that poor phonological encoding skills impact upon AWC ability to perceive phonemes accurately. This adds some support to Van Zaalen's (2009) theory of phonological cluttering, but it is important to note that motor planning and motor execution may also be impaired in AWC. Further work is needed to ascertain the involvement of each of these processes of speech/language production. The idea that motor planning and/or execution may be implicated is not discussed in any depth by Van Zaalen (2009), but may also offer an explanation for difficulties observed in cluttering. It may be a combination of phonological encoding difficulties and motor planning and/or motor execution difficulties taken together that result in the deviant speech patterns observed in cluttering. Furthermore, the notion of sub groups of cluttering is not supported anywhere is this data as there are no indications of any bimodal distributions with consistently small standard deviations. This suggests that AWC are performing in a homogeneous way (like AWS and controls). That is not to say that sub groups of AWC are not possible, however based upon this data it seems unlikely that the two groups that exist do so due to one group having difficulties with phonological encoding and the other due to difficulties with grammatical encoding (as Van Zaalen, 2009, Van Zaalen et al., 2011a suggest). Based upon this data what appears more likely, if subgroups do exist, is that as Ward (2006) suggested, the two groups may be motoric and linguistic. The sub groups may differ with one group having a greater difficulty with motoric aspects of speech (e.g. accurate motor planning and motor execution) and the other greater difficulty with linguistic planning (e.g. difficulties with lexical access). As phonological encoding occurs alongside motor assembly/planning and lexical retrieval (Levelt, 1998) it is perfectly possible that phonological encoding may be impaired in both of these potential sub groups.

The results here from AWC are also consistent with the covert repair hypothesis (CRH), (Postma and Kolk, 1993). This hypothesis suggests that stuttering is due to making repairs to a faulty articulatory plan and that this articulatory plan is faulty due to slowed and inaccurate phonological encoding. In AWC it may be that inaccurate and or slowed phonological encoding results in stalling behaviours, e.g. a high use of normal non fluencies which are used to allow time to make repairs to the articulatory plan. It has been documented by Myers and Bakker (2013) that those who clutter are described by clinicians as using a significantly larger number of normal dysfluencies than their fluent counterparts. Normal non fluencies include behaviours such as: fillers like *ummm* and *errr*, interjections and pauses. The term maze behaviours has also been used when describing the speech of AWC (Ward, 2006). It is possible that these maze behaviours, or normal non fluencies, occur for a similar reason to stuttering behaviour in AWS (as suggested by the CRH, Postma and Kolk (1993)) and that they are a result of error detection in the articulatory plan. Unlike AWS who have been deemed to 'over' identify errors in the articulatory plan (Bernstein & Wijen, 2007; Postma & Kolk, 1993), AWC may detect errors and then use maze behaviours e.g. fillers, pausing, hesitation to give themselves more time to attempt a correction. This idea, however, does not answer all of the questions. How can it be that AWC are reported to have reduced awareness of the errors in their speech if they are using maze behaviours and normal non fluencies to give themselves time to correct their errors? And if they do use maze behaviours as a stalling technique could this not be as a result of difficulties with lexical assess, or sentence construction rather than as a result of error detection?

In response to these questions it has been found that when AWC slow their speech they are able to be fluent (Van Zaalen et al., 2011a; Ward, 2006). This may suggest that with slower speech there is more time to detect and correct errors in the articulatory plan before they occur in overt speech. It may also be that with a slower rate of speech phonological encoding can occur unimpaired, resulting in an accurate articulatory plan and fluent speech. Regarding AWC having a reduced awareness of their speech errors this idea, although held by a great many, (Daly 1996; Daly & Cantrell, 2006; Ward 2006; Weiss, 1964) is based upon clinical experience and self-reports from AWC. There have not, to date, been any studies investigating this directly. What is needed is a large, well-controlled investigating looking at the ability of those who clutter to detect errors in their speech and the speech of others. Such a task has been completed with AWS (Postma & Kolk, 1992), and it was found that error detection was no different in AWS to controls, suggesting that stuttering is not caused by a self-monitoring deficit. The same conclusions cannot yet be drawn about AWC and it is possible that the reported 'lack of awareness' of speech errors is due to poor internal monitoring and not due to being unaware. The notion that AWC have poor awareness of their speech and their errors has been questioned more recently by Van Zaalen (2014) and Ancell (2014). Van Zaalen (2014) reported an increasing number of cases in which AWC felt great distress at their speech not being understood and of clients reporting that they know their speech is not clear. What remains to be answered is if this is as a result of negative listener responses, or if they are actually aware of online errors as they speak. It may also be that the severity of the clutter may impact upon how aware AWC are of their errors; for example, those with a mild clutter may not be aware of their dysfluency as they are not asked frequently to slow down or repeat themselves, they also make fewer errors in need of detection and repair. By contrast, those who have a severe clutter will be regularly asked to repeat and will make far more errors needing repair.

A further explanation for maze behaviours and an increased number of normal non fluencies in the speech of AWC is that they are not a product of stalling to correct a faulty articulatory plan due to slow and/or impaired phonological encoding. Instead they may be due to difficulties with lexical access (Bretherton-Furness & Ward 2012; Ward, 2006). Bretherton-Furness and Ward (2012) found that AWC named significantly fewer items than controls in an association naming task. This was also the case in the pilot study reported in chapter three of this thesis. Using tasks of this nature has been criticised however, as although they assess lexical access they are also reliant upon other executive functions; for example, they require good working memory skills and demand high levels of attention, they also appear related to education level (Cahn-Weiner, Boyle & Malloy, 2002; Rodriguez-Aranda & Martinussen, 2006; Sumerall, Timmons, James, Ewing & Oehlert, 1997). Thus it may be that previous findings resulted not from difficulties with lexical access, but rather due to difficulties with memory and attention. It was also suggested by Sasisekaran and De Nil (2006) that differences in task performance cannot be due difficulties with lexical access as they used familiarisation prior to their task being completed (phoneme monitoring in silent picture naming). Familiarisation was conducted as in the silent picture naming task pictures needed to be named accurately in order for the correct phoneme to be monitored for. Familiarisation was also used prior to the tasks given to participnats in our study and the same words were used in our phoneme monitoring in real words task, were used in the silent picture naming task. Therefore, participants were already familiar with the words used, suggesting that lexical retrieval is not implicated here. Further assessment of lexical assess, e.g. by using lexical decision making tasks, should be conducted with AWC before any conclusions can be drawn regarding why AWC are dysfluent. What can be concluded here is that like AWS, AWC have difficulty detecting phonemes in real words but not in non-words.

As has been suggested with AWS, it may be that the difference between real and non-words, in terms of accuracy at detecting phonemes, may be due to the increased burden real words place on receptive language skills. The picture emerging with both groups is that phonological encoding may only be impaired, or become difficult, once there is additional cognitive load involved, e.g. the activation and competing of semantic nodes (Levelt, 1989) in order to establish what the word means. An alternative view is that the difficulties are not phonological but purely semantic. It has been suggested that AWC may have difficulties with lexical access (Bretherton-Furness & Ward, 2012; Daly, 1996; Daly & Cantrell, 2006; Van Zaalen, Wijnen & Dejonckere, 2009d; Ward, 2006). This may be what is not only causing the dysfluencies in the speech of AWC (as have been discussed above), but it may also be the reason they are less accurate at phoneme monitoring in real words vs. non-words. No such suggestion regarding difficulties with lexical access has been made for AWS and the prevailing opinion remains that AWS have a deficit in phonological encoding. At this stage it is not clear whether AWC have difficulties with lexical access and phonological encoding or just one of these two processes. Further work addressing this question is needed before conclusions can be drawn.

To further investigate which factors may affect AWC's difficulty with phoneme monitoring in real words (RWPM) exploratory analysis using GEE was used. It was found that AWC were significantly less accurate at detecting /r/ and /s/ compared to all other phonemes. According to the IPC (Jakielski, 1998) /r/ would get a score of one out of two as it is an approximant sound, but it is also in an easy to produce alveolar position. The same can be said of /s/ which gets a score of one out of two as it is a fricative, but is also in an easy to produce alveolar position. Based upon the IPC, the sounds that would be expected to be most difficult to detect, which were used in these tasks, include: /k, f, l, r, s, ʃ/. AWC did follow this to some extent finding /r/ and /s/ more difficult than other phonemes, as noted earlier though AWS did not follow this with /n/ being the most difficult to detect which scores zero.

These differences suggest that AWC are behaving differently to controls and AWS. Whilst like AWS there was a significant main effect and AWC were significantly less accurate at detecting phonemes in real words, there are different factors causing this difference. With AWS /n/ was detected significantly less accurately than any other phoneme, suggesting that for them most phonemes were equally difficult to detect. Controls were most accurate at detecting /b, d, f, n, p, t/, and least accurate at detecting /k, l, m, r, s, ʃ/, demonstrating that as a group there were more differences between phonemes for them than for the other two groups. Also of interest is that according to the IPC (Jakielski, 1998) most of these accuretly detected sounds are low scoring sounds (the majority are: stops or nasals, alveolars, bilabials or labiodentals). /f/ is the only phoneme scoring one out of two according to the IPC, the others score zero. This may be due to controls being subject to the predictive complexities laid out in the IPC but those who are dysfluent may not be. This could be because they have phonological encoding difficulties and therefore sounds are not more or less complex for them in the same way that they are for their fluent peers. What may be of interest is to investigate a broader range of sounds including /g, h, j/, which score either one or two out of two on the IPC, to see if it is the case that only controls appear affected by sound complexity as defined by the IPC.

AWC were also significantly more accurate at phoneme detection in real words when there was no target sound to monitor for compared to when it occurred in any other position. This means that they were significantly more accurate at detecting when a phoneme was not present compared to when it was in any other position in the word. It is not clear why this is the case, especially given that when just comparing target present vs. target not present there was no significant effect. It may be that this is a type one error or it may be that it is easier to establish that a sound is not present vs. when it is in any other position but not when the question is just present or not. This appears to be the case only for AWC, as controls and AWS did not show this same trend.

8.4.3 Phoneme monitoring in silent reading – Results for AWS

As expected, when completing phoneme monitoring in written words there were no differences between AWS and controls in terms of accuracy. However, unexpectedly AWS took significant longer than controls when completing this task. This was not expected as there has been no evidence to suggest that AWS have any phonological awareness difficulties related to reading. Poor grapheme to phoneme correspondence is seen in dyslexia (Fox, 1994; Goswami, 2000; Snowling, 1980) but has not been described as occurring in those who stutter. All participants were screened for having co-morbidities and as there were no outliers and consistently little variation in the data it is unlikely that further diagnoses are confounding the results here.

Indefrey and Levelt (2000) describe silent reading tasks as involving phonological code retrieval, and phonological encoding but also a task 'lead in' which they define as visual word recognition. Therefore, the task used here is a relatively simple one as there is no need for the participant to go through conceptual preparation or lexical selection as they would in the silent picture naming task discussed below. Results from the present study suggest that even with less cognitive load i.e. not having to go through conceptual preparation and lexical selection, the process of phoneme monitoring is still slowed in AWS. This is indicative of phonological encoding and phonological code retrieval being areas of difficulty for AWS. This result, whilst unexpected, is consistent with the RWPM results which also found AWS differ to controls in their ability to monitor for the presence of a spoken phoneme in a real word. The main difference in the silent reading task being that it was speed of responses rather than accuracy of responses which was adversely affected. Note that this pattern differs from that of the dyslexic population who have been found to be less accurate than their peers when completing tasks requiring knowledge of grapheme to phoneme correspondence (Fox, 1994; Snowling, 1980).

The finding that AWS have slower response times to controls in this phoneme monitoring in silent reading task is also consistent with work described earlier completed by Sasisekaran & De Nil, (2006); Sasisekaran, De Nil, Smyth & Johnson (2006). They also found that AWS were slower than controls when performing phoneme monitoring tasks but were similar in terms of accuracy. Once again these findings are supportive of the covert repair hypothesis that phonological encoding is slowed in AWS.

It must also be considered that slower response times in this task for AWS may be as a result of stuttering rather than being indicative of a phonological encoding deficit. As has been discussed AWS differ from their fluent counterparts in terms of practice effects (Smits-Bandstra, 2010) and whilst many studies have found that there are no differences between AWS and controls in simple reaction time tasks (De Nil & Saint-Cyr, 2006; Hennessey, Nang & Beilby, 2008; Smits- Bandstra, 2010; Till, Goldsmith & Reich, 1981) it has already been reported here that AWS were slower than controls on both reaction time tasks used (simple and complex). It is, therefore possible that results can be explained by differences in practice effects or due to having a population of AWS who have a greater than is typical difficulty with reaction time tasks.

As has been reported already the exploratory analysis to look at the potential impact of predictors such as target sound, found that for AWS no factors held as significant in the GEE model.

8.4.4 Phoneme monitoring in silent reading – Results for AWC

In this task AWC did not perform significantly differently to controls in terms of accuracy or time taken to complete the task. This suggests that when reading real words rather than hearing them there is no difficulty with phoneme monitoring and thus no difficulties with phonological encoding. As has been described above, for AWS, this task is simpler than phoneme monitoring when listening to a word (Indefrey & Levelt, 2000) therefore, it could be that AWC only have difficulties with phonological encoding when a task is complex and demanding.

Findings from the pilot study (chapter three) led to the prediction that AWC would perform as controls in terms of accuracy but that they would be slower than controls. Due to there being so little research with AWC making predictions for tasks has been based on very limited previous data. The pilot study suggested that AWC may have a generalised phoneme monitoring deficit as they were slower at the sound detection and morphological detection tasks. They were also slower than controls at the sound detection task regardless of the sound used. Thus further suggesting that AWC have a generalised difficulty rather than a more specific one e.g. one that is limited to phoneme monitoring in silent picture naming as in AWS (Sasisekaran & De Nil, 2006). The findings here do not support the hypothesis that AWC would be slower than controls and thus results suggest that AWC do not have a generalised phoneme monitoring deficit and only have difficulties when tasks are more demanding e.g. phoneme monitoring in real words.

Methodological differences between tasks here and tasks completed in the pilot are a likely cause for the differences in results; for example, in the morphological detection task used in the pilot study participants were asked to identify morphological endings (e.g. –*ing*) rather than a range of individual phonemes. There were also far fewer trails used in the pilot study and words used in the sound detection task were all low frequency, multisyllabic words, whereas due to using the Snodgrass words the majority in the main study were frequently occurring, monosyllabic or bisyllabic words. A further difference was that in the pilot study sounds to be monitored for appeared written on the screen rather than being played via headphones. Therefore, in the pilot study there was more demand upon participants as they had to convert graphemes seen on the screen to phonemes to listen for. This additional complexity may be the reason that AWC took longer than controls when completing the tasks but once the additional load was removed (as in the main study) AWC no longer took more time than controls.

Findings that AWC do not differ to control also demonstrate how AWC differ from those who are dyslexic. As described earlier it has been found that those who are dyslexic are less accurate than controls when completing tasks requiring knowledge of grapheme to phoneme correspondence (Fox, 1994; Snowling, 1980). There is no evidence here or from previous studies to suggest that AWC have any difficulties with grapheme to phoneme correspondence.

8.4.5 Silent picture naming – Results for AWS

When completing the phoneme monitoring in silent picture naming task AWS were significantly less accurate than controls. This finding was not expected and did not support the hypothesis that there would be no differences in terms of accuracy between AWS and controls. Based upon previous findings by Sasisekaran and De Nil (2006) it was expected that AWS would be slower than controls when completing this task but just as accurate. The opposite was found in this case. One reason for the difference in results found here compared to Sasisekaran and De Nil's (2006) and Sasisekaran, De Nil, Smyth and Johnson (2006) may be due to the differences in stimuli. In the work completed by Sasisekaran, De Nil, Smyth and Johnson (2006) they only used 14 different target words and bisyllabic words. They also used different phonemes e.g. /d, g, s, l, f, r, p, t, k, d/. In the work here 226 different target words were used giving a far greater breadth of data. In Sasisekaran and De Nil's (2006) study phonological complexity was manipulated (noun phrases and compound nouns) which resulted in just seven target words being used. Once again this is a very limited number of targets and thus differences may not have been found in terms of accuracy in phoneme monitoring in silent picture naming.

Sasisekaran and De Nil (2006) and Sasisekaran, De Nil, Smyth and Johnson (2006) found that AWS were slower than controls in completing this task and suggested that these differences were due to a delay in activating and then encoding a sound segment or due to a delay in self-monitoring the output from phonological encoding. Here there were no differences in terms of time taken but there were in terms of accuracy, therefore the same can be said when interpreting these results as when interpreting Sasisekaran, De Nil, Smyth and Johnson's (2006) results. Differences in accuracy are likely down to errors in activating and then encoding phonemes or due to an error in self-monitoring the output.

The results here are consistent with the phoneme monitoring in real words task (described above). Therefore, a similar interpretation can be made that AWS have phoneme monitoring difficulties due to difficulties activating the correct phonemes and then encoding them into the word, as suggested by Sasisekaran & De Nil (2006). It has been found by Postma and Kolk (1992) that AWS do not appear to have a self-monitoring deficit (in terms of monitoring for their own speech errors) and therefore difficulties are down to the slowed or faulty activation of phonological segment nodes (Postma & Kolk, 1993). This slowed activation is then thought to lead to appropriate phoneme choice taking longer and being more susceptible to error.

8.4.6 Silent picture naming – Results for AWC

AWC performed as AWS; they were significantly less accurate than controls but they were no different in terms of time taken to respond. This result partially supports the experimental hypothesis. In the pilot tasks (chapter three) sound detection and morphological detection, AWC were slower than controls but such a difference was not seen here. This may be due to methodological differences e.g. in the sound detection task graphemes were given to represent the phonemes rather than phonemes being played via headphones, as they were here. Morphological detection requires the ability to segment a word e.g. recognise the segment *-ed* or *-ing* whereas phoneme monitoring does not require this. These differences in tasks used may be the reason that AWC were not slower than controls in silent picture naming.

Finding that AWC were significantly less accurate than controls when monitoring for a phoneme during silent picture naming was as predicted. This hypothesis was made based upon the 'approaching' significant difference that was found in the sound detection task in the pilot. It has also been suggested by Van Zaalen, Wijnen & Dejonckere (2009d) that AWC may have difficulties with phonological encoding (they suggested subgroups as discussed above). The idea of subgroups is not supported by this data, however. AWC in this task behaved in a very similar way to each other (as they did in the RWPM task). Rather than subgroups perhaps it may be more appropriate to think of a cluttering spectrum (Ward, 2006). This idea will be discussed in further depth below when the implications of results are outlined.

8.5 Syllable detection tasks – Results for AWS and AWC

As there were no significant differences between AWS, AWC and controls in both the syllable detection tasks in terms of accuracy and response time the results and their interpretations will be discussed together. It was expected that AWS and AWC would both perform significantly more slowly and significantly less accurately than controls in both tasks; a predictions that was not supported here.

Levelt (1998) described phonological encoding as involving; the *generation of segments that constitute words* and the *integration of sound segments in syllable frames*. Therefore, phonological encoding may be impaired at one of both of these stages. It has been seen, from the results above, that both AWC and AWS appear to have some impairment in phonological encoding, specifically, in accurately identifying phonemes in real words and in silent picture naming. In terms of Levelt's stages of phonological encoding these difficulties relate to *generating the correct sound segments for words*. Results in the syllable detection tasks, however, suggest that impairment is specific to this stage in phonological encoding as there were no difficulties with correctly identifying the number of syllables both in real and non-words. It is however, unlikely that these processes occur independently to each other. However, directly investigating each stage of phonological encoding seems implausible; especially given Coles, Smid, Scheffers and Otten (1995) and Meyer's (1992) comment that it is difficult to test and manipulate it directly as it is a complex process embedded within language formulation.

Whilst the p values from the ANOVAs were not significant for response time in either syllable detection task, the value for syllable detection in real words (SDRW) was approaching significance. Based upon the means for the three groups there was a large difference between the mean scores for AWC and controls (0.81 and 0.94 respectively). Those who stutter performed between the other two groups (mean score of 0.89). This suggests that of the three groups, AWC had the greatest difficulty with this task but due to the larger standard deviation than in RWPM results were not significantly different. The differences between groups for syllable detection in non-words (SDNW) were not so pronounced and results were far from significant in this task. This pattern is similar to what was seen between RWPM and NWPM above, with AWC and AWS being significantly less accurate at RWPM but comparable to controls in NWPM. Whilst it is important to stress that there is not a significantly difference between groups in SDRW there is still a pattern that is noteworthy. This pattern is further evidence to suggest that when real words are used, those who are dysfluent (especially AWC in this case) have far greater difficulty with tasks assessing phonological encoding. As has been discussed above, this may be due to real words being more cognitively/linguistically demanding and thus activing lexical information which may impair the accuracy of phonological encoding.

Wingate (1988) proposed that there is a delay in the retrieval and encoding of syllable rhyme during speech production in AWS and this then leads to overt stuttering behaviours. Packman, Code and Onslow (2007) propose the syllable invitation theory (SI theory) and the Vmodel both of which suggest that AWS have difficulty initiating syllables and that stuttering begins when motoric and linguistic demands are increased by the speaker having to alter the stress within words once they move beyond just babbling as an infant. It is not clear from these proposed ideas whether or not those who stutter have any difficulties with perceiving and identifying syllables. Results here suggest that although AWS and AWC may have difficulties with phonological encoding they appear to be isolated to the accurate perception of phonemes rather than syllables.

8.6 Research implications

The current LCD definition suggests that cluttering is a rate based disorder (St Louis & Schult, 2011) and there is no suggestion that there are any semantic, syntactic or phonological difficulties associated with cluttering. The results reported here suggest that AWC may have difficulties with phonological encoding (in real words) and this may be one reason why their speech contains errors such as irregular speaking rate, excessive normal dysfluencies, excessive collapsing or deletions of syllables and irregular syllable stress. If AWC are creating inaccurate articulatory plans due to inaccurate phonological encoding this could then lead to errors such as sounds being missed or distorted and may disrupt the rhythm of speech as revisions are attempted and excessive normal dysfluencies are used to allow more time to find the words/sounds needed. Despite results suggesting that AWC may have a phonological encoding deficit that is not to say it is the only process that may be going wrong and, much like in stuttering, it is unlikely that one theory or one area of deficit can explain all the characteristics of the disorder.

In the tasks used in this study AWS and AWC performed in a very similar way, it may be that the two disorders are caused by similar deficits but that the resulting behaviours differ. Neurologically AWS and AWC have been found to share abnormal functionality in similar areas of the brain when completing various speech and non-speech tasks. Compared to fluent speakers AWS have been found to have: reduced activity in the primary motor cortex, auditory cortex and Rolandic operculum in the left hemisphere (Brown, Ingham, Ingham, Laird & Fox, 2005). AWS have also been found to have: over activity in the SMA, cingulate motor area and cerebellar vermis (Brown, Ingham, Ingham, Laird & Fox, 2005). AWC are described as strikingly similar to fluent speakers at a cortical level (Ward, Connally, Pliatsikas, Bretherton-Furness, & Watkins, 2015); however, they do show greater activity in the premotor cortex on the lateral surface bilaterally and in the pre-supplementary motor area (Ward et al., 2015). These results suggest that in both AWS and AWC there is reduced activity in key motor processing areas of the brain. Compared to fluent speakers AWC had reduced activity in the lateral anterior cerebellum bilaterally. This suggests that both AWC and AWS have deviant cerebellum activity although AWS show over activation and AWC show under activation. Finally, subcortically, AWC demonstrate greater activity in the basal ganglia (Ward et al., 2015). Alm (2004) has also implicated the basal ganglia in AWS suggesting that it is impaired in its ability to produce timing cues for speech. In sum, current evidence suggests that similar brain areas are implicated in both disorders of fluency. So it may be that these neurological differences are causing some similar areas of difficulty e.g. phonological encoding; although it is highly unlikely that subcortical activity would implicate phonological encoding. Due to the exact neurological differences not being consistent in both disorders the resulting behaviours differ; fast, irregular speech rate in AWC and prolongations, blocks and repetitions in AWS.

The definition of both stuttering and cluttering, as discussed in chapters one and two, describe both disorders in terms of what we, as listeners, can hear. Despite results here suggesting that AWC may have a phonological encoding impairment it would be premature and over stating of results to suggest that the LCD definition needs revision. What results do suggest is that when diagnosing cluttering clinicians should think about more than what they can hear their clients saying and assessment should include evaluation of phonological awareness (deemed the most effective may of assessing phonological encoding, Coles, Smid, Scheffers & Otten, 1995; Meyer, 1992). Scaler Scott and Ward (2013) warn that the diagnosis and assessment of cluttering is largely subjective at present, and there is a need for a valid and reliable method of objective assessment. Whilst there is on-going work by Bakker and Myers (2008) on developing the freeware CLASP, this is not meant as an assessment protocol but rather as an assessment tool for objectively measuring rate and fluency. Further assessment tools and more detailed diagnostic criteria are needed for the valid and reliable diagnosis of cluttering, especially for those who have a mild clutter, which can often be missed.

In terms of the implications of results on the treatment of cluttering, ideas from this work are very speculative at this stage. As Scaler Scott and Ward (2013) point out, working merely on reducing the rate of speech with those who clutter may get their speech clearer when sitting in a clinic room for a short period but carry over will be very limited. There needs to be ‘buy in’ from the client and activities, cues and reinforces should all be natural (Scaler Scott & Ward, 2013). With this in mind the authors suggest activities including working on discourse and conversation structure, e.g. using a pyramid model whereby the most important information is at the top of the model representing a small amount of information to orientate the listener to the message and then working down adding additional information if/when appropriate. Although potentially less ‘natural’ the results here suggest that working on phonological awareness may be appropriate. It is important to stress though that tasks would need to be high level in order to challenge AWC. The control tasks used as screening measures in this study demonstrate that tasks would need to be high level. This is because there were no differences between AWC and controls in terms of ability to detect rhyme or ability to detect the initial or final sound in a spoken and then repeated monosyllabic words or non-word. Tasks used should be done to improve awareness that correctly identifying and manipulating phonemes may be difficult for the client. High level phonological awareness tasks for example, blending and segmenting individual phonemes may be appropriate. If tasks of this nature are used in therapy they should make up part of a session/block of treatment and would not form the basis or be the focus of work. Whether therapy of this nature should be completed with children who clutter (CWC) remains to be seen as so far there has not been any work completed regarding phonological encoding in CWC.

From the point of view of AWS results support previous findings that AWS have difficulties with phonological encoding (Bosshardt, 1993; Byrd, Vallely, Anderson & Sussman, 2012; Hennessey, Nang & Beilby, 2008; Ludlow, et al., 1997; Nippold, 2002; Sasisekaran & De Nil, 2006; Sasisekaran, De Nil, Smyth & Johnson, 2006; Vincent, Grela & Gilbert, 2012; Weber-Fox, Spencer, Spruill & Smith, 2004). Results also support the covert repair hypothesis (Postma & Kolk, 1992) however; this theory cannot explain all of the characteristics of stuttering or the reasons for its onset. For example, it cannot explain why psychological stuttering may begin or why some speakers have more blocks and others have more prolongations. It also does not offer any explanations as to why some children recover and others do not and why some adults and teenagers who stutter respond well to therapy and others do not. The notion that one theory can explain all aspects of stuttering or all reasons that may cause it seems implausible and restrictive given the multifactorial, heterogeneous nature of stuttering. The same could also be said regarding cluttering. What may be more appropriate would be to think of fluency disorders as being caused by and characterised by different theories/explanations. What may explain one person's stuttering or cluttering may not apply to another person and what may explain some fluency behaviours in some speakers may not adequately describe them in others.

Finally, it may be appropriate to think of fluency from an encoding model point of view. Byrd, Sheng, Ratner and Gkalitsiou (2015), and Coalson and Byrd (2015), have conducted work with AWS looking at phonological encoding, most recently from the perspective of phonological working memory (Byrd, Sheng, Ratner & Gkalitsiou, 2015). They found that AWS had an impairment of verbatim phonological information and sub vocal rehearsal aspects of Baddeley's (2003) model of working memory. These difficulties with phonological working memory appear to be subtle with no impairment in basic memory function. McGill and Byrd (2016) have also implicated phonological working memory as possibly being impaired in AWS. They suggested that differences in phonological working memory, including visual-to-sound conversions, lexical access, and sub-vocal manipulations, may compromise AWS ability to be fluent. Coalson and Byrd (2015) identified that AWS are less accurate at phoneme monitoring when the target sound is not in an initial stress position. They concluded that stress and syllable boundary assignment may affect the time taken during phonological encoding. This could then result in a delay in speech planning and then to stuttering behaviours. This work has almost exclusively been conducted from an output point of view. Perhaps it would be more appropriate to heed Sasisekaran's (2014) advice that work investigating phonological encoding using overt speech is complicating the issue with other processes such as lexical retrieval, motor planning and motor execution. Given that phonological working memory has also be identified as an area of difficulty impacting upon phonological encoding (Byrd, Sheng, Ratner & Gkalitsiou, 2015; McGill & Byrd, 2016) a model of encoding in fluency must consider how this and lexical retrieval, motor planning and motor execution may impact upon accurate and timely phonological encoding. There is a need for more work like that completed in this thesis, where overt speech in not required, to ensure that what is being tested is purely phonological encoding and not other processes e.g. motor planning/execution.

8.7 Limitations

Although there are 14 AWC and 14 AWS included here, having a larger number of participants would improve the power of the findings. Research with clinical populations is frequently compromised by small group numbers. Work that has been completed with AWC is mainly completed with small numbers, and there may be a number of reasons for this. Firstly, cluttering is considered a rare condition; AWC are often unaware that they have a treatable communication disorder and finally, there is no definitively agreed upon definition of cluttering. Due to the large effect sizes that were obtained e.g. d= 1.2 in RWPM there was 0.92 power which is extremely high. This suggests that despite the small numbers used here power remains high, making results robust.

One limitation of this work is that using the Snodgrass picture set constrained the words that could be used in RWPM to a set of nouns, the majority of which were one or two syllables in length. There were very few words with the stress on the second or final syllable and the majority of words had three, four or five phonemes. This limits how accurate results from the generalised estimating equation (GEE) might be, as there is not an equal number of words in each level of each predictor (e.g. there are very few four syllable words – 3.1%, see appendix 26). The result of this could be that factors affecting accuracy or time taken may have been underestimated or missed, e.g. for the GEE used to assess how each factor effected the accuracy of AWC to detect phoneme in real words the effect for the number of phonemes did not hold with further analysis. This might be due to only words with more than five phonemes negatively impacting upon accuracy and due to the small number of words with more than 5 phonemes the impact of them may have been missed (type two error).

For the same reasons as those described above it was not possible to use as wide a range of phonemes as would have been ideal. According to the IPC (Jakielski, 1998) /g, h, j/ are more complex phonologically and therefore would receive a higher IPC score than /b, p, t, d/. Using sounds that are harder to produce may also demonstrate that they are also harder to perceive. Including a full range of phonemes used in English would also give a broader range of results rather than focusing mainly on those with low IPC scores which is what we have here.

8.8 Future research

Findings from reaction time tasks need to be replicated as there are no other data at present for AWC. They should also be replicated with AWS due to the conflicting nature of what has been found between the results here and previous findings. Expanding upon Smits-Bandstra (2010) findings may also be useful as although it is highlighted that AWS differ to controls in terms of practice effects and guidelines are given for using reaction time tasks these could be made more detailed. For example; what is the number of trails needed to ensure AWS have learnt a task, both complex and simple? And how does this affect reaction time?

To expand upon phoneme monitoring tasks it may be interesting to see how else semantics may influence AWS and AWC ability to monitor for phonemes. For example, semantically ambiguous words could be used e.g. those that have multiple meanings e.g. *bark* and *date* or those with related senses e.g. *twist* which has multiple dictionary definitions and differs semantically depending upon the context it is used in. These words have multiple entries within the lexicon (Rodd, Gaskell & Marslen-Wilson, 2002), which Borowsky and Masson (1995) have found affects lexical decision making and word naming (reading a word aloud). For AWS and AWC it may be that the additional load of having multiple entries within the lexicon results in slower phonological encoding and thus slower and less accurate phoneme monitoring. If AWS and AWC are 'held up' in the stages of lexical retrieval to a greater extent that their fluent peers it would suggest that the process of phonological encoding is made more difficult with increased lexical complexity. A further way to increase the complexity of this task may be to use phonologically more complex words. Sasisekaran and De Nil (2006) manipulated phonological complexity by using noun phrases and compound nouns (*green house* vs. *greenhouse*). They found no differences between the two conditions but argued that they had not made words complex enough. One way to tackle this would be to manipulate phonological complexity in a different manner e.g. using words with less frequent bigrams or trigrams or words with unusual sound combinations and low familiarity scores e.g. *zori* which is a type of sandal (Harley, 2003). In the non-word task it may also be interesting to use words that violate English phonotactic rules e.g. *mbotto* and investigate if there is a difference between words of this nature and words which adhere to English phonotactic rules.

In terms of the syllable detection tasks, as has already been mentioned, there was no significant differences between the three groups. This result needs to be replicated before any conclusions can be drawn about AWS and AWC ability to correctly recognise syllables. It is possible that this stage of phonological encoding is not an area of deficit but it may be that the task was not challenging enough. Further research should use words with a higher number of syllables e.g. between four and seven. It has been suggested by Byrd et al. (2012) that tasks used to assess non-word reception have not been challenging enough e.g. words have not contain enough syllables. The same may apply here and, as Byrd et al. (2012) found, by using words up to seven syllables long there then may be a difference between the three groups. It would be expected that AWC would perform less accurately than controls and AWS would perform more slowing than controls. This prediction is based on the fact that there were large mean differences between AWC and controls in terms of accuracy and large differences in response time between AWS and controls when completing syllable detection in real words and non-words.

More broadly, further work should focus on cluttering more generally. There is still a great deal we do not know, not only about phonological encoding but also about attention and inhibition e.g. how do those who clutter perform on a Colour-Word interference task (Stroop, 1935), which tests the ability to inhibit unwanted responses by asking participants to respond to the colour name presented rather than the colour the word is presented in. Other executive functions warranting further research include working memory and planning (both linguistic planning tasks and more general planning tasks e.g. planning a time schedule) as these may impact upon fluency. For example, if those who clutter have poor working memory skills they are less likely to be able to complete tasks such as non-word repetition which requires a degree of working memory. Before we can make conclusions about the language skills of those who clutter we must first have a clear understanding of any potential impact from impaired executive functioning.

A further area of interest when working with AWC is motor speech skills. In AWS it is well established that factors such as voice onset times and vowel duration times differ in AWS compared to fluent controls. Voice onset times have been found to be longer in AWS compared to controls (Adams, 1987; Agnello & Wingate, 1972; Hand & Luper, 1980; Hillman & Gilbert, 1977; Metz, Conture & Caruso, 1979; Ward, 1990; Zimmerman, 1980). This well-established difference between AWS and controls has not been investigated in AWC. As has already been discussed the LCD definition is largely reliant upon listener perception rather than any objective measure of fluency.

Differences between AWC and controls in terms of voice onset time and/or vowel duration times may offer clinicians further diagnostic criteria by which to diagnose cluttering.

8.9 Conclusion

In conclusion, it has been found that AWS and AWC both have difficulties with phonological encoding, specifically when monitoring for phonemes in real words and in silent picture naming. Results support earlier findings that AWS have slowed and/or error prone phonological encoding and lend support to the notion that AWC also experience similar difficulties. Results may be due to tasks using real words, rather than non-words, placing greater linguistic demand upon AWS and AWC which results in phonological encoding becoming prone to error.

AWS and AWC consistently performed similarly across most tasks with the main differences between the two groups being response times in both the simple and complex reaction time tasks and in phoneme monitoring in silent reading (PMSR). It was unexpectedly, found that AWS took longer than controls and AWC to complete the simple and complex reaction time tasks and also took longer when completing PMSR. Also unexpectedly there were no differences between AWS, AWC and controls in terms of ability to detect syllables in both real and non-words.

As discussed, the results have implication for our understanding of cluttering and on how we define, diagnose and treat it. Results also suggest that the idea of two subgroups of cluttering is not supported in this data and a spectrum of cluttering may be a more accurate way of describing differences in characteristics and severity.

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Appendices

1. Appendix 1

Words used in sound detection task of the pilot study

The target sound is: 'f'

Prettified

Officiate

Censorial

Limerick

Affronting

Painterly

Stupefying

Humidify

Chortling

Protrusion

The target sound is: 'v'

Alveolar

Gravitated

Idealized

Wrangled

Peevishly

Nutritive

Fledgling

Quenchable

Covertly

Denuders

The target sound is: 'sh'

Aguishly

Federalise

Echograms

Backlash

Priggish

Supinated

Intermesh

Colloquium

Dishevel

Lexicalise

The target sound is: 'j'

Dejections

Assonant

Heptagons

Projectile

Fastidious

Threshers

Subjoined

Cajoling

Raffling

Objector

The target sound is: 'p'

Abductions

Gapingly

Refutably

Juxtapose

Ownership

Hospitable

Flockings

Relapsing

Chlorinate

Combustive

The target sound is: 'b'

Marlstone

Shackling

Compatible

Darksome

Marblings

Elapsing

Columbines

Scrubland

Hospitable

Fluoridate

The target sound is: 'l'

Vagrants

Obliquely

Kennelling

Occupancy

Sacrament

Whiptails

Subtilize

Withering

Valproate

Keratinize

The target sound is: 'r'

Factiously

Trunnion

Vacuumed

Lineation

Acuminate

Lecherous

Varicella

Biconvex

Fluorinate

Abruption

2. Appendix 2

Words used in morphological detection task of the pilot study

Loop	**Jumped**
Lost	**Elephants**
Tempting	**Walking**
House	**Pant**
Flowered	**Rabbits**
Happy	**Laughed**
Gardens	**Table**
Run	**Wasted**
Partying	**Crazy**
Oranges	**Countries**
Pianos	**Charged**
Steal	**Begin**
Bricking	**Eat**
Pictured	**Breath**
Salt	**Labouring**

3. Appendix 3

Words used in rhyme judgement task of the pilot study

1. Word – Bird
2. Hot - Table
3. Computer - Router
4. Pet - Vet
5. Fish – Pie
6. Flour - Magnet
7. Dress – Mess
8. File – Bile
9. Fruit – Orange
10. Cow – Sow
11. Five – Nine
12. Kitten – Bitten
13. House - Video
14. Royal - Bulb
15. Cone - Bone
16. Key - Lock
17. Sweat - Threat
18. Politics – Commons
19. Straight - Rate
20. Dance - Prance
21. Sky - Sun
22. Jelly – Light
23. Bite - Fight
24. Turtle - Glass

25. Queen - Prince
26. Throne – Moan
27. Up – Over
28. Work - Snake
29. Sofa – Picture
30. Weight – Skate
31. Break – Mend
32. Glass – Brass
33. Poster - Cake
34. Matter – Batter
35. Monkey - Carpet
36. Wrote - Quote
37. Mate - Bait
38. Cat – Bat
39. Complain - Gate
40. Date – Ate

4. Appendix 4

Categories given in the verbal fluency task

1. Words beginning with ‘p’
2. Words beginning with ‘j’
3. Jobs you could have
4. Foods that humans eat
5. Words beginning with ‘b’
6. Emotions you may feel
7. Words beginning with ‘f’
8. Things associated with school
9. Words beginning with ‘sh’
10. Types of furniture
11. Words beginning with ‘l’
12. Words beginning with ‘v’
13. Things you find in the kitchen
14. Words beginning with ‘r’
15. Items of clothing

5. Appendix 5

Words given in the sentence planning task – create a sentence

1. Flowers beautiful market
2. Holding paper dress
3. Birds together sky
4. Talking shop meat
5. Cooking jail brother
6. Shop local money
7. Beef table field
8. Cut blood Orange
9. Marsh flood wet
10. Running red train

6. Appendix 6

Jumbled sentences given in the sentence planning task – jumbled sentences. The number after each sentence refers to how many possibilities there are for a sentence to be created.

1. Money can be a contentious topic
    a. A topic money be can contentious **x2**
2. You really must not do that
    b. That do you must really not **x2**
3. Counting is learnt early at school
    c. Early at counting school learnt is **x2**
4. The dog has always been terribly wild
    c. Always the terribly wild been dog has **x2**
5. She was only fourteen when it happened
    d. It was she fourteen when only happened **x4**
6. Now he knew what the price was
    e. Was he price knew now the what **x3**
7. If things continue like this we will leave
    f. Things leave if we this continue will like **x5**
8. More expensive clothes don’t make you look thinner
    g. Don’t clothes thinner you look expensive more make **x3**
9. Why must people be so horribly rude to others
    h. So horribly people be must others rude why to **x2**
10. Water is really essential to be fit and healthy
    i. Healthy fit really be water and essential is to **x3**
11. Drinking is a student’s favourite pastime so it’s said
    j. Favourite it’s so pastime a is drinking student’s said **x3**
12. I miss the olden days when things seemed much simpler
    k. Seemed when olden much I the things miss simpler days **x1**
13. Typing letters is so much quicker than writing them by hand
    l. Them than quicker hand so typing is letters by much writing **x2**
14. It is not the amount of money you make that matters
    m. Not matters it make is money of that amount you the **x2**
15. Cleaning windows can take ages and is never much fun
    n. Fun take windows ages never is can cleaning much and **x3**

7. Appendix 7

Sentence pairs used in the sentence comprehension task

1. The doctor was shot by the policeman (passive)
2. The doctor shot the policeman (active)

3. The cat is barked at by the dog (passive)
4. The dog is barking at the cat (active)

5. The cat is on the blue mat (active)
6. The mat the cat is on is blue (embedding)

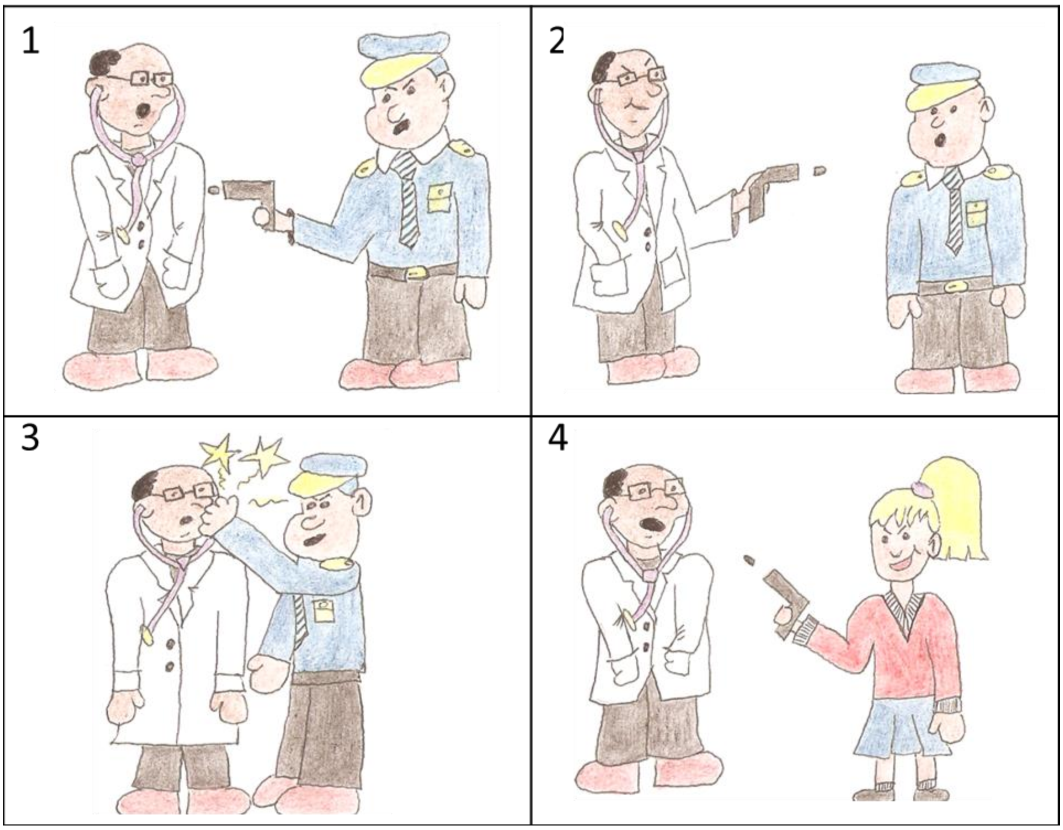
7. The fluffy rat is next to the bin (active)
8. The rat that is fluffy is next to the bin (embedding)

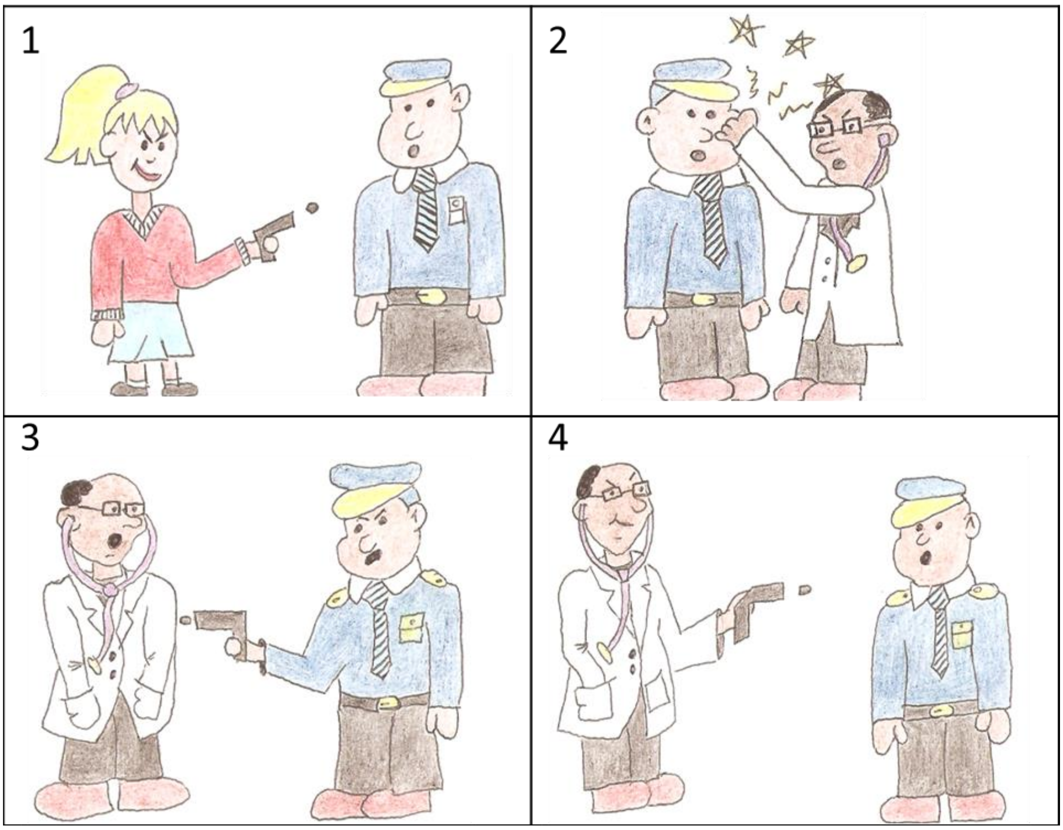
9. The blue tree is in the background (active)
10. The tree in the background is not blue (embedding and negation)

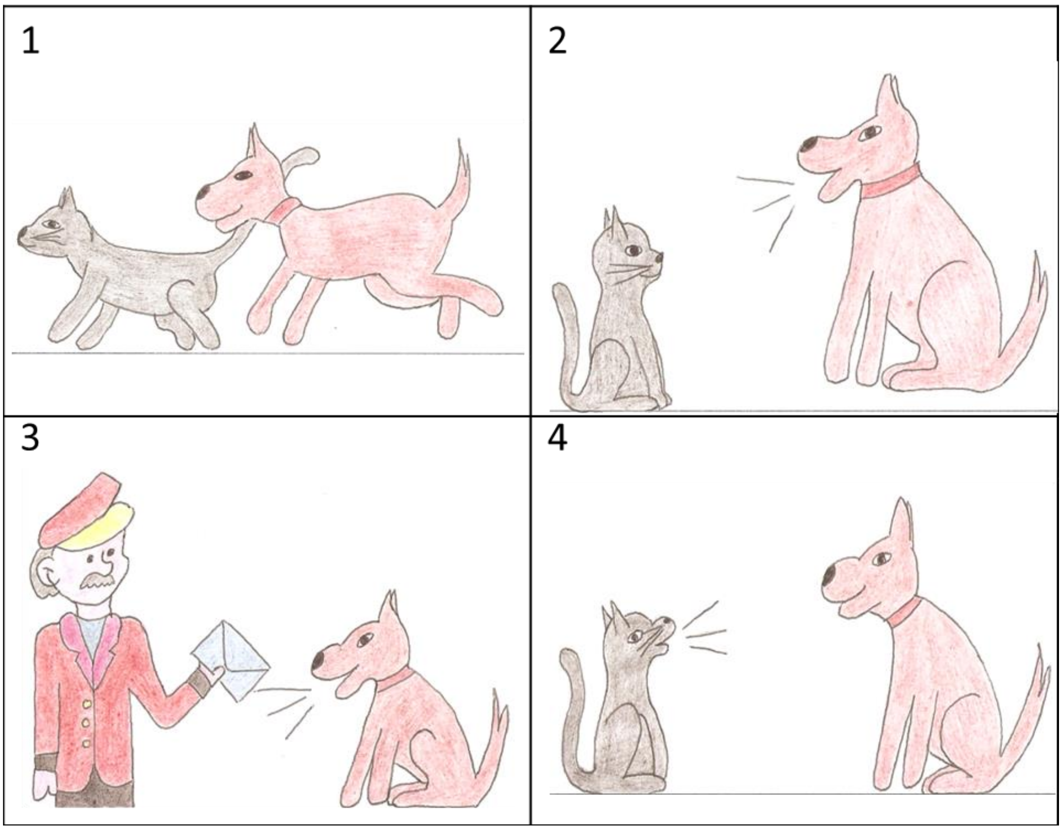
11. The purple pencil is next to the key (active)
12. The pencil next to the key is not purple (embedding and negation)

8. Appendix 8

Pictures used in the sentence comprehension task



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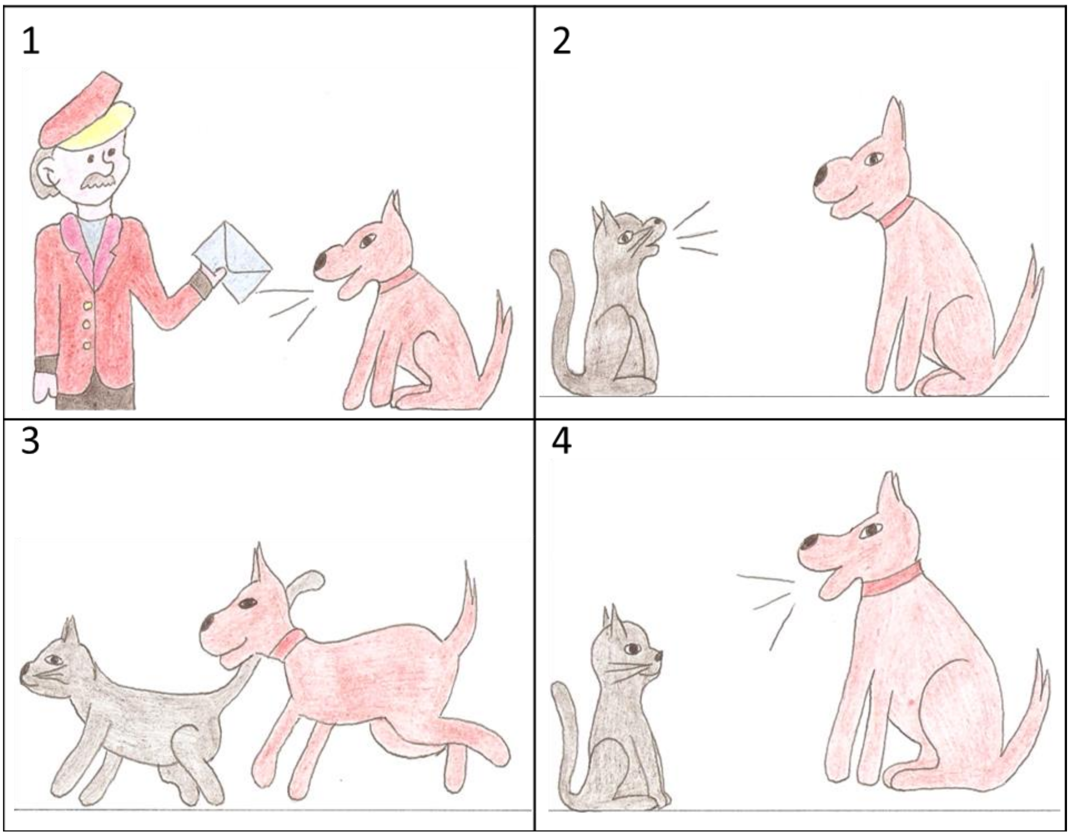
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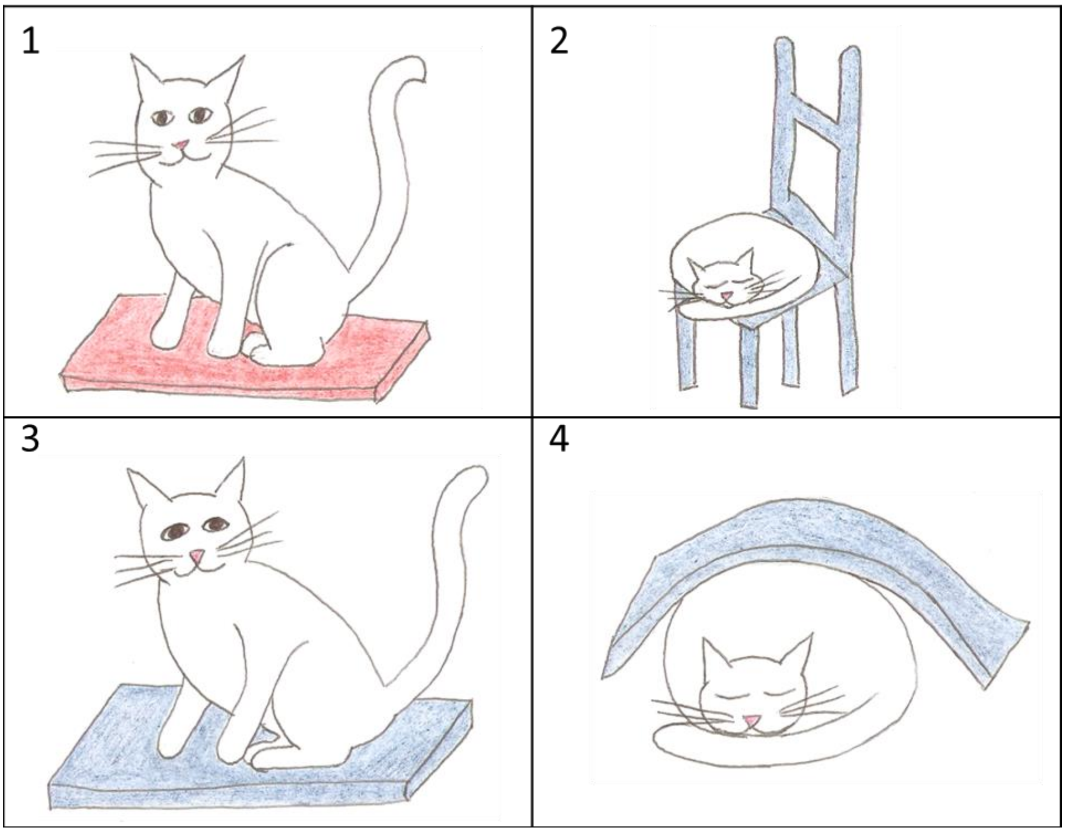
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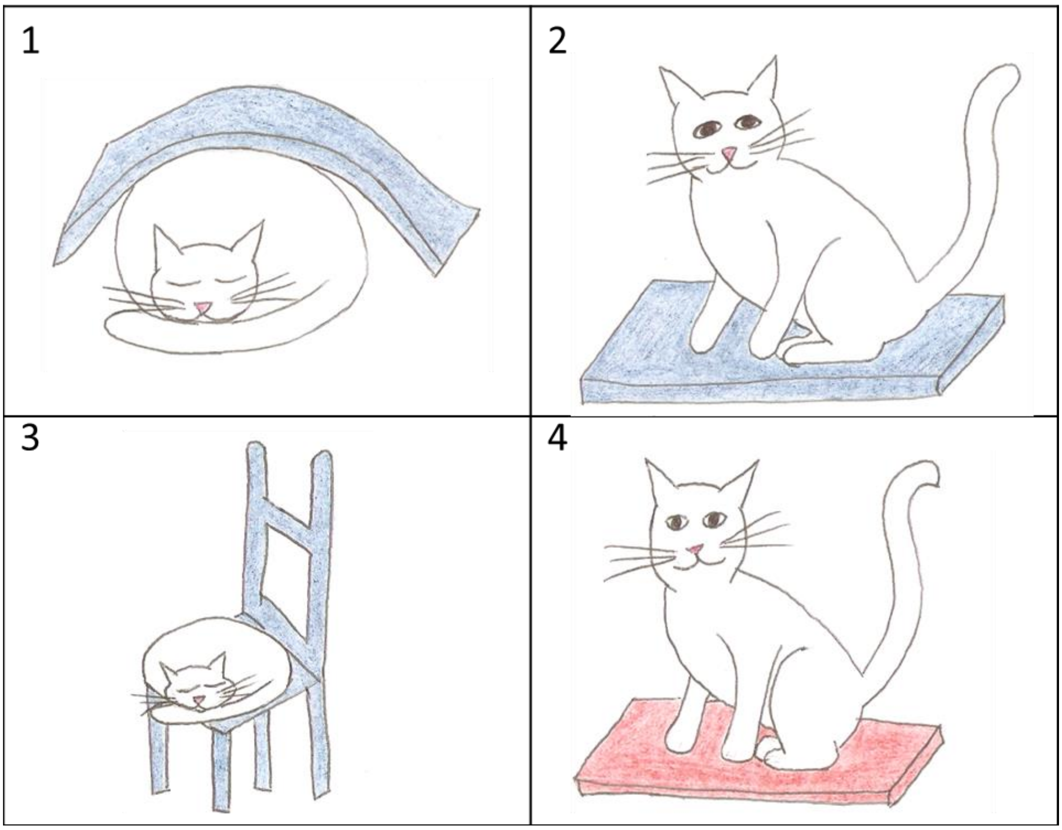
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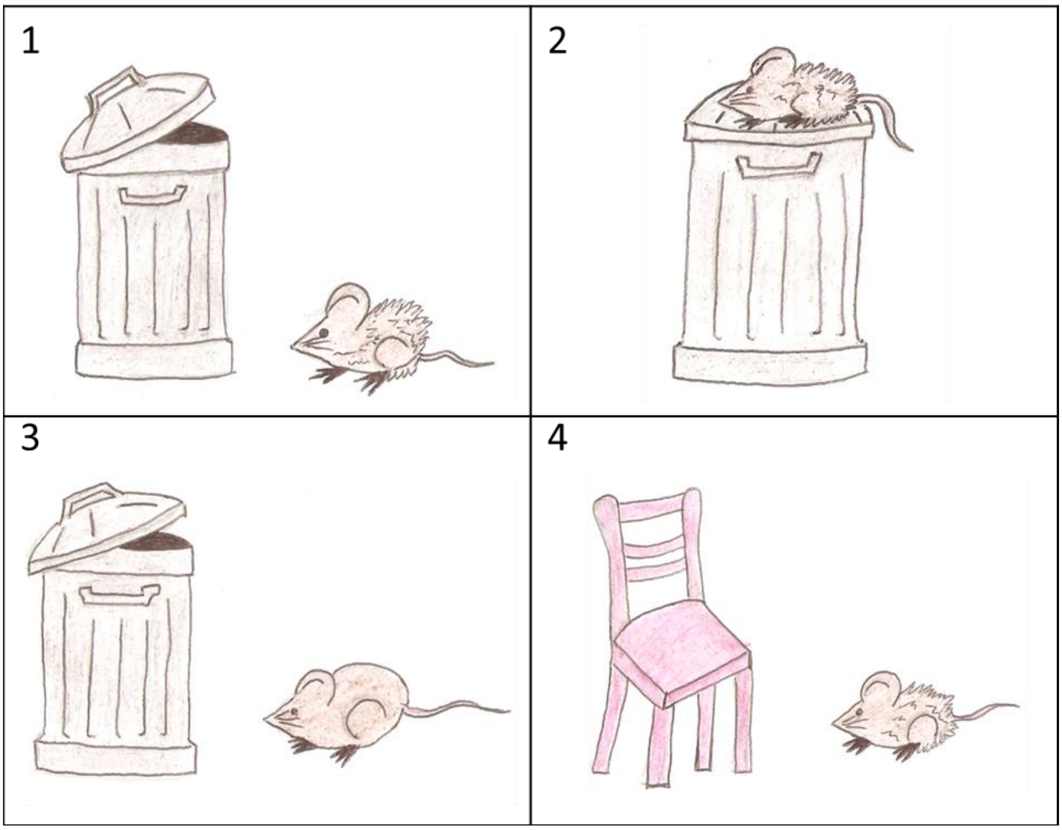
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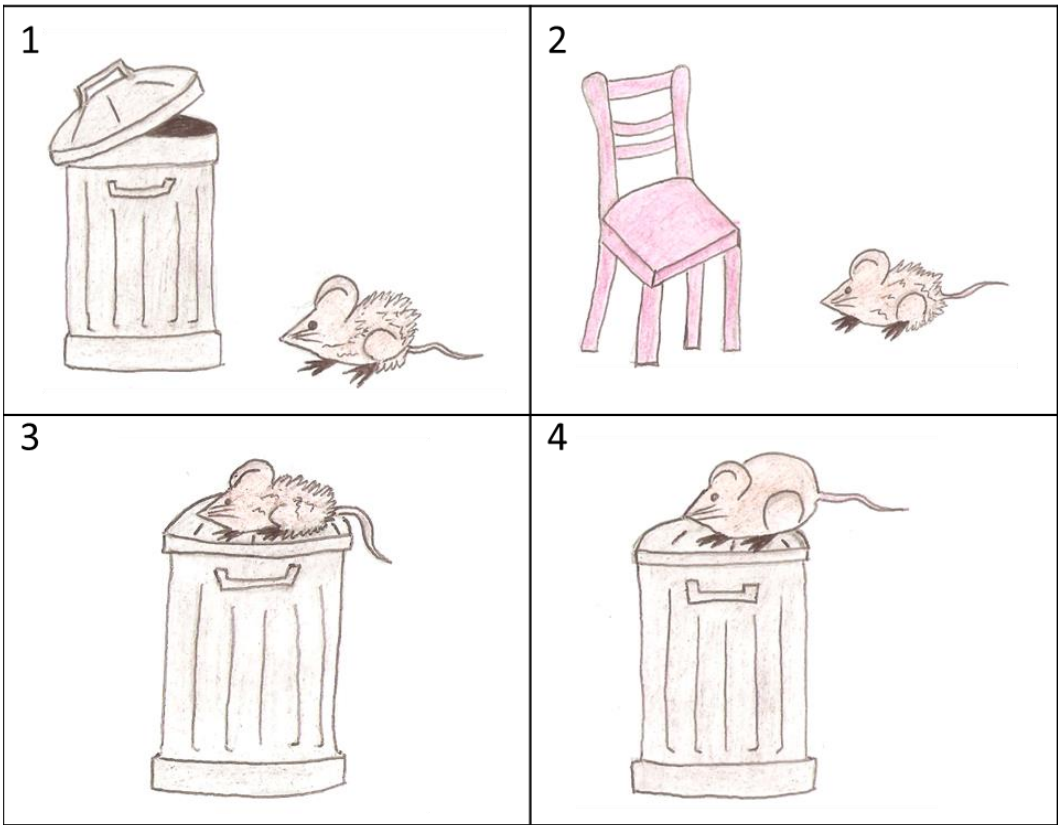
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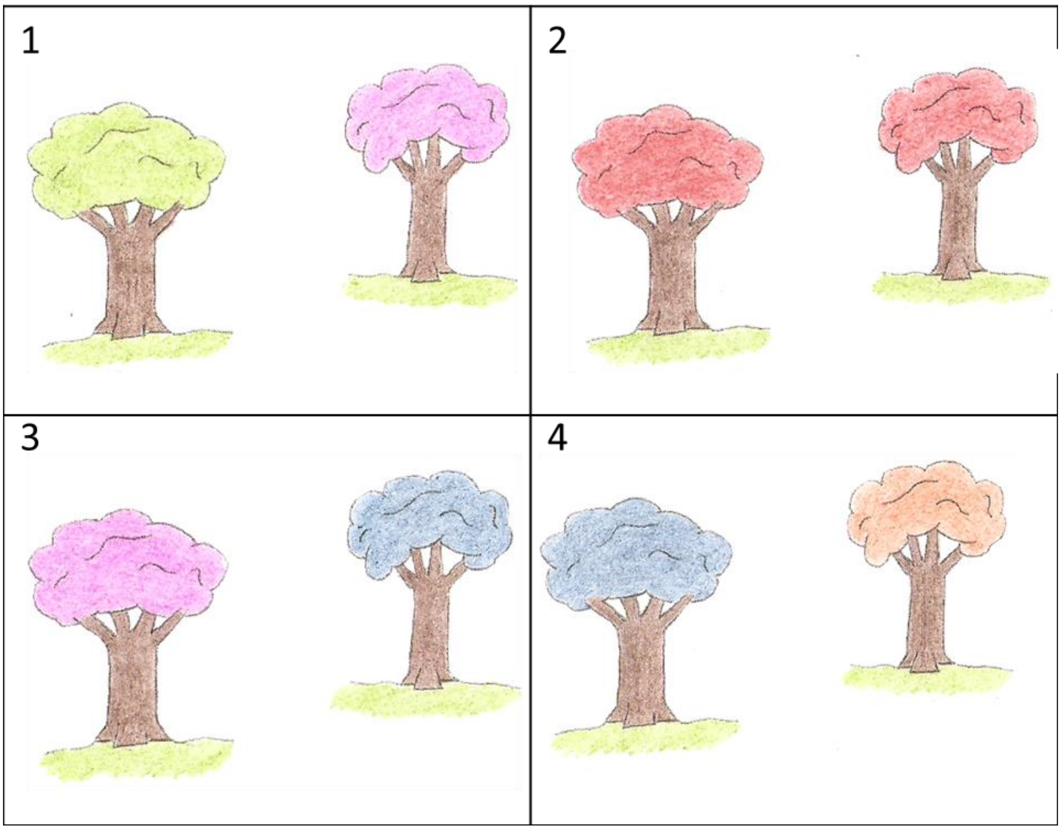
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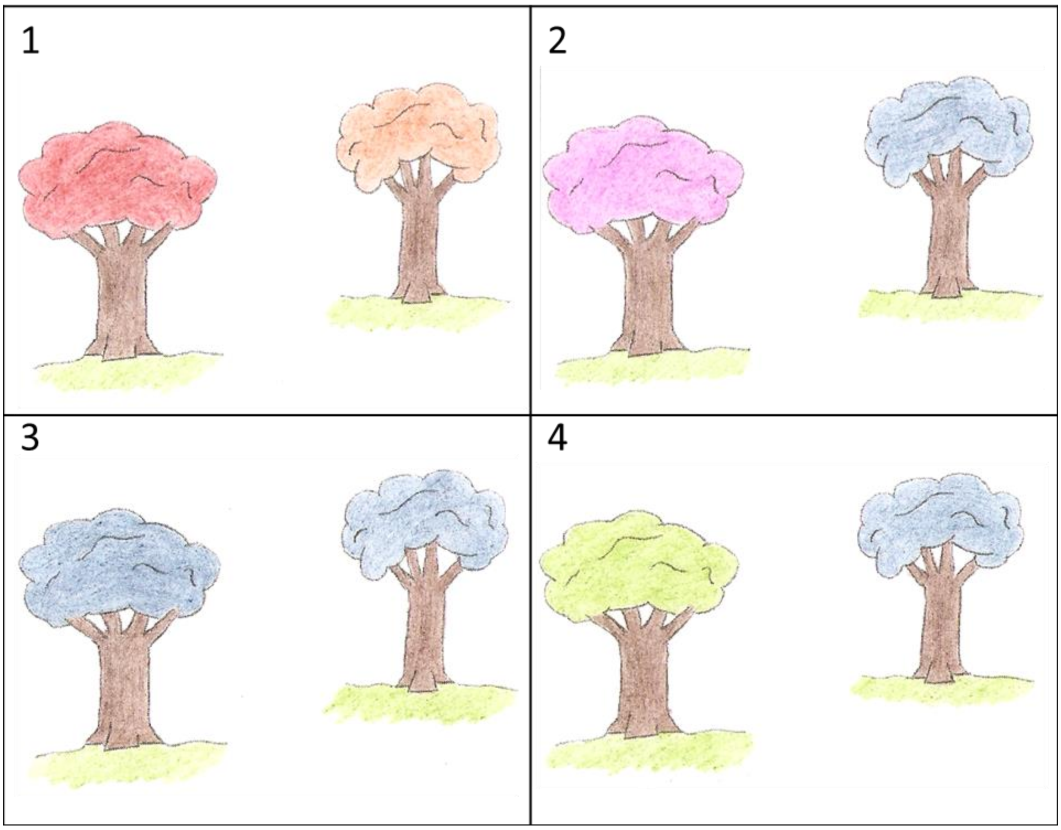
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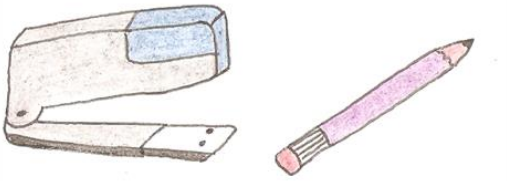

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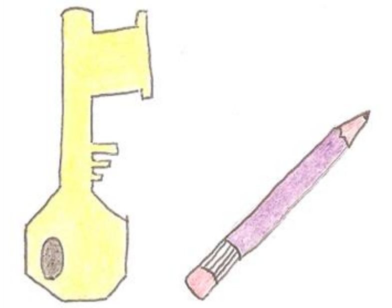

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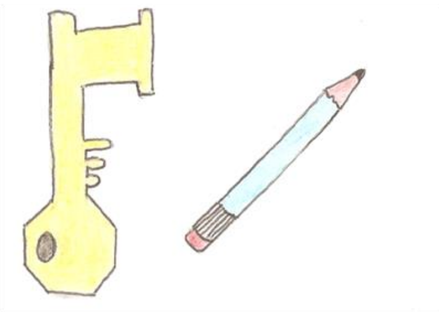

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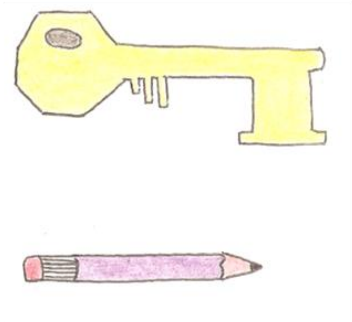

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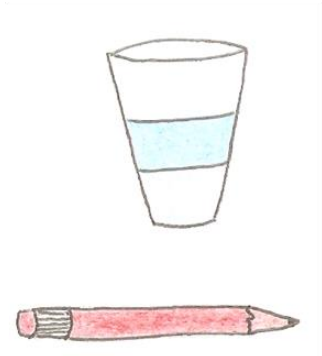

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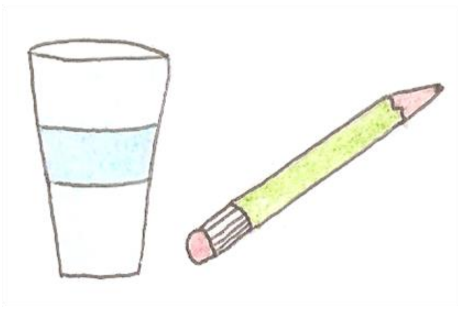

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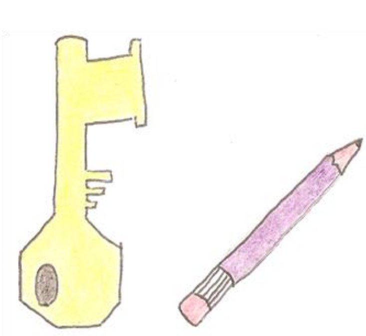

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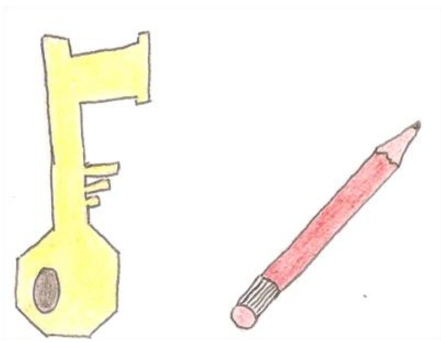


9. Appendix 9

Sentences used in the sentence production task

Low complexity (no clause in NP)

1. The strong and agile wolves hunt in the hills that are next to the lake.
2. The round and shiny doorknob sticks in the cold weather that we get in Wales
3. The short but tedious film had a sad ending that made everyone cry.
4. The tough and angry lawyer won the case that had been covered in the newspapers.
5. The proud but gifted player left the team that was threatening to trade him.
6. The large but old car belongs to the girl who we met at the salsa club.

High complexity (relative clause in NP)

7. The thief who was cornered escaped from the police who were trying to catch him.
8. The troops that are training marched through the woods that are full of bears.
9. The birds that are frightened flew into the forest that the company wants to chop down.
10. The horse that was training bit the young child who was wearing a pink shirt.
11. The teacher who was useless taught the introductory course that's now a requirement.
12. The plane that was leaving climbed higher into the sky that was clear and blue.

Low complexity (object- subject relatives)

13. The girl loved the boy who moved to the southern part of the country.
14. The bird ate the worm that crawled across the ground and into the nest.
15. The plane flew the people who were excited about the upcoming election for prime minister.

High complexity (subject-object relatives)

16. The woman the man liked got the new position of supervisor with the school.
17. The boss the man hated resigned from the job and took some time off.
18. The writer the young student loved had trouble getting funds for his new book.

Low complexity (main-subordinate)

19. The shrewd politician lied because he wanted to win the election for city council.
20. The young boy cried when his mother took the toy out of his room.
21. The angry man yelled when the police arrested him and took him to jail.

High complexity (subordinate-main)

22. Due to the snowstorm and high gusty winds, the superintendent closed the schools.
23. Because the girl was in charge of the party, the boy called the girl's home.
24. When the plane landed on the ground, the captain welcomed everyone to New York.

Low complexity (actives)

25. The black and white cat chased the small dog down the busy city street.
26. The large black car hit a yellow school bus late one rainy Friday afternoon.
27. The young mother comforted the child in the waiting room of the doctor's office.

High complexity (passives)

28. The fast mouse was chased by the clever fox and ran into the woods.
29. The burglar was chased by the local police and sped away from the bank.
30. The student was reprimanded by the teacher and refused to bring the homework.

Low complexity (verb phrase complement)

31. The policeman asked the driver to pull over to the side of the road.
32. The mother forced the child to leave the playground in the park and return home.
33. The teacher told the students in the room to sit down and be quiet.

High complexity (adjunct clause)

34. The teacher lectured the students after returning the assignments that were due last week.
35. The dog ate the food after drinking the water that was in the bowl.
36. The child played with the toy while waiting for his mum to return.

10. Appendix 10

Scoring for the sentence production task

1 – One error is made e.g. adding or omitting a morphological ending, adding or omitting one word, one error in word order, one revision. Only one or these errors can be present to score a 1.

2 - Two errors is made e.g. adding or omitting a morphological ending, adding or omitting two words, two errors in word order, two revisions (separate revisions). Only two of these errors can be present to score a two.

3 - Three errors is made e.g. adding or omitting a morphological ending, adding or omitting three words, three errors in word order, three revisions (separate revisions). Only three of these errors can be present to score a 3.

4 - Four errors is made e.g. adding or omitting a morphological ending, adding or omitting four words, four errors in word order, four or more revisions (separate revisions). Four errors must be made in total (or more so long as a score of 5 does not apply).

5 – The meaning has been considerably changed, no attempt is made, or an attempt is made but stopped half way through or before.

11. Appendix 11

Screening Questions - **Phonetic encoding in stuttering and cluttering**

Male or Female (please circle)

Date of birth:………………………………………………………………………………………………………..

Highest level of education:………………………………………………………………………..............

Are you right handed? Yes No (please circle)

1. Have you ever been diagnosed with a hearing impairment or difficulty (e.g. hearing loss or tinnitus)?

   No

   Yes (please give details)……………………………………………………………………………………
   ……

2. Have you ever been diagnosed by a speech and language therapist as having a speech and or language difficulty (specific language impairment, articulation disorder, delayed language acquisition, or other)?

   No

   Yes (please give details)……………………………………………………………………………………
   ……

3. Have you ever been diagnosed with a developmental disorder including, dyslexia, autism, dyspraxia, ADD/ADHD?

   No

   Yes (please give details)……………………………………………………………………………………

   ……

4. Have you been diagnosed as having a stutter/stammer or clutter or both? (Please circle)

   Stutter/Stammer Clutter Stutter/Stammer and Clutter NA

5. If yes, when were you diagnosed and when did you develop your dysfluency?

   ……

   ……

12. Appendix 12

Handedness scores for all participants

Participant	Group	Handedness Score
1	AWC	75
2	AWC	400
3	AWC	275
4	AWC	400
5	AWC	400
6	AWC	400
7	AWC	-400
8	AWC	400
9	AWC	400
10	AWC	400
11	AWC	400
12	AWC	-200
13	AWC	400
14	AWC	400
1	AWS	400
2	AWS	375
3	AWS	400
4	AWS	400
5	AWS	400
6	AWS	400
7	AWS	275
8	AWS	400
9	AWS	400
10	AWS	400
11	AWS	400
12	AWS	400
13	AWS	400
14	AWS	400
1	CTL	400
2	CTL	400

3	CTL	400
4	CTL	300
5	CTL	200
6	CTL	400
7	CTL	400
8	CTL	350
9	CTL	350
10	CTL	-100
11	CTL	400
12	CTL	350
13	CTL	400
14	CTL	325
15	CTL	350

13. Appendix 13

Percentage syllables stuttered and SSI-4 scores for all AWS

AWS	% stuttered syllable in 209 sylables of the Rainbow Passage	% stuttered syllable in 203-217 sylables of conversation	SSI-4 score
1	1.44%	11.62%	12 (mild)
2	2.87%	16.76%	15 (mild)
3	1.91%	34.40%	17 (mild)
4	41.63%	21.70%	21 (mild)
5	29.67%	14.60%	19 (mild)
6	2.87%	5.32%	12 (mild)
7	25.84%	23.70%	25 (moderate)
8	12.92%	7.89%	21 (mild)
9	4.31%	17.00%	17 (mild)
10	5.26%	26.32%	18 (mild)
11	7.66%	4.34%	14 (mild)
12	1.44%	22.40%	13 (mild)
13	0.96%	32.14%	19 (mild)
14	7.2%	12.74%	22 (mild)

14. Appendix 14

Screen shot of the stimuli usedin the simple reacton time task

15. Appendix 15

Number strings used in the complex reaction time task

3114141124

4234231123

3213131121

1331433424

1423422322

2412144223

4444224223

2124121313

4333444143

1222431422

4322222332

2122144331

3342224131

1431344131

3421233424

1111313314

4121314443

3411211122

2221224214

2234421314

16. Appendix 16

All Snodgrass words used with trascriptions

Accordion	ə**kɔ**:diən	ə	k	ɔ:	d	i	ə	n		
Aeroplane	**eə**rəpleɪn	eə	r	ə	p	l	eɪ	n		
Alligator	**æl**ɪgeɪtə	æ	l	ɪ	g	eɪ	t	ə		
Anchor	**æŋ**kə	æ	ŋ	k	ə					
Ant	ænt	æ	n	t						
Apple	**æp**əl	æ	p	ə	l					
Arm	ɑ:m	ɑ:	m							
Arrow	**ær**əʊ	æ	r	əʊ						
Artichoke	**ɑ**:tɪtʃəʊk	ɑ:	t	ɪ	tʃ	əʊ	k			
Ashtray	**æʃ**treɪ	æ	ʃ	t	r	eɪ				
Asparagus	**æs**pærəgəs	æ	s	p	æ	r	ə	g	ə	s
Axe	æks	æ	k	s						
Ball	bɔ:l	b	ɔ:	l						
Balloon	bə**lu**:**n**	b	ə	l	u:	n				
Banana	bə**nɑ**:nə	b	ə	n	ɑ:	n	ə			
Barn	bɑ:n	b	ɑ:	n						
Barrel	**bæ**rəl	b	æ	r	ə	l				
Basket	**bɑ**:skɪt	b	ɑ:	s	k	ɪ	t			
Bat	bæt	b	æ	t						
Bear	beə	b	eə							
Bed	bed	b	e	d						
Bee	bi	b	i							
Beetle	**bi**təl	b	i	t	ə	l				
Bell	bel	b	e	l						
Belt	belt	b	e	l	t					
Bike	baɪk	b	aɪ	k						
Bird	bɜ:d	b	ɜ:	d						
Blouse	blaʊz	b	l	aʊ	z					
Book	bʊk	b	ʊ	k						
Boot	bu:t	b	u:	t						
Bottle	**bɒt**əl	b	ɒ	t	ə	l				
Bow	baʊ	b	aʊ							

Bowl	baʊl	b	aʊ	l						
Box	bɒks	b	ɒ	k	s					
Bread	bred	b	r	e	d					
Broom	bru:m	b	r	u:	m					
Brush	brʌʃ	b	r	ʌ	ʃ					
Bus	bʌs	b	ʌ	s						
Butterfly	**bʌt**əflaɪ	b	ʌ	t	ə	f	l	aɪ		
Button	**bʌt**ən	b	ʌ	t	ə	n				
Cake	keɪk	k	eɪ	k						
Camel	**kæm**əl	k	æ	m	ə	l				
Candle	**kæn**dəl	k	æ	n	d	ə	l			
Cannon	**kæn**ən	k	æ	n	ə	n				
Cap	kæp	k	æ	p						
Car	kɑ:	k	ɑ:							
Carrot	**kær**ət	k	æ	r	ə	t				
Cat	kæt	k	æ	t						
Caterpillar	**kæt**əpɪlə	k	æ	t	ə	p	ɪ	l	ə	
Celery	**sel**əri	s	e	l	ə	r	i			
Chain	tʃeɪn	tʃ	eɪ	n						
Chair	tʃeə	tʃ	eə							
Cherry	**tʃe**ri	tʃ	e	r	i					
Chicken	**tʃɪk**ɪn	tʃ	ɪ	k	ɪ	n				
Chisel	**tʃɪs**əl	tʃ	ɪ	s	ə	l				
Church	tʃɜ:tʃ	tʃ	ɜ:	tʃ						
Cigar	sɪgɑ:	s	ɪ	g	ɑ:					
Cigarette	sɪgə**ret**	s	ɪ	g	ə	r	e	t		
Clock	klɒk	k	l	ɒ	k					
Cloud	klaʊd	k	l	aʊ	d					
Clown	klaʊn	k	l	aʊ	n					
Coat	kəʊt	k	əʊ	t						
Comb	kəʊm	k	əʊ	m						
Corn	kɔ:n	k	ɔ:	n						
Couch	kaʊtʃ	k	aʊ	tʃ						
Cow	kaʊ	k	aʊ							

Crown	kraʊn	k	r	aʊ	n			
Cup	kʌp	k	ʌ	p				
Deer	dɪə	d	ɪə					
Desk	desk	d	e	s	k			
Dog	dɒg	d	ɒ	g				
Doll	dɒl	d	ɒ	l				
Donkey	**dɒŋ**ki	d	ɒ	ŋ	k	i		
Door	dɔ:	d	ɔ:					
Doorknob	**dɔ**:nɒb	d	ɔ:	n	ɒ	b		
Dress	dres	d	r	e	s			
Drum	drʌm	d	r	ʌ	m			
Duck	dʌk	d	ʌ	k				
Eagle	**i**gəl	i	g	ə	l			
Ear	ɪə	ɪə						
Elephant	**el**ɪfənt	e	l	ɪ	f	ə	n	t
Envelope	**en**vələʊp	e	n	v	ə	l	əʊ	p
Eye	aɪ	aɪ						
Fence	fens	f	e	n	s			
Finger	**fɪŋ**gə	f	ɪ	ŋ	g	ə		
Fish	fɪʃ	f	ɪ	ʃ				
Flag	flæg	f	l	æ	g			
Flower	**flaʊ**ə	f	l	aʊ	ə			
Flute	flu:t	f	l	u:	t			
Fly	flaɪ	f	l	aɪ				
Foot	fʊt	f	ʊ	t				
Fork	fɔ:k	f	ɔ:	k				
Fox	fɒks	f	ɒ	k	s			
Frog	frɒg	f	r	ɒ	g			
Giraffe	dʒɪ**rɑ:f**	dʒ	ɪ	r	ɑ:	f		
Glass	glɑ:s	g	l	ɑ:	s			
Glasses	**glɑ:s**ɪs	g	l	ɑ:	s	ɪ	s	
Glove	glʌv	g	l	ʌ	v			
Goat	gaʊt	g	aʊ	t				
Gorilla	gə**rɪl**ə	g	ə	r	ɪ	l	ə	

Grapes	greɪps	g	r	eɪ	p	s				
Grasshopper	**grɑ:s**hɒpə	g	r	ɑː	s	h	ɒ	p	ə	
Guitar	gɪ**tɑ**:	g	ɪ	t	ɑː					
Gun	gʌn	g	ʌ	n						
Hair	heə	h	eə							
Hammer	**hæm**ə	h	æ	m	ə					
Hand	hænd	h	æ	n	d					
Hanger	**hæŋ**ə	h	æ	ŋ	ə					
Harp	hɑːp	h	ɑː	p						
Hat	hæt	h	æ	t						
Heart	hɑːt	h	ɑː	t						
Helicopter	**hel**ɪkɒptə	h	e	l	ɪ	k	ɒ	p	t	ə
Horse	hɔːs	h	ɔː	s						
House	haʊs	h	aʊ	s						
Iron	**aɪ**ən	aɪ	ə	n						
Jacket	**dʒæk**ɪt	dʒ	æ	k	ɪ	t				
Kangaroo	kæŋgər**u**:	k	æ	ŋ	g	ə	r	uː		
Kettle	**ket**əl	k	e	t	ə	l				
Key	ki	k	i							
Kite	kaɪt	k	aɪ	t						
Knife	naɪf	n	aɪ	f						
Ladder	**læd**ə	l	æ	d	ə					
Lamp	læmp	l	æ	m	p					
Leaf	lif	l	i	f						
Leg	leg	l	e	g						
Lemon	**lem**ən	l	e	m	ə	n				
Leopard	**lep**əd	l	e	p	ə	d				
Lettuce	**let**ɪs	l	e	t	ɪ	s				
Lion	**laɪ**ən	l	aɪ	ə	n					
Lips	lɪps	l	ɪ	p	s					
Lobster	**lɒb**stə	l	ɒ	b	s	t	ə			
Lock	lɒk	l	ɒ	k						
Mitten	**mɪt**ən	m	ɪ	t	ə	n				
Monkey	**mʌŋ**ki	m	ʌ	ŋ	k	i				

Moon	mu:n	m	u:	n						
Motorbike	**məʊ**təbaɪk	m	əʊ	t	ə	b	aɪ	k		
Mountain	**maʊn**tɪn	m	aʊ	n	t	ɪ	n			
Mouse	maʊs	m	aʊ	s						
Mushroom	**mʌʃ**ru:m	m	ʌ	ʃ	r	u:	m			
Nail	**neɪ**əl	n	eɪ	ə	l					
Necklace	**nek**ləs	n	e	k	l	ə	s			
Needle	**ni**dəl	n	i	d	ə	l				
Nose	naʊz	n	aʊ	z						
Nut	nʌt	n	ʌ	t						
Onion	**ʌn**jən	ʌ	n	j	ə	n				
Orange	**ɒ**rɪndʒ	ɒ	r	ɪ	n	dʒ				
Ostrich	**ɒs**trɪdʒ	ɒ	s	t	r	ɪ	dʒ			
Owl	aʊl	aʊ	l							
Paintbrush	**peɪnt**brʌʃ	p	eɪ	n	t	b	r	ʌ	ʃ	
Peach	pitʃ	p	i	tʃ						
Peacock	**pi**kɒk	p	i	k	ɒ	k				
Peanut	**pi**nʌt	p	i	n	ʌ	t				
Pear	peə	p	eə							
Pen	pen	p	e	n						
Pencil	**pen**səl	p	e	n	s	ə	l			
Penguin	**peŋ**gwɪn	p	e	ŋ	g	w	ɪ	n		
Pepper	**pep**ə	p	e	p	ə					
Piano	**pi**ænəʊ	p	i	æ	n	əʊ				
Pig	pɪg	p	ɪ	g						
Pineapple	**paɪn**æpəl	p	aɪ	n	æ	p	ə	l		
Pipe	paɪp	p	aɪ	p						
Pliers	**plaɪ**əz	p	l	aɪ	ə	z				
Plug	plʌg	p	l	ʌ	g					
Potato	pə**teɪ**təʊ	p	ə	t	eɪ	t	əʊ			
Pumpkin	**pʌmp**kɪn	p	ʌ	m	p	k	ɪ	n		
Rabbit	**ræb**ɪt	r	æ	b	ɪ	t				
Raccoon	**ræk**u:n	r	æ	k	u:	n				
Rhinoceros	**raɪ**nɒsərʊs	r	aɪ	n	ɒ	s	ə	r	ʊ	s

Ring	rɪŋ	r	ɪ	ŋ						
Ruler	**ru**:**l**ə	r	uː	l	ə					
Salt	sɒlt	s	ɒ	l	t					
Sandwich	**sæn**wɪdʒ	s	æ	n	w	ɪ	dʒ			
Saw	sɔː	s	ɔː							
Scissors	**sɪz**əs	s	ɪ	z	ə	s				
Screw	skruː	s	k	r						
Screwdriver	**skru**:draɪvə	s	k	r	uː	d	r	aɪ	v	ə
Seahorse	**si**hɔ:s	s	i	h	ɔː	s				
Seal	**si**əl	s	i	ə	l					
Sheep	ʃip	ʃ	i	p						
Shirt	ʃɜ:t	ʃ	ɜː	t						
Shoe	ʃuː	ʃ	uː							
Skirt	skɜ:t	s	k	ɜː	t					
Skunk	skʌŋk	s	k	ʌ	ŋ	k				
Sledge	sledʒ	s	l	e						
Snail	**sne**ɪəl	s	n	eɪ	ə	l				
Snake	sneɪk	s	n	eɪ	k					
Snowman	**snəʊ**mæn	s	n	əʊ	m	æ	n			
Sock	sɒk	s	ɒ	k						
Spider	**spaɪ**də	s	p	aɪ	d	ə				
Spoon	spu:n	s	p	uː	n					
Squirrel	**skwɪ**rəl	s	k	w	ɪ	r	ə	l		
Star	stɑː	s	t	ɑː						
Stool	stu:l	s	t	uː	l					
Stove	staʊv	s	t	aʊ	v					
Strawberry	**strɔ**:beri	s	t	r	ɔː	b	e	r	i	
Suitcase	**su**:**t**keɪs	s	uː	t	k	eɪ	s			
Sun	sʌn	s	ʌ	n						
Swan	swɒn	s	w	ɒ	n					
Sweater	**swet**ə	s	w	e	t	ə				
Swing	swɪŋ	s	w	ɪ	ŋ					
Table	**teɪ**bəl	t	eɪ	b	ə	l				
Telephone	**tel**əfəʊn	t	e	l	ə	f	əʊ	n		

Television	**tel**əvɪʒən	t	e	l	ə	v	ɪ	ʒ	ə	n
Thumb	θʌm	θ	ʌ	m						
Tie	taɪ	t	aɪ							
Tiger	**taɪ**gə	t	aɪ	g	ə					
Toaster	**təʊst**ə	t	əʊ	s	t	ə				
Toe	taʊ	t	aʊ							
Tomato	tə**mɑ**:təʊ	t	ə	m	ɑː	t	əʊ			
Toothbrush	**tu**:**θ**brʌʃ	t	uː	θ	b	r	ʌ	ʃ		
Train	treɪn	t	r	eɪ	n					
Tree	tri	t	r	i						
Truck	trʌk	t	r	ʌ	k					
Trumpet	**trʌm**pɪt	t	r	ʌ	m	p	ɪ	t		
Turtle	**tɜ**:təl	t	ɜː	t	ə	l				
Umbrella	ʌm**brel**ə	ʌ	m	b	r	e	l	ə		
Vase	vɑ:z	v	ɑː	z						
Violin	**vaɪ**əlɪn	v	aɪ	ə	l	ɪ	n			
Watch	wɒtʃ	w	ɒ	tʃ						
Watermelon	**wɔ**:təmelɒn	w	ɔː	t	ə	m	e	l	ɒ	n
Well	wel	w	e	l						
Wheel	**wi**əl	w	i	ə	l					
Whistle	**wɪs**əl	w	ɪ	s	ə	l				
Windmill	**wɪnd**mɪl	w	ɪ	n	d	m	ɪ	l		
Window	**wɪn**dəʊ	w	ɪ	n	d	əʊ				
Zebra	**zeb**rə	z	e	b	r	ə				

17. Appendix 17

Words excluded from the Snodgrass picture set

1. baby carriage (pram)
2. clothespin (peg)
3. dresser (draws)
4. football (American football)
5. football helmet (American football helmet)
6. French horn (noun phrase)
7. frying pan (noun phrase)
8. garbage can (bin)
9. ironing board (noun phrase)
10. light bulb (noun phrase)
11. light switch (noun phrase)
12. nail file (noun phrase)
13. pants (trousers)
14. pitcher (not commonly used in English)
15. pocketbook (not commonly used in English)
16. Pot (pan)
17. record player (noun phrase)
18. refrigerator (fridge)
19. rocking chair (noun phrase)
20. roller skate (noun phrase)
21. rolling pin (noun phrase)
22. rooster (cockerel)
23. sail boat (noun phrase)
24. spinning wheel (noun phrase)
25. tennis racket (noun phrase)
26. thimble (not commonly used)
27. top (not commonly used in English)
28. traffic light (noun phrase)
29. vest (not commonly used in English)
30. wagon (not commonly used in English)
31. watering can (noun phrase)
32. wine glass (noun phrase)
33. wrench (spanner)

18. Appendix 18

Divison of real words into groups based upon which phoneme will be monitored for.

word p	structure	syllables	word d	structure	syllables
Artichoke	VCVCVC	3	Tiger	CVCV	2
Glass	CCVC	1	Potato	CVCVCV	3
Apple	VCVC	2	Ladder	CVCV	2
Watch	CVC	1	Screwdriver	CCCVCCVCV	3
Leopard	CVCVC	2	Pipe	CVC	1
Cap	CVC	1	Bird	CVC	1
Glove	CCVC	1	Snail	CCVC	1
Windmill	CVCCVC	2	Hand	CVCC	1
Key	CV	1	Window	CVCCV	2
Lamp	CVCC	1	Clown	CCVC	1
Snake	CCVC	1	Bed	CVC	1
Harp	CVC	1	Frog	CCVC	1
Trumpet	CCVCCVC	2	Accordion	VCVCCVC	4
Hanger	CVCV	2	Screw	CCCV	1
Chicken	CVCVC	2	Cloud	CCVC	1
Cup	CVC	1	Ring	CVC	1
Barn	CVC	1	Needle	CVCVC	2
Sheep	CVC	1	Bread	CCVC	1
Asparagus	VCCVCVCVC	4	Eagle	VCVC	2

word m	structure	syllables	word s	structure	syllables
Kite	CVC	1	Grasshopper	CCVCCVCV	3
Tomato	CVCVCV	3	Violin	CVVCVC	3
Star	CCV	1	Lettuce	CVCVC	2
Camel	CVCVC	2	Bell	CVC	1
Hammer	CVCV	2	Bow	CV	1
Lips	CVCC	1	Bus	CVC	1
Arm	VC	1	Vase	CVC	1
Broom	CCVC	1	Mouse	CVC	1
Hat	CVC	1	Nail	CVC	1
Bottle	CVCVC	2	Flag	CCVC	1
Glasses	CCVCVC	2	Banana	CVCVCV	3
Watermelon	CVCVCVCVC	4	House	CVC	1
Fox	CVC	1	Nut	CVC	1
Thumb	CVC	1	Mountain	CVCCVC	2
Lemon	CVCVC	2	Pencil	CVCCVC	2
Rhinoceros	CVCVCVCVC	4	Whistle	CVCVC	2
Clock	CCVC	1	Turtle	CVCC	2

Pepper	CVCV	2
Drum	CCVC	1

word k	**structure**	**syllables**
Aeroplane	VCVCCVC	3
Anchor	VCCV	2
Iron	VVC	2
Spider	CCVCV	2
Basket	CVCCVC	2
Jacket	CVCVC	2
Belt	CVCC	1
Book	CVC	1
Monkey	CVCCV	2
Deer	CV	1
Fork	CVC	1
Sock	CVC	1
Finger	CVCCV	2
Swan	CCVC	1
Suitcase	CVCCVC	2
Dog	CVC	1
Plug	CCVC	1
Raccoon	CVCVC	2
Bike	CVC	1

Chisel	CVCVC	2
Pear	CV	1

word n	**structure**	**syllables**
Pineapple	CVCVCVC	3
Moon	CVC	1
Cake	CVC	1
Spoon	CCVC	1
Bowl	CVC	1
Cannon	CVCVC	2
Corn	CVC	1
Bee	CV	1
Pen	CVC	1
Lock	CVC	1
Peanut	CVCVC	2
Envelope	VCCVCVC	3
Television	CVCVCVCVC	4
Axe	VCC	1
Candle	CVCCVC	2
Blouse	CCVC	1
Ear	VV	2
Coat	CVC	1

word t	**structure**	**syllables**
Caterpillar	CVCVCVCV	4
Lion	CVVC	2
Crown	CCVC	1
Kettle	CVCVC	2
Mitten	CVCVC	2
Sledge	CCVC	1
Door	CV	1
Ant	VCC	1
Cat	CVC	1
Foot	CVC	1
Wheel	CVC	1
Hair	CV	1
Motorbike	CVCVCVC	3
Sandwich	CVCCCVC	2
Beetle	CVCVC	2
Salt	CVCC	1
Nose	CVC	1
Sweater	CCVCV	2

word l	**structure**	**syllables**
Cherry	CVCV	2
Celery	CVCVCV	3
Cigarette	CVCVCVC	3
Snowman	CCVCVC	2
Balloon	CVCVC	2
Well	CVC	1
Train	CCVC	1
Goat	CVC	1
Ball	CVC	1
Couch	CVC	1
Owl	VC	1
Ruler	CVCV	2
Bat	CVC	1
Alligator	VCVCVCV	4
Stool	CCVC	1
Guitar	CVCV	2
Doll	CVC	1
Scissors	CVCVC	2
Necklace	CVCCVC	2

word	structure	syllables	word	structure	syllables
b			**f**		
Swing	CCVC	1	Butterfly	CVCVCCV	3
Sun	CVC	1	Tree	CCV	1
Gun	CVC	1	Telephone	CVCVCVC	3
Lobster	CVCCCV	2	Kangaroo	CVCCVCV	3
Skunk	CCVCC	1	Chair	CV	1
Penguin	CVCCCVC	2	Stove	CCVC	1
Rabbit	CVCVC	2	Elephant	VCVCVCC	3
Onion	VCCVC	2	Eye	V	1
Zebra	CVCCV	2	Bear	CV	1
Seahorse	CVCVC	2	Horse	CVC	1
Dress	CCVC	1	Helicopter	CVCVCVCCV	4
Toaster	CVCCV	2	Giraffe	CVCVC	2
Car	CV	1	Comb	CVC	1
Strawberry	CCCVCVCV	3	Duck	CVC	1
Table	CVCVC	2	Skirt	CCVC	1
Chain	CVC	1	Knife	CVC	1
Donkey	CVCCV	2	Grapes	CCVCC	1
Church	CVC	1	Leaf	CVC	1
Doorknob	CVCVC	2	Shirt	CVC	1

word	structure	syllables	word	structure	syllables
r			**sh**		
Toe	CV	1	Tie	CV	1
Arrow	VCV	2	Truck	CCVC	1
Peacock	CVCVC	2	Umbrella	VCCCVCV	3
Saw	CV	1	Mushroom	CVCCVC	2
Shoe	CV	1	Leg	CVC	1
Carrot	CVCVC	2	Brush	CCVC	1
Barrel	CVCVC	2	Fish	CVC	1
Pumpkin	CVCCCVC	2	Flower	CCVC	2
Heart	CVC	1	Box	CVCC	1
Flute	CCVC	1	Cow	CV	1
Ostrich	VCCCVC	2	Cigar	CVCV	2
Orange	VCVCV	2	Ashtray	VCCCV	2
Button	CVCVC	2	Piano	CVVCV	3
Gorilla	CVCVCV	3	Pig	CVC	1
Peach	CVC	1	Paintbrush	CVCCCCVC	2
Fly	CCV	1	Fence	CVCC	1
Squirrel	CCCVCVC	2	Desk	CVCC	1
Seal	CVC	1	Pliers	CCVVC	1
Boot	CVC	1	toothbrush	CVCCCVC	2

19. Appendix 19

Transcription of non-words used in NWPM task

affardion	ə**fɑ**:diən	ə	f	ɑ:	d	i:	ə	n		
airotrat	**aɪ**rəʊtreɪt	aɪ	r	əʊ	t	r	eɪ	t		
aium	eɪəm	eɪ	ə	m						
alchar	**æl**tʃɑ:	æ	l	tʃ	ɑ:					
aleicator	**æl**aɪkætə	æ	l	aɪ	k	æ	t	ə		
arl	ɑ:l	ɑ:	l							
arribrork	**æ**ribɔ:k	æ	r	i:	b	ɔ:	k			
ashtart	**æʃ**tɑ:t	æ	ʃ	t	ɑ:	t				
aspuraros	əs**pu**:rərɒs	ə	s	p	u:	r	ə	r	ɒ	s
awn	ɔ:n	ɔ:	n							
baid	beɪd	b	eɪ	d						
balleen	bə**li**:**n**	b	ə	l	i:	n				
bame	beɪm	b	eɪ	m						
baomin	baɪəʊ**mɪn**	b	aɪ	əʊ	m	ɪ	n			
barse	bɑ:s	b	ɑ:	s						
baskel	**bæs**kəl	b	æ	s	k	ə	l			
beckle	**bek**əl	b	e	k	ə	l				
benserphy	**ben**səfi:	b	e	n	s	ə	f	i:		
bephy	**be**fi:	b	e	f	i:					
bettle	**be**təl	b	e	t	ə	l				
bileny	**bɪl**əni	b	ɪ	l	ə	n	i:			
bimatu	bə**mɑ**:tu:	b	ə	m	ɑ:	t	u:			
blatt	blæt	b	l	æ	t					
bleef	bli:f	b	l	i:	f					
blempet	**blem**pɪt	b	l	e	m	p	ɪ	t		
blof	blɒf	b	l	ɒ	f					
blop	blɒp	b	l	ɒ	p					
blower	**blaʊ**ə	b	l	aʊ	ə					
bon	bɒn	b	ɒ	n						
bothon	**bɒθ**ən	b	ɒ	θ	ə	n				
bown	baʊn	b	aʊ	n						
brab	bræb	b	r	æ	b					
brang	bræŋ	b	r	æ	ŋ					

briper	**brɪ**pə	b	r	ɪ	p	ə				
broob	bru:b	b	r	u:	b					
caterbergar	**kæt**əbɜ:gə	k	æ	t	ə	b	ɜ:	g	ə	
cazz	kæz	k	æ	z						
cen	sen	s	e	n						
chamon	**tʃæm**ən	tʃ	æ	m	ə	n				
chan	tʃæn	tʃ	æ	n						
chay	tʃeɪ	tʃ	eɪ							
chazzen	**tʃæz**ən	tʃ	æ	z	ə	n				
chocket	**tʃɒk**et	tʃ	ɒ	k	e	t				
chribdriver	**tʃrɪb**draɪvə	tʃ	r	ɪ	b	d	r	aɪ	v	ə
ciparaud	kɪpə**raʊd**	k	ɪ	p	ə	r	aʊ	d		
cliers	**klaɪ**əs	k	l	aɪ	ə	z				
cloap	klaʊp	k	l	aʊ	p					
cripocebar	kraɪ**pɒk**əbɑ:	k	r	aɪ	p	ɒ	k	ə	b	ɑ:
croat	krəʊt	k	r	əʊ	t					
doak	dəʊk	d	əʊ	k						
dobster	**dɒb**stə	d	ɒ	b	s	t	ə			
dooshel	**du**:ʃel	d	u:	ʃ	e	l				
doy	dɔɪ	d	ɔɪ							
draysors	**dreɪ**səs	d	r	eɪ	s	ə	s			
drokes	drəʊks	d	r	əʊ	k	s				
druzzers	**dʌz**əs	d	ʌ	z	ə	z				
eem	i:m	i:	m							
elger	elgə	e	l	g	ə					
elt	elt	e	l	t						
emephens	**em**əfens	e	m	ə	f	e	n	s		
enledeve	**en**lədi:v	e	n	l	ə	d	i:	v		
erry	**er**i:	e	r	i:						
fanver	**fæn**və	f	æ	n	v	ə				
feap	feəp	f	eə	p						
feen	fi:n	f	i:	n						
felesuson	felə**su:s**ən	f	e	l	ə	s	u:	s	ə	n
fitten	**fɪt**ən	f	ɪ	t	ə	n				
fluel	**flu**:əl	f	l	u:	ə	l				
frash	fræʃ	f	r	æ	ʃ					

gasel	**gæs**əl	g	æ	s	ə	l				
gecklass	**gek**ləs	g	e	k	l	ə	s			
geeler	**gi**ːlə	g	iː	l	ə					
gic	gɪk	g	ɪ	k						
gouse	gaʊs	g	aʊ	s						
gral	grɑːl	g	r	ɑː	l					
gresslurper	**gres**lɜːpə	g	r	e	s	l	ɜː	p	ə	
grooth	gruːθ	g	r	uː	θ					
gyk	gaɪk	g	aɪ	k						
heek	hiːk	h	iː	k						
hemitelter	**hem**ɪteltə	h	e	m	ɪ	t	e	l	t	ə
hent	hent	h	e	n	t					
herk	hɜːk	h	ɜː	k						
hes	hes	h	e	s						
hin	hɪn	h	ɪ	n						
holl	hɒl	h	ɒ	l						
hoy	hɔɪ	h	ɔɪ							
indon	**ɪnd**ən	ɪ	n	d	ə	n				
jarl	**dʒɑ**ːl	dʒ	ɑː	l						
jek	dʒek	dʒ	e	k						
kaintgrush	**keɪnt**grʌʃ	k	eɪ	n	t	g	r	ʌ	ʃ	
kangbresh	**kæŋ**breʃ	k	æ	ŋ	b	r	e	ʃ		
kartepike	**kɑ**ːtəpaɪk	k	ɑː	t	ə	p	aɪ	k		
keahosse	**keə**hɒs	k	eə	h	ɒ	s				
keb	keb	k	e	b						
kengsuin	**keŋg**suːn	k	e	ŋ	g	s	uː	n		
kerruce	**kɜ**ː**r**əs	k	ɜː	r	ə	s				
ket	ket	k	e	t						
kiraffe	kɪ**ræf**	k	ɪ	r	æ	f				
kly	klaɪ	k	l	aɪ						
knal	næl	n	æ	l						
knarsh	naːʃ	n	ɑː	ʃ						
knoy	nɔɪ	n	ɔɪ							
knuss	nʌs	n	ʌ	s						
kooster	**ku**ː**st**ə	k	uː	s	t	ə				
korocha	kə**rəʊ**tʃə	k	ə	r	əʊ	tʃ	ə			

kotermagon	**kɒt**əmægən	k	ɒ	t	ə	m	æ	g	ə	n
koz	kɒz	k	ɒ	z						
kushtoom	**kʌʃ**tuːm	k	ʌ	ʃ	t	uː	m			
kyenafful	**kaɪ**næfəl	k	aɪ	n	æ	f	ə	l		
lamuna	lə**mu**ːnə	l	ə	m	uː	n	ə			
lauve	laʊv	l	aʊ	v						
lemephane	**lem**əfeɪn	l	e	m	ə	f	eɪ	n		
lial	**laɪ**əl	l	aɪ	ə	l					
litch	lɪtʃ	l	ɪ	tʃ						
lont	lɒnt	l	ɒ	n	t					
loopard	**lu**ːpəd	l	uː	p	ə	d				
lork	lɔːk	l	ɔː	k						
lumf	lʌmf	l	ʌ	m	f					
lup	lʌp	l	ʌ	p						
maint	meɪnt	m	eɪ	n	t					
marnon	**mɑ**ː**n**ən	m	ɑː	n	ə	n				
miago	**maɪ**əgaʊ	m	aɪ	ə	g	aʊ				
monvey	**mɒn**veɪ	m	ɒ	n	v	eɪ				
moontart	**mu**ː**n**tɑːt	m	uː	n	t	ɑː	t			
mowel	**maʊ**l	m	aʊ	l						
mup	mʌp	m	ʌ	p						
neesar	niː**sɑ**ː	n	iː	s	ɑː					
nurr	nɜː	n	ɜː							
oa	əʊ	əʊ								
oal	əʊl	əʊ	l							
oo	uː	uː								
ool	uːl	uː	l							
orinch	**ɒ**rɪntʃ	ɒ	r	ɪ	n	tʃ				
otript	**ɒt**rɪpt	ɒ	t	r	ɪ	p	t			
oun	aʊn	aʊ	n							
pab	pæb	p	æ	b						
pabbit	**pæb**ɪt	p	æ	b	ɪ	t				
pable	**pæb**əl	p	æ	b	ə	l				
peanyl	**pi**ː**n**ɪl	p	iː	n	ɪ	l				
pell	pel	p	e	l						
phek	fek	f	e	k						

phep	fep	f	e	p				
phlam	flæm	f	l	æ	m			
pid	pɪd	p	ɪ	d				
pigar	pɪ**ga**:	p	ɪ	g	ɑ:			
pleen	pli:n	p	l	i:	n			
pleeter	**pli**:**t**ə	p	l	i:	t	ə		
plice	plaɪs	p	l	aɪ	s			
pocate	pɪ**keɪ**tə	p	ɪ	k	eɪ	t	ə	
pompkun	**pɒmp**kən	p	ɒ	m	p	k	ə	n
poncel	**pɒn**səl	p	ɒ	n	s	ə	l	
prane	preɪn	p	r	eɪ	n			
prill	prɪl	p	r	ɪ	l			
purler	**pɜ**:**l**ə	p	ɜ:	l	ə			
rankey	**ræŋ**ki:	r	æ	ŋ	k	i:		
roorshob	**rɜ**:ʃɒb	r	ɜ:	ʃ	ɒ	b		
rop	rɒp	r	ɒ	p				
rurl	**rɜ**:l	r	ɜ:	l				
sackoon	sæk**u**:**n**	s	æ	k	u:	n		
san	sæn	s	æ	n				
sangacee	sæŋgæ**ki**:	s	æ	ŋ	g	ə	k	i:
sareknich	**sɑ**:**k**nɪtʃ	s	ɑ:	k	n	ɪ	tʃ	
sarf	sa:f	s	ɑ:	f				
sarul	**sɑ**:rəl	s	ɑ:	r	ə	l		
seetle	**si**:**t**əl	s	i:	t	ə	l		
semel	**sem**əl	s	e	m	ə	l		
sharit	**ʃæ**rɪt	ʃ	æ	r	ɪ	t		
shasel	**ʃæs**əl	ʃ	æ	s	ə	l		
sherp	ʃɜ:p	ʃ	ɜ:	p				
shoy	ʃɔɪ	ʃ	ɔɪ					
shuff	ʃʌf	ʃ	ʌ	f				
sibna	**sɪb**nə	s	ɪ	b	n	ə		
sint	sɪnt	s	ɪ	n	t			
sirt	sɜ:t	s	ɜ:	t				
slom	slɒm	s	l	ɒ	m			
slud	slʌd	s	l	ʌ	d			
smed	smed	s	m	e	d			

smish	smɪʃ	s	m	ɪ	ʃ				
soam	səʊm	s	əʊ	m					
soun	saʊn	s	aʊ	n					
sowch	saʊtʃ	s	aʊ	tʃ					
spad	spæd	s	p	æ	d				
spowcan	**spaʊ**kæn	s	p	aʊ	k	æ	n		
spurch	spɜːtʃ	s	p	ɜː	tʃ				
squirret	**skwɪ**rɪt	s	k	w	ɪ	r	ɪ	t	
stang	stæŋ	s	t	æ	ŋ				
steck	stek	s	t	e	k				
stodd	stɒd	s	t	ɒ	d				
stoth	stɒθ	s	t	ɒ	θ				
streybechy	**streɪ**betʃi	s	t	r	eɪ	b	e	tʃ	i
suilcash	**suːl**kæʃ	s	uː	l	k	æ	ʃ		
suntle	**sʌn**təl	s	ʌ	n	t	ə	l		
swit	swɪt	s	w	ɪ	t				
tammer	**tæm**ə	t	æ	m	ə				
tarner	**tɑːn**ə	t	ɑː	n	ə				
tauder	**taʊd**ə	t	aʊ	d	ə				
tesh	teʃ	t	e	ʃ					
thar	θɑː	θ	ɑː						
thimb	θɪm	θ	ɪ	m					
thow	θaʊ	θ	aʊ						
thu	θuː	θ	uː						
tider	**taɪ**də	tʃ	aɪ	d	ə				
toch	tɒtʃ	t	ɒ	tʃ					
tolt	tɒlt	t	ɒ	l	t				
toop	tuːp	t	uː	p					
torple	**tɔːp**əl	t	ɔː	p	ə	l			
trage	treɪdʒ	t	r	eɪ	dʒ				
trink	trɪnk	t	r	ɪ	n	k			
troin	trɔɪn	t	r	ɔɪ	n				
tror	trɔː	t	r	ɔː					
tull	tʌl	t	ʌ	l					
uppel	**ʌp**əl	ʌ	p	ə	l				
usfrolla	ʌs**frɒ**lə	ʌ	s	f	r	ɒ	l	ə	

vern	vɜːn	v	ɜː	n				
vill	vɪl	v	ɪ	l				
vorl	vɔːl	v	ɔː	l				
wandow	**wænd**aʊ	w	æ	n	d	aʊ		
weedle	**wi**ː**d**əl	w	iː	d	ə	l		
weff	wef	w	e	f				
whath	wæθ	w	æ	θ				
willmict	**wɪl**mɪkt	w	ɪ	l	m	ɪ	k	t
wop	wɒp	w	ɒ	p				
wrurp	rɜːp	r	ɜː	p				
yock	jɒk	j	ɒ	k				
zay	zeɪ	z	eɪ					
zow	zaʊ	z	aʊ					

20. Appendix 20

Bigram count for Snodgrass words and non-words created to match them.

Words			Non-words			Diff
r	ʌ	6	r	ʌ	1	5
s	k	7	s	k	2	5
e	l	10	e	l	6	4
h	æ	4	h	æ	0	4
l	ɪ	5	l	ɪ	1	4
r	uː	6	r	uː	2	4
t	əʊ	4	t	əʊ	0	4
ʌ	m	5	ʌ	m	1	4
ʌ	t	4	ʌ	t	0	4
w	ɪ	7	w	ɪ	3	4
ɒ	k	6	ɒ	k	3	3
ɑː	s	4	ɑː	s	1	3
æ	p	3	æ	p	0	3
b	ʌ	3	b	ʌ	0	3
f	l	5	f	l	2	3
g	ə	7	g	ə	4	3
g	l	3	g	l	0	3
ɪ	ŋ	3	ɪ	ŋ	0	3
ɪ	g	4	ɪ	g	1	3
ɪ	s	3	ɪ	s	0	3
l	e	5	l	e	2	3
n	eɪ	3	n	eɪ	0	3
ŋ	k	4	ŋ	k	1	3
p	e	4	p	e	1	3
p	iː	4	p	iː	1	3
r	ə	6	r	ə	3	3
s	n	3	s	n	0	3
t	ə	16	t	ə	13	3
t	ɪ	3	t	ɪ	0	3
uː	t	3	uː	t	0	3

ɒ	g	2	ɒ	g	0	2
æ	r	4	æ	r	2	2
æ	k	3	æ	k	1	2
æ	n	7	æ	n	5	2
aʊ	z	2	aʊ	z	0	2
b	iː	2	b	iː	0	2
b	r	7	b	r	5	2
ɔː	s	2	ɔː	s	0	2
d	ɒ	3	d	ɒ	1	2
d	ɔː	2	d	ɔː	0	2
ə	l	20	ə	l	18	2
ə	r	5	ə	r	3	2
ə	t	2	ə	t	0	2
ɜː	t	3	ɜː	t	1	2
eɪ	k	2	eɪ	k	0	2
h	ɑː	2	h	ɑː	0	2
h	ɔː	2	h	ɔː	0	2
ɪ	n	8	ɪ	n	6	2
ɪ	z	2	ɪ	z	0	2
k	æ	8	k	æ	6	2
k	ɔː	2	k	ɔː	0	2
k	əʊ	2	k	əʊ	0	2
k	aʊ	2	k	aʊ	0	2
k	ɪ	4	k	ɪ	2	2
k	s	3	k	s	1	2
l	ɑː	2	l	ɑː	0	2
n	ɒ	2	n	ɒ	0	2
n	əʊ	2	n	əʊ	0	2
n	d	4	n	d	2	2
p	aɪ	3	p	aɪ	1	2
p	s	2	p	s	0	2
r	iː	4	r	iː	2	2
r	e	4	r	e	2	2

s	ɪ	4	s	ɪ	2	2
s	w	3	s	w	1	2
s	ɒ	2	s	ɒ	0	2
t	aɪ	2	t	aɪ	0	2
t	eɪ	2	t	eɪ	0	2
tʃ	ɪ	2	tʃ	ɪ	0	2
ʌ	ŋ	2	ʌ	ŋ	0	2
ʌ	ʃ	4	ʌ	ʃ	2	2
ʌ	k	2	ʌ	k	0	2
ʌ	n	3	ʌ	n	1	2
ɒ	ŋ	1	ɒ	ŋ	0	1
ɑː	m	1	ɑː	m	0	1
ɑː	p	1	ɑː	p	0	1
ɑː	z	1	ɑː	z	0	1
æ	t	4	æ	t	3	1
aɪ	t	1	aɪ	t	0	1
aɪ	f	1	aɪ	f	0	1
aɪ	n	2	aɪ	n	1	1
aɪ	g	1	aɪ	g	0	1
aɪ	ə	4	aɪ	ə	3	1
aʊ	t	1	aʊ	t	0	1
aʊ	s	2	aʊ	s	1	1
aʊ	l	2	aʊ	l	1	1
b	æ	2	b	æ	1	1
b	aʊ	2	b	aʊ	1	1
b	ʊ	1	b	ʊ	0	1
b	aɪ	2	b	aɪ	1	1
b	eə	1	b	eə	0	1
b	uː	1	b	uː	0	1
ɔː	n	2	ɔː	n	1	1
ɔː	t	1	ɔː	t	0	1
ɔː	d	1	ɔː	d	0	1
ɔː	b	1	ɔː	b	0	1

d	ɪə	1	d	ɪə	0	1
d	m	1	d	m	0	1
d	e	1	d	e	0	1
dʒ	æ	1	dʒ	æ	0	1
dʒ	ɪ	1	dʒ	ɪ	0	1
e	d	2	e	d	1	1
e	g	1	e	g	0	1
e	p	2	e	p	1	1
e	t	4	e	t	3	1
e	r	2	e	r	1	1
e	dʒ	1	e	dʒ	0	1
ə	n	12	ə	n	11	1
ə	p	2	ə	p	1	1
ə	v	1	ə	v	0	1
ɜː	d	1	ɜː	d	0	1
eə	r	1	eə	r	0	1
eɪ	p	1	eɪ	p	0	1
eɪ	l	1	eɪ	l	0	1
əʊ	p	1	əʊ	p	0	1
əʊ	n	1	əʊ	n	0	1
əʊ	s	1	əʊ	s	0	1
f	ɪ	2	f	ɪ	1	1
f	ɒ	1	f	ɒ	0	1
f	ɔː	1	f	ɔː	0	1
f	ʊ	1	f	ʊ	0	1
f	əʊ	1	f	əʊ	0	1
g	eɪ	1	g	eɪ	0	1
g	ʌ	1	g	ʌ	0	1
g	w	1	g	w	0	1
h	aʊ	1	h	aʊ	0	1
h	eə	1	h	eə	0	1
iː	g	1	iː	g	0	1
iː	l	2	iː	l	1	1

iː	h	1	iː	h	0	1
iː	æ	1	iː	æ	0	1
iː	tʃ	1	iː	tʃ	0	1
iː	p	1	iː	p	0	1
ɪ	dʒ	1	ɪ	dʒ	0	1
ɪ	f	1	ɪ	f	0	1
ɪ	ʒ	1	ɪ	ʒ	0	1
j	ə	1	j	ə	0	1
k	iː	3	k	iː	2	1
k	r	3	k	r	2	1
k	ʌ	2	k	ʌ	1	1
l	æ	3	l	æ	2	1
l	aʊ	4	l	aʊ	3	1
l	əʊ	1	l	əʊ	0	1
l	ə	9	l	ə	8	1
l	eɪ	1	l	eɪ	0	1
m	aʊ	2	m	aʊ	1	1
m	p	3	m	p	2	1
m	əʊ	1	m	əʊ	0	1
m	b	1	m	b	0	1
m	ʌ	2	m	ʌ	1	1
n	aʊ	1	n	aʊ	0	1
n	aɪ	1	n	aɪ	0	1
n	e	1	n	e	0	1
n	ʌ	2	n	ʌ	1	1
n	dʒ	1	n	dʒ	0	1
n	j	1	n	j	0	1
n	w	1	n	w	0	1
ŋ	g	3	ŋ	g	2	1
ŋ	ə	1	ŋ	ə	0	1
p	ʌ	1	p	ʌ	0	1
p	eɪ	1	p	eɪ	0	1
p	eə	1	p	eə	0	1

r	ɑː	2	r	aː	1	1
r	ʊ	1	r	ʊ	0	1
s	iː	2	s	iː	1	1
s	ɔː	1	s	ɔː	0	1
s	h	1	s	h	0	1
ʃ	r	1	ʃ	r	0	1
ʃ	iː	1	ʃ	iː	0	1
ʃ	uː	1	ʃ	uː	0	1
t	ɜː	1	t	ɜː	0	1
t	k	1	t	k	0	1
t	b	1	t	b	0	1
tʃ	əʊ	1	tʃ	əʊ	0	1
tʃ	e	1	tʃ	e	0	1
tʃ	ɜː	1	tʃ	ɜː	0	1
tʃ	eə	1	tʃ	eə	0	1
ʊ	k	1	ʊ	k	0	1
ʊ	t	1	ʊ	t	0	1
ʊ	s	1	ʊ	s	0	1
uː	m	2	uː	m	1	1
uː	d	1	uː	d	0	1
v	aɪ	1	v	aɪ	0	1
v	ɑː	1	v	ɑː	0	1
ʌ	v	1	ʌ	v	0	1
ʌ	g	1	ʌ	g	0	1
w	e	2	w	e	1	1
w	ɒ	2	w	ɒ	1	1
w	ɔː	1	w	ɔː	0	1
z	e	1	z	e	0	1
ʒ	ə	1	ʒ	ə	0	1
θ	ʌ	1	θ	ʌ	0	1
θ	b	1	θ	b	0	1
ɒ	b	2	ɒ	b	2	0
ɒ	tʃ	1	ɒ	tʃ	1	0

ɒ	s	2	ɒ	s	2	0
ɒ	r	1	ɒ	r	1	0
ɑː	f	1	ɑː	f	1	0
ɑː	n	2	ɑː	n	2	0
æ	m	3	æ	m	3	0
æ	d	1	æ	d	1	0
æ	g	1	æ	g	1	0
aɪ	p	1	aɪ	p	1	0
aɪ	d	1	aɪ	d	1	0
aɪ	v	1	aɪ	v	1	0
aɪ	m	0	aɪ	m	0	0
aʊ	ə	1	aʊ	ə	1	0
aʊ	v	1	aʊ	v	1	0
aʊ	tʃ	1	aʊ	tʃ	1	0
aʊ	n	3	aʊ	n	3	0
b	ə	3	b	ə	3	0
b	ɒ	2	b	ɒ	2	0
b	ɑː	2	b	ɑː	2	0
b	ɜː	1	b	ɜː	1	0
b	s	1	b	s	1	0
ɔː	l	1	ɔː	l	1	0
d	r	3	d	r	3	0
d	ʌ	1	d	ʌ	1	0
d	ə	4	d	ə	4	0
d	əʊ	1	d	əʊ	1	0
e	ŋ	1	e	ŋ	1	0
e	s	2	e	s	2	0
ə	b	2	ə	b	2	0
ə	g	1	ə	g	1	0
ə	k	1	ə	k	1	0
ɜː	tʃ	1	ɜː	tʃ	1	0
eə	d	0	eə	d	0	0
eɪ	b	1	eɪ	b	1	0

eɪ	ə	1	eɪ	ə	1	0
eɪ	n	4	eɪ	n	4	0
eɪ	s	1	eɪ	s	1	0
eɪ	t	2	eɪ	t	2	0
əʊ	t	2	əʊ	t	2	0
əʊ	m	2	əʊ	m	2	0
f	ə	1	f	ə	1	0
g	ɑː	1	g	ɑː	1	0
g	ɪ	1	g	ɪ	1	0
iː	d	1	iː	d	1	0
iː	k	1	iː	k	1	0
iː	f	1	iː	f	1	0
iː	ə	1	iː	ə	1	0
ɪ	r	2	ɪ	r	2	0
ɪ	ʃ	1	ɪ	ʃ	1	0
ɪ	tʃ	2	ɪ	tʃ	2	0
k	ɑː	1	k	ɑː	1	0
k	aɪ	1	k	aɪ	1	0
k	eɪ	2	k	eɪ	2	0
k	l	4	k	l	4	0
k	ɒ	2	k	ɒ	2	0
k	ɜː	1	k	ɜː	1	0
k	w	1	k	w	1	0
l	uː	2	l	uː	2	0
m	æ	1	m	æ	1	0
m	e	1	m	e	1	0
n	iː	1	n	iː	1	0
n	ɑː	1	n	ɑː	1	0
p	ə	6	p	ə	6	0
p	l	3	p	l	3	0
p	k	1	p	k	1	0
p	t	1	p	t	1	0
p	uː	1	p	uː	1	0

r	aɪ	2	r	aɪ	2	0
r	ɔː	1	r	ɔː	1	0
r	aʊ	1	r	aʊ	1	0
s	t	7	s	t	7	0
s	ʌ	1	s	ʌ	1	0
ʃ	ɜː	1	ʃ	ɜː	1	0
ʃ	ɔː	0	ʃ	ɔː	0	0
t	aʊ	1	t	aʊ	1	0
t	r	7	t	r	7	0
tʃ	eɪ	1	tʃ	eɪ	1	0
uː	n	4	uː	n	4	0
uː	l	2	uː	l	2	0
uː	θ	1	uː	θ	1	0
v	ə	2	v	ə	2	0
v	ɪ	1	v	ɪ	1	0
w	iː	1	w	iː	1	0
ɒ	l	2	ɒ	l	3	-1
ɒ	p	2	ɒ	p	3	-1
ɒ	t	1	ɒ	t	2	-1
ɒ	f	0	ɒ	f	1	-1
ɒ	z	0	ɒ	z	1	-1
ɒ	d	0	ɒ	d	1	-1
ɑː	d	0	ɑː	d	1	-1
ɑː	t	3	ɑː	t	4	-1
ɑː	ʃ	0	ɑː	ʃ	1	-1
ɑː	k	0	ɑː	k	1	-1
ɑː	r	0	ɑː	r	1	-1
æ	θ	0	æ	θ	1	-1
aɪ	k	2	aɪ	k	3	-1
aɪ	əʊ	0	aɪ	əʊ	1	-1
aɪ	r	0	aɪ	r	1	-1
aɪ	s	0	aɪ	s	1	-1
aʊ	d	1	aʊ	d	2	-1

aʊ	p	0	aʊ	p	1	-1
aʊ	k	0	aʊ	k	1	-1
b	e	4	b	e	5	-1
b	ɔː	0	b	ɔː	1	-1
b	ɪ	1	b	ɪ	2	-1
b	d	0	b	d	1	-1
b	n	0	b	n	1	-1
ɔː	k	1	ɔː	k	2	-1
ɔː	p	0	ɔː	p	1	-1
ɔɪ	n	0	ɔɪ	n	1	-1
d	iː	1	d	iː	2	-1
d	aʊ	0	d	aʊ	1	-1
d	ɔɪ	0	d	ɔɪ	1	-1
d	uː	0	d	uː	1	-1
dʒ	ɑː	0	dʒ	ɑː	1	-1
dʒ	e	0	dʒ	e	1	-1
e	b	0	e	b	1	-1
e	n	4	e	n	5	-1
e	tʃ	0	e	tʃ	1	-1
ə	d	1	ə	d	2	-1
ə	s	4	ə	s	5	-1
ə	z	1	ə	z	2	-1
ɜː	g	0	ɜː	g	1	-1
ɜː	n	0	ɜː	n	1	-1
ɜː	k	0	ɜː	k	1	-1
ɜː	r	0	ɜː	r	1	-1
ɜː	ʃ	0	ɜː	ʃ	1	-1
eə	p	0	eə	p	1	-1
eə	h	0	eə	h	1	-1
eɪ	d	0	eɪ	d	1	-1
eɪ	m	0	eɪ	m	1	-1
eɪ	dʒ	0	eɪ	dʒ	1	-1
əʊ	k	1	əʊ	k	2	-1

əʊ	tʃ	0	əʊ	tʃ	1	-1
əʊ	l	0	əʊ	l	1	-1
f	ɑː	0	f	ɑː	1	-1
f	r	1	f	r	2	-1
f	æ	0	f	æ	1	-1
f	eɪ	0	f	eɪ	1	-1
f	eə	0	f	eə	1	-1
g	æ	0	g	æ	1	-1
g	aʊ	1	g	aʊ	2	-1
g	e	0	g	e	1	-1
g	aɪ	0	g	aɪ	1	-1
g	iː	0	g	iː	1	-1
g	s	0	g	s	1	-1
h	ɒ	1	h	ɒ	2	-1
h	ɔɪ	0	h	ɔɪ	1	-1
h	ɜː	0	h	ɜː	1	-1
h	ɪ	0	h	ɪ	1	-1
h	iː	0	h	iː	1	-1
iː	t	1	iː	t	2	-1
iː	b	0	iː	b	1	-1
iː	m	0	iː	m	1	-1
iː	s	0	iː	s	1	-1
iː	v	0	iː	v	1	-1
ɪ	t	6	ɪ	t	7	-1
ɪ	k	2	ɪ	k	3	-1
ɪ	m	0	ɪ	m	1	-1
ɪ	d	0	ɪ	d	1	-1
j	ɒ	0	j	ɒ	1	-1
k	ʌ	0	k	ʌ	1	-1
k	uː	1	k	uː	2	-1
k	eə	0	k	eə	1	-1
k	n	0	k	n	1	-1
k	t	0	k	t	1	-1

l	ɒ	3	l	ɒ	4	-1
l	aɪ	4	l	aɪ	5	-1
l	ɔː	0	l	ɔː	1	-1
l	ɜː	0	l	ɜː	1	-1
l	ʌ	2	l	ʌ	3	-1
l	t	2	l	t	3	-1
l	k	0	l	k	1	-1
l	m	0	l	m	1	-1
l	tʃ	0	l	tʃ	1	-1
l	g	0	l	g	1	-1
m	ɑː	1	m	ɑː	2	-1
m	aɪ	0	m	aɪ	1	-1
m	ɒ	0	m	ɒ	1	-1
m	eɪ	0	m	eɪ	1	-1
m	uː	1	m	uː	2	-1
m	f	0	m	f	1	-1
n	æ	1	n	æ	2	-1
n	ɔɪ	0	n	ɔɪ	1	-1
n	ɜː	0	n	ɜː	1	-1
n	v	1	n	v	2	-1
n	s	2	n	s	3	-1
n	tʃ	0	n	tʃ	1	-1
n	l	0	n	l	1	-1
n	k	0	n	k	1	-1
ŋ	b	0	ŋ	b	1	-1
p	aʊ	0	p	aʊ	1	-1
p	ɪ	3	p	ɪ	4	-1
r	ɔɪ	0	r	ɔɪ	1	-1
s	ɜː	0	s	ɜː	1	-1
s	e	1	s	e	2	-1
s	əʊ	0	s	əʊ	1	-1
s	f	0	s	f	1	-1
s	p	3	s	p	4	-1

ʃ	t	1	ʃ	t	2	-1
ʃ	ɒ	0	ʃ	ɒ	1	-1
ʃ	ʌ	0	ʃ	ʌ	1	-1
ʃ	ɔɪ	0	ʃ	ɔɪ	1	-1
ʃ	e	0	ʃ	e	1	-1
t	ɑː	2	t	ɑː	3	-1
t	e	2	t	e	3	-1
t	ɔː	0	t	ɔː	1	-1
t	uː	2	t	uː	3	-1
t	ʌ	0	t	ʌ	1	-1
t	g	0	t	g	1	-1
tʃ	ɒ	0	tʃ	ɒ	1	-1
tʃ	ɑː	0	tʃ	ɑː	1	-1
tʃ	ə	0	tʃ	ə	1	-1
tʃ	iː	0	tʃ	iː	1	-1
tʃ	r	0	tʃ	r	1	-1
tʃ	aɪ	0	tʃ	aɪ	1	-1
uː	b	0	uː	b	1	-1
uː	ə	0	uː	ə	1	-1
uː	ʃ	0	uː	ʃ	1	-1
uː	r	0	uː	r	1	-1
v	ɔː	0	v	ɔː	1	-1
v	ɜː	0	v	ɜː	1	-1
v	eɪ	0	v	eɪ	1	-1
ʌ	d	0	ʌ	d	1	-1
ʌ	f	0	ʌ	f	1	-1
ʌ	l	0	ʌ	l	1	-1
ʌ	s	1	ʌ	s	2	-1
ʌ	z	0	ʌ	z	1	-1
z	ə	1	z	ə	2	-1
z	aʊ	0	z	aʊ	1	-1
z	eɪ	0	z	eɪ	1	-1
θ	aː	0	θ	aː	1	-1

θ	aʊ	0	θ	aʊ	1	-1
θ	ɪ	0	θ	ɪ	1	-1
θ	uː	0	θ	uː	1	-1
θ	ə	0	θ	ə	1	-1
ɒ	n	2	ɒ	n	4	-2
ɒ	θ	0	ɒ	θ	2	-2
ɒ	m	0	ɒ	m	2	-2
æ	l	1	æ	l	3	-2
æ	ŋ	3	æ	ŋ	5	-2
æ	ʃ	1	æ	ʃ	3	-2
æ	z	0	æ	z	2	-2
æ	f	0	æ	f	2	-2
b	eɪ	0	b	eɪ	2	-2
e	f	0	e	f	2	-2
e	ʃ	0	e	ʃ	2	-2
ə	f	2	ə	f	4	-2
ə	m	2	ə	m	4	-2
ɜː	l	0	ɜː	l	2	-2
g	r	2	g	r	4	-2
h	e	1	h	e	3	-2
ɪ	p	1	ɪ	p	3	-2
ɪ	l	3	ɪ	l	5	-2
ɪ	b	0	ɪ	b	2	-2
m	ə	3	m	ə	5	-2
m	ɪ	2	m	ɪ	4	-2
n	ə	2	n	ə	4	-2
n	ɪ	0	n	ɪ	2	-2
p	ɜː	0	p	ɜː	2	-2
p	r	0	p	r	2	-2
r	ɒ	1	r	ɒ	3	-2
r	eɪ	3	r	eɪ	5	-2
s	aʊ	0	s	aʊ	2	-2
s	æ	1	s	æ	3	-2

s	ə	4	s	ə	6	-2
s	l	1	s	l	3	-2
s	m	0	s	m	2	-2
s	uː	1	s	uː	3	-2
ʃ	æ	0	ʃ	æ	2	-2
t	æ	0	t	æ	2	-2
uː	s	0	uː	s	2	-2
uː	p	0	uː	p	2	-2
ʌ	p	1	ʌ	p	3	-2
w	æ	0	w	æ	2	-2
ɑː	l	0	ɑː	l	3	-3
æ	s	0	æ	s	3	-3
æ	b	1	æ	b	4	-3
ɜː	p	0	ɜː	p	3	-3
f	e	1	f	e	4	-3
f	iː	0	f	iː	3	-3
iː	n	1	iː	n	4	-3
k	e	1	k	e	4	-3
l	iː	1	l	iː	4	-3
n	t	4	n	t	7	-3
p	æ	1	p	æ	4	-3
p	ɒ	0	p	ɒ	3	-3
r	æ	2	r	æ	5	-3
r	ɜː	0	r	ɜː	3	-3
r	əʊ	1	r	əʊ	4	-3
tʃ	æ	0	tʃ	æ	3	-3
e	k	1	e	k	5	-4
e	m	1	e	m	5	-4
k	ə	1	k	ə	5	-4
r	ɪ	4	r	ɪ	8	-4
s	ɑː	0	s	ɑː	4	-4
t	ɒ	0	t	ɒ	4	-4
b	l	1	b	l	6	-5

Total	**754**	**754**

21. Appendix 21

Divison of non-words into groups based upon which phoneme will be monitored for.

word	structure	syllables
p		
arribork	VCVCVC	3
smish	CCVC	1
uppel	VCVC	2
whath	CVC	1
loopard	CVCVC	2
rop	CVC	1
stoth	CCVC	1
willmict	CVCCVC	2
arl	VC	1
blop	CCVC	1
stang	CCVC	1
toop	CVC	1
blempet	CCVCCVC	2
tarner	CVCV	2
chazzen	CVCVC	2
lup	CVC	1
vorl	CVC	1
sherp	CVC	1
aspuraros	VCCVCVCVC	4

word	structure	syllables
d		
tider	CVCV	2
pocate	CVCVCV	3
tauder	CVCV	2
chribdriver	CCCVCCVCV	3
feap	CVC	1
baid	CVC	1
fluel	CCVC	1
spad	CVCC	1
wansow	CVCCV	2
broob	CCVC	1
pid	CVC	1
gral	CCVC	1
affardion	VCVCCVC	4
bleef	CCCV	1
smed	CCVC	1
vern	CVC	1
weedle	CVCVC	2
stodd	CCVC	1
elger	VCVC	2

word	structure	syllables
m		
yock	CVC	1
bimatu	CVCVCV	3
toch	CCV	1
semel	CVCVC	2
tammer	CVCV	2
slud	CVCC	1
eem	VC	1
phlam	CCVC	1
cen	CVC	1
beckle	CVCVC	2
draysors	CCVCVC	2
kotermagon	CVCVCVCVC	4
swit	CVC	1
thimb	CVC	1
chamon	CVCVC	2
cripocebar	CVCVCVCVC	4
steck	CCVC	1

word	structure	syllables
s		
gresslurper	CCVCCVCV	3
baomin	CVVCVC	3
kerruce	CVCVC	2
vill	CVC	1
zay	CV	1
hes	CVC	1
barse	CVC	1
gouse	CVC	1
mowel	CVC	1
blof	CCVC	1
lamuna	CVCVCV	3
knuss	CVC	1
gic	CVC	1
moontart	CVCCVC	2
poncel	CVCCVC	2
gasel	CVCVC	2
torple	CVCC	2

purler	CVCV	2
slom	CCVC	1

word	structure	syllables
k		
airotrat	VCVCCVC	3
alkar	VCCV	2
aium	VVC	2
briper	CCVCV	2
baskel	CVCCVC	2
chocket	CVCVC	2
hent	CVCC	1
doak	CVC	1
rankey	CVCCV	2
thow	CV	1
gyk	CVC	1
phek	CVC	1
fanver	CVCCV	2
brab	CCVC	1
suilcash	CVCCVC	2
mup	CVC	1
lont	CCVC	1
sackoon	CVCVC	2
heek	CVC	1

word	structure	syllables
t		
caterbergar	CVCVCVCV	4
lial	CVVC	2
brang	CCVC	1
bettle	CVCVC	2
fitten	CVCVC	2
grooth	CCVC	1
doy	CV	1
elt	VCC	1
ket	CVC	1
sirt	CVC	1
rurl	CVC	1
awn	CV	1
kartepike	CVCVCVC	3
sareknich	CVCCCVC	2
seetle	CVCVC	2
croat	CCVC	1
bame	CVC	1
pleeter	CCVCV	2

shasel	CVCVC	2
nurr	CV	1

word	structure	syllables
n		
kyenafful	CVCVCVC	3
chan	CVC	1
soam	CVC	1
trion	CCVC	1
holl	CVC	1
marnon	CVCVC	2
feen	CVC	1
thar	CV	1
hin	CVC	1
lork	CVC	1
peanyl	CVCVC	2
enledeve	VCCVCVC	3
felesuson	CVCVCVCVC	4
keb	VCC	1
suntle	CVCCVC	2
spurch	CCVC	1
oo	VV	2
herk	CVC	1

word	structure	syllables
l		
bephy	CVCV	2
bileny	CVCVCV	3
ciparaud	CVCVCVC	3
spowcan	CCVCVC	2
balleen	CVCVC	2
pell	CVC	1
prane	CCVC	1
soun	CVC	1
tull	CVC	1
wrurp	CVC	1
ool	VC	1
geeler	CVCV	2
bon	CVC	1
aleicator	VCVCVCV	4
prill	CCVC	1
neesar	CVCV	2
knal	CVC	1
duzzers	CVCVC	2
gecklass	CVCCVC	2

word	structure	syllables
b		
cloap	CCVC	1
koz	CVC	1
san	CVC	1
dobster	CVCCCV	2
trink	CCVCC	1
kengsuin	CVCCCVC	2
pabbit	CVCVC	2
indon	VCCVC	2
sibna	CVCCV	2
keahosse	CVCVC	2
trage	CCVC	1
kooster	CVCC V	2
zow	CV	1
streybechy	CCCVCVCV	3
pable	CVCVC	2
phep	CVC	1
monvey	CVCCV	2
knarsh	CVC	1
roorshob	CVCVC	2

word	structure	syllables
f		
benserphy	CVCVCCV	3
tror	CCV	1
lemephane	CVCVCVC	3
sangacee	CVCCVCV	3
chay	CV	1
tolt	CVCC	1
emephens	VCVCVCC	3
oa	V	1
shoy	CV	1
lauve	CVC	1
hemitelter	CVCVCVCCV	4
kiraffe	CVCVC	2
jek	CVC	1
cazz	CVC	1
plice	CCVC	1
sarf	CVC	1
drokes	CCVCC	1
weff	CVC	1
sowch	CVC	1

word	structure	syllables
r		
hoy	CV	1
erry	VCV	2
dooshel	CVCVC	2
oal	CV	1
knoy	CV	1
sharit	CVCVC	2
sarul	CVCVC	2
pompkun	CVCCCVC	2
litch	CVC	1
maint	CCVC	1
ortript	VCCCVC	2
orinch	VCVCV	2
bothon	CVCVC	2
korocha	CVCVCV	3
shuff	CVC	1
kly	CCV	1
squirret	CCCVCVC	2
jarl	CVC	1
bown	CVC	1

word	structure	syllables
sh		
thu	CV	1
blatt	CCVC	1
usfrolla	VCCCVCV	3
kushtoom	CVCCVC	2
wop	CVC	1
frash	CCVC	1
tesh	CVC	1
blower	CCVC	2
sint	CVCC	1
oun	CV	1
pigar	CVCV	2
ashtart	VCCCV	2
miago	CVVCV	3
pab	CVC	1
kaintgrush	CVCCCCVC	2
pleen	CVCC	1
lumf	CVCC	1
cliers	CCVVC	1
kangbresh	CVCCCVC	2

22. Appendix 22

Snodgrass pictures


Accordion


Aeroplane


Alligator


Anchor


Ant


Apple


Arm


Arrow


Artichoke

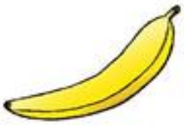

Ashtray


Asparagus


Axe


Ball


Balloon


Banana


Barn


Barrel


Basket


Bat


Bear

Bed

Bee

Beetle

Bell

Belt

Bike

Bird

Blouse

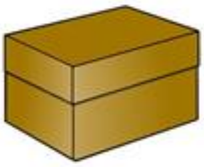
Book

Boot

Bottle

Bow

Bowl



Box

Bread

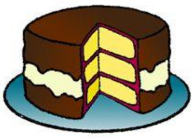
Broom

Brush

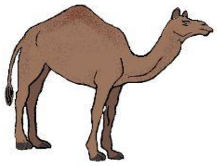
Bus

Butterfly

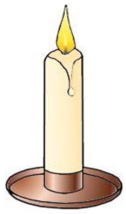
Button



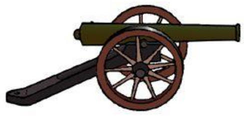
Cake



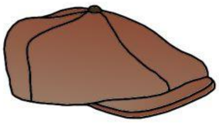
Camel



Candle

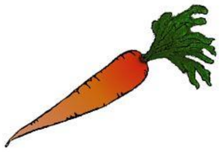


Cannon



Cap

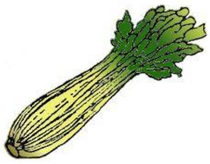
Car



Carrot

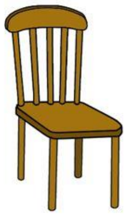
Cat

Caterpillar

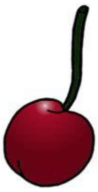


Celery

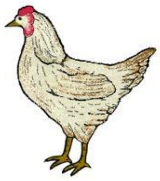
Chain



Chair



Cherry



Chicken

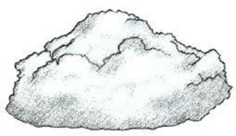
Chisel

Church

Cigar

Cigarette

Clock



Cloud

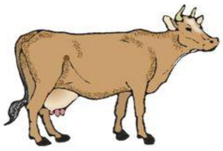
Clown

Coat

Comb

Corn

Coach



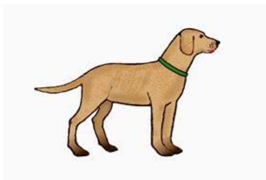
Cow

Crown

Cup

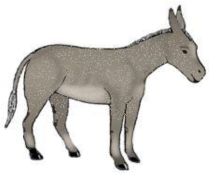
Deer

Desk



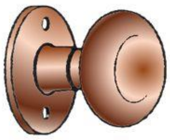
Dog

Doll



Donkey

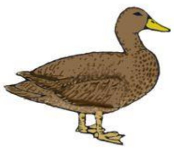
Door



Doorknob

Dress

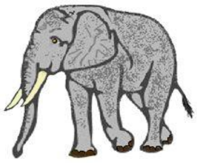
Drum



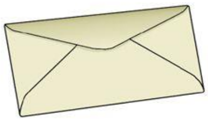
Duck

Eagle

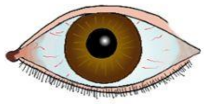
Ear



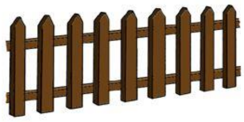
Elephant



Envelope

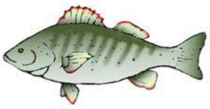


Eye



Fence

Finger

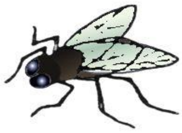


Fish

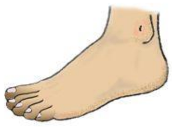
Flag

Flower

Flute

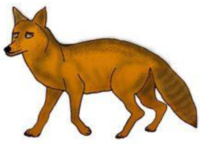


Fly

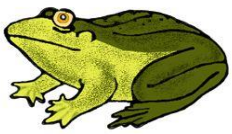


Foot

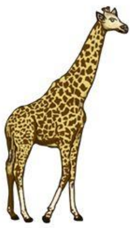
Fork



Fox



Frog



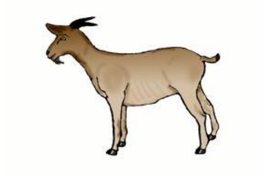
Giraffe

Guitar

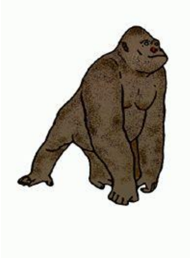
Glass

Glasses

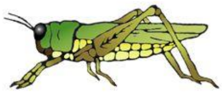
Glove



Goat


Gorilla


Grapes


Grasshopper


Gun


Hair


Hammer


Hand

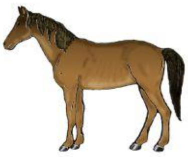

Hanger


Harp

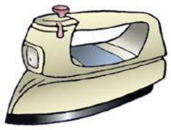

Hat


Heart

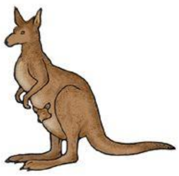

Helicopter

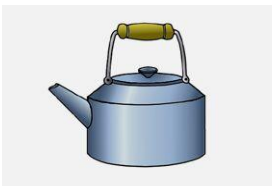

Horse


House

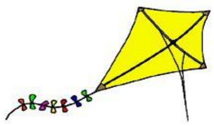

Iron


Jacket


Kangaroo


Kettle


Key


Kite

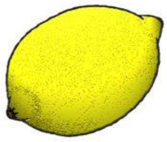
Knife

Ladder

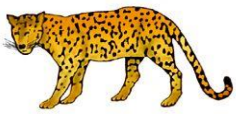
Lamp

Leaf

Leg

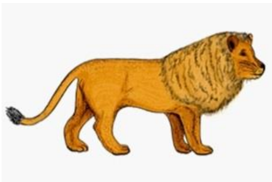


Lemon

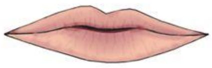


Leopard

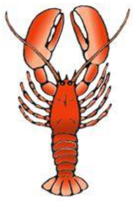
Lettuce



Lion

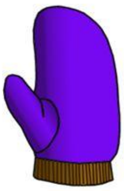


Lips

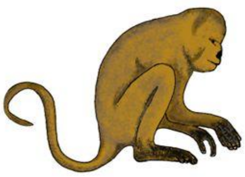


Lobster

Lock



Mitten



Monkey

Moon

Motorbike

Mountain

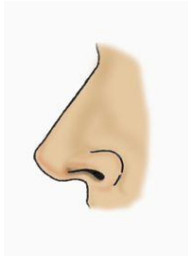
Mouse

Mushroom

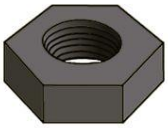
Nail

Necklace

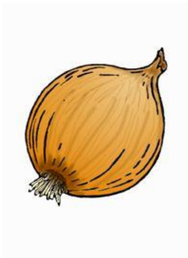
Needle



Nose



Nut

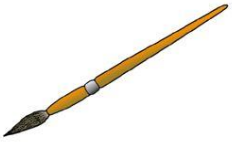


Onion

Orange

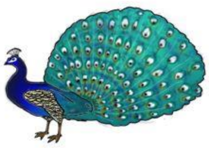
Ostrich

Owl

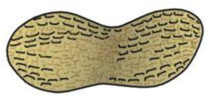


Paintbrush

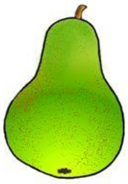
Peach



Peacock



Peanut

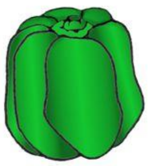


Pear

Pen

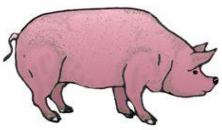
Pencil

Penguin



Pepper

Piano



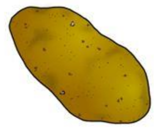
Pig

Pineapple

Pipe

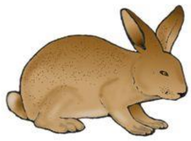
Pliers

Plug

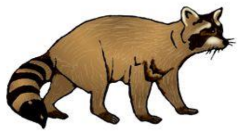


Potato

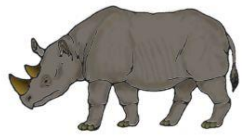
Pumpkin



Rabbit

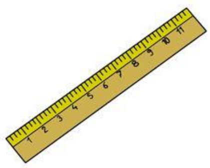


Racoon

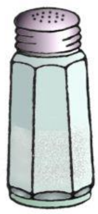


Rhinoceros

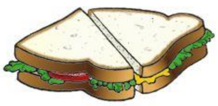
Ring



Ruler



Salt



Sandwich

Saw

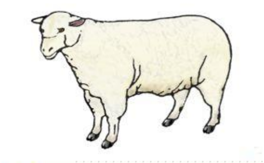
Scissors

Screwdrive

Screw

Seahorse

Seal



Sheep

Shirt

Shoe

Skirt

Skunk

Sledge

Snail

Snake

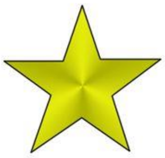
Snowman

Sock

Spider

Spoon

Squirrel



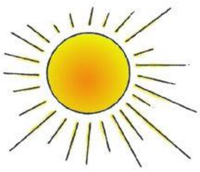
Star

Stool

Stove

Strawberry

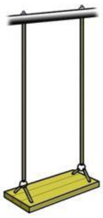
Suitcase



Sun

Swan

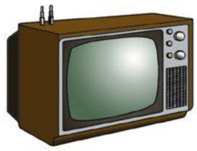
Sweater



Swing

Table

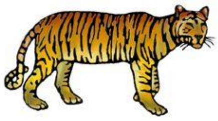
Telephone



Television

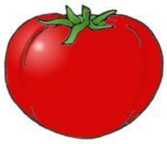
Thumb

Tie



Tiger

Toaster



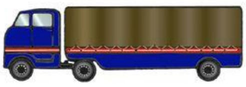
Tomato

Toe

Toothbrush

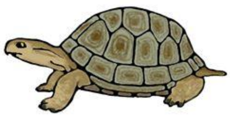
Train

Tree



Truck

Trumpet



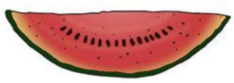
Turtle

Umbrella

Vase

Violin

Watch



Watermelo

Well

Wheel

Whistle

Windmill

Window

Zebra

23. Appendix 23

Words used in the syllable dection task and their frequency scores

Words	Log Freq from HAL study
abacus	6.24
accordion	6.38
acorn	9.024
aeroplane	5.384
alligator	6.583
apostrophe	6.122
arrow	8.899
artichoke	5.198
asparagus	5.652
avocado	5.704
bacteria	8.443
ballerina	4.942
balloon	8.436
banana	7.965
binoculars	6.865
bottle	9.833
butterfly	7.494
cactus	7.099
calculator	8.264
camel	8.124
candle	7.908
canoe	7.454
carrot	7.269
caterpillar	6.023
celery	6.596
cemetery	7.296
certificate	8.828
cigarette	7.966
compass	7.549
dictionary	9.507
dominoes	5.333
electrician	5.878
elephant	8.855
elevator	8.076
envelope	9.289
escalator	5.242
fertilizer	7.116

flower	8.746
funnel	6.673
generator	9.116
gladiator	5.981
gorilla	7.205
grasshopper	5.991
guitar	10.118
hammock	5.118
hanger	6.868
harmonica	6.507
helicopter	8.071
igloo	4.984
invitation	8.278
jaguar	8.742
kangaroo	6.707
kettle	7.313
laboratory	9.719
lion	8.945
macaroni	5.841
magazine	11.009
margarita	
medication	8.195
monkey	8.493
motorbike	5.193
mozzarella	
mushroom	7.535
muzzle	7.543
octopus	6.802
origami	
palette	8.215
pedestrian	6.639
pelican	7.035
pencil	8.013
penguin	7.706
pineapple	6.457
potassium	7.224
potato	8.064
pretzel	5.024
pyramid	8.449
racket	6.509
radiator	6.957
rhinoceros	4.762
scissors	7.222

screwdriver	7.067
snowman	6.683
stethoscope	5.024
strawberry	7.391
suitcase	7.096
telephone	10.583
television	10.024
thermometer	6.544
tomato	7.667
toothbrush	6.328
trellis	5.529
tripod	6.947
umbrella	7.565
unicorn	8.174
vaseline	6.491
violin	7.857
volcano	8.024
watermelon	5.956
wheelchair	7.08
whistle	7.891

3% of the words are more familiar than 2SDs above the mean non are below

3% of the words cannot be computed by the software

24. Appendix 24

Phonetic transcription for non-words used in SDNW task

atorn	**eɪt**ɔːn	eɪ	t	ɔː	n			
erry	**er**iː	e	r	iː				
balleen	bə**liːn**	b	ə	l	iː	n		
beckle	**bek**əl	b	e	k	ə	l		
baptus	**bæp**təs	b	æ	p	t	ə	s	
semel	**sem**əl	s	e	m	ə	l		
suntle	**sʌn**təl	s	ʌ	n	t	ə	l	
caloe	kə**luː**	k	ə	l	uː			
sharit	**ʃær**ɪt	ʃ	æ	r	ɪ	t		
tumbas	**tʌmb**əs	t	ʌ	m	b	ə	s	
blorer	**blɔː**ə	b	l	ɔː	ə			
fusel	**fʌs**əl	f	ʌ	s	ə	l		
neesar	niː**sɑː**	n	iː	s	ɑː			
halok	**hæl**ək	h	æ	l	ə	k		
tarner	**tɑːn**ə	t	ɑː	n	ə			
itroo	**ɪt**ruː	ɪ	t	r	uː			
bettle	**bet**əl	b	e	t	ə	l		
lial	**laɪ**əl	l	aɪ	ə	l			
rankey	**ræn**kiː	r	æ	n	k	iː		
kushtoom	**kʌʃ**tuːm	k	ʌ	ʃ	t	uː	m	
moshel	**mɒʃ**əl	m	ɒ	ʃ	ə	l		
kasit	**kæs**ɪt	k	æ	s	ɪ	t		
poncel	**pɒn**səl	p	ɒ	n	s	ə	l	
kengsuin	**keŋg**suːn	k	e	ŋ	g	s	uː	n
klaitsel	**kleɪt**səl	k	l	eɪ	t	s	ə	l
kacket	**kæk**ət	k	æ	k	ə	t		
duzzers	**dʌz**əs	d	ʌ	z	ə	s		
spowcan	**spaʊ**kæn	s	p	aʊ	k	æ	n	

suilcash	**su**ː**l**kæʃ	s	uː	l	k	æ	ʃ			
licktrush	**lɪk**trʌʃ	l	ɪ	k	t	r	ʌ	ʃ		
stuckes	**stʌk**ɪs	s	t	ʌ	k	ɪ	s			
treegel	**tri**ːgəl	t	r	iː	g	ə	l			
gelchair	**gel**tʃeə	g	e	l	tʃ	eə				
gasel	**gæs**əl	g	æ	s	ə	l				
aiteres	**eɪt**ərəs	eɪ	t	ə	r	ə	s			
airotrat	**aɪr**əʊtreɪt	aɪ	r	əʊ	t	r	eɪ	t		
arribork	**æ**riːbɔːk	æ	r	iː	b	ɔː	k			
lamuna	lə**mu**ːnə	l	ə	m	uː	n	ə			
benserphy	**ben**sɜːfiː	b	e	n	s	ɜː	f	iː		
bileny	**bɪl**əniː	b	ɪ	l	ə	n	iː			
pelitry	**pel**ɪtriː	p	e	l	ɪ	t	r	iː		
ciparaud	kɪpə**raʊd**	k	ɪ	p	ə	r	aʊ	d		
linshenter	**lɪn**ʃəntə	l	ɪ	n	ʃ	ə	n	t	ə	
domurees	**dɒm**əriːz	d	ɒ	m	ə	r	iː	z		
emephens	**em**əfens	e	m	ə	f	e	n	s		
enledeve	**en**lədiːv	e	n	l	ə	d	iː	v		
korocha	kə**rəʊ**tʃə	k	ə	r	əʊ	tʃ	ə			
gresslurper	**gres**lɜːpə	g	r	e	s	l	ɜː	p	ə	
chiguar	**tʃɪg**jʊə	tʃ	ɪ	g	j	ʊ	ə			
sangacee	sæŋgæ**ki**ː	s	æ	ŋ	g	æ	k	iː		
cavureen	kævə**ri**ː**n**	k	æ	v	ə	r	iː	n		
kartepike	**kɑ**ːtəpaɪk	k	ɑː	t	ə	p	aɪ	k		
ectepen	**ek**təpən	e	k	t	ə	p	ə	n		
reliten	**rel**ɪtən	r	e	l	ɪ	t	ə	n		
kyenafful	**kaɪ**næfəl	k	aɪ	n	æ	f	ə	l		
pocate	pə**keɪ**tə	p	ə	k	eɪ	t	ə			
laitamid	**leɪ**təmɪd	l	eɪ	t	ə	m	ɪ	d		
chribdriver	**tʃrɪb**draɪvə	tʃ	r	ɪ	b	d	r	aɪ	v	ə

skortisnote	**skɔːt**əsnəʊt	s	k	ɔː	t	ə	s	n	əʊ	t	
streybechy	**streɪ**betʃiː	s	t	r	eɪ	b	e	tʃ	iː		
lemephane	**lem**əfeɪn	l	e	m	ə	f	eɪ	n			
bimatu	bə**mɑ**ːtuː	b	ə	m	ɑː	t	uː				
usfrolla	ʌs**frɒ**lə	ʌ	s	f	r	ɒ	l	ə			
unirale	**ju**ː**n**ərɑːl	j	uː	n	ə	r	ɑː	l			
lickateen	**lɪk**ətiːn	l	ɪ	k	ə	t	iː	n			
baomin	baɪəʊ**mɪn**	b	aɪ	əʊ	m	ɪ	n				
pulkainor	pəl**keɪ**nɔː	p	ə	l	k	eɪ	n	ɔː			
affardion	ə**fɑ**ːdiːən	ə	f	ɑː	d	iː	ə	n			
aleicator	**æl**aɪkætə	æ	l	aɪ	k	æ	t	ə			
akeltraphe	ə**kel**trəfiː	ə	k	e	l	t	r	ə	f	iː	
asmuraros	əs**mu**ːrɑːrɒs	ə	s	m	uː	r	ɑː	r	ɒ	s	
aletardow	ælə**tɑ**ːdəʊ	æ	l	ə	t	ɑː	d	əʊ			
mesteria	mes**tɪə**riːə	m	e	s	t	ɪə	r	iː	ə		
geliraler	gelə**rɑ**ː**l**ə	g	e	l	ə	r	ɑː	l	ə		
finotuzes	fɪ**nɒt**jʊzəz	f	ɪ	n	ɒ	t	j	ʊ	z	ə	z
pigculieser	**pɪn**kjʊlaɪsə	p	ɪ	n	k	j	ʊ	l	aɪ	s	ə
caterbergar	**kæt**əbɜːgə	k	æ	t	ə	b	ɜː	g	ə		
pertifanet	pə**tɪf**ænət	p	ə	t	ɪ	f	æ	n	ə	t	
elactritel	ɪlæk**trɪt**əl	ɪ	l	æ	k	t	r	ɪ	t	ə	l
alenowper	**æl**ɪnəʊpə	æ	l	ɪ	n	əʊ	p	ə			
elshiraiter	**elʃ**əreɪtə	e	l	ʃ	ə	r	eɪ	t	ə		
fertipere	**fɜ**ː**t**əperə	f	ɜː	t	ə	p	e	r	ə		
janegicker	**dʒæn**əgɪkə	dʒ	æ	n	ə	g	ɪ	k	ə		
gledioror	**gled**iːəʊrə	g	l	e	d	iː	əʊ	r	ə		
garmelicker	gɑː**mel**ɪkə	g	ɑː	m	e	l	ɪ	k	ə		
hemitelter	**hem**ɪteltə	h	e	m	ɪ	t	e	l	t	ə	
igvilathen	ɪgvɪ**leɪ**θən	ɪ	g	v	ɪ	l	eɪ	θ	ə	n	
zabovatory	zə**bɒ**vətriː	z	ə	b	ɒ	v	ə	t	r	iː	

satarot	sætə**rəʊt**iː	s	æ	t	ə	r	əʊ	t	iː		
korgiseeter	kɔːgə**si**ːtə	k	ɔː	g	ə	s	iː	t	ə		
mopilation	mɒpɪ**leɪ**ʃən	m	ɒ	p	ɪ	l	eɪ	ʃ	ə	n	
dolsarella	dɒlsɪ**kel**ə	d	ɒ	l	s	ɪ	k	e	l	ə	
orelarny	ɒrə**lɑːn**iː	ɒ	r	ə	l	ɑː	n	iː			
derestrian	dɪ**res**triːən	d	ɪ	r	e	s	t	r	iː	ə	n
letassiun	lə**tæs**eɪən	l	ə	t	æ	s	eɪ	ə	n		
teliator	**te**liːeɪtə	t	e	l	iː	eɪ	t	ə			
cripocebar	kraɪ**pɒk**əbɑː	k	r	aɪ	p	ɒ	k	ə	b	ɑː	
felesuson	**fel**əsuːsən	f	e	l	ə	s	uː	s	ə	n	
shemuniker	ʃə**mʌn**ɪkə	ʃ	ə	m	ʌ	n	ɪ	k	ə		
kotermagon	**kɒt**ɜːmægən	k	ɒ	t	ɜː	m	æ	g	ə	n	

25. Appendix 25

Bigram count for words and non-words created to match for syllable detection tasks.

Words			Non-words			Diff
ɒ	t	2	ɒ	t	2	0
ɒ	m	2	ɒ	m	1	1
ɒ	p	2	ɒ	p	1	1
ɒ	k	2	ɒ	k	1	1
ɒ	r	2	ɒ	r	1	1
ɒ	s	2	ɒ	s	1	1
ɒ	ʃ	0	ɒ	ʃ	1	-1
ɒ	n	2	ɒ	n	1	1
ɒ	d	1	ɒ	d	0	1
ɒ	v	0	ɒ	v	1	-1
ɒ	l	1	ɒ	l	2	-1
ɑː	l	0	ɑː	l	2	-2
ɑː	m	2	ɑː	m	1	1
ɑː	s	1	ɑː	s	0	1
ɑː	g	1	ɑː	g	0	1
ɑː	d	1	ɑː	d	2	-1
ɑː	t	2	ɑː	t	2	0
ɑː	n	1	ɑː	n	2	-1
ɑː	r	0	ɑː	r	1	-1
æ	l	4	æ	l	4	0
æ	k	4	æ	k	3	1
æ	r	3	æ	r	2	1
æ	s	2	æ	s	3	-1
æ	m	2	æ	m	0	2
æ	b	1	æ	b	0	1
æ	d	1	æ	d	0	1
æ	p	1	æ	p	1	0

æ	v	1	æ	v	1	0
æ	g	2	æ	g	1	1
æ	ŋ	2	æ	ŋ	1	1
æ	n	2	æ	n	4	-2
æ	f	0	æ	f	1	-1
æ	ʃ	0	æ	ʃ	1	-1
æ	t	1	æ	t	3	-2
aɪ	z	1	aɪ	z	0	1
aɪ	ə	2	aɪ	ə	1	1
aɪ	v	1	aɪ	v	1	0
aɪ	n	2	aɪ	n	1	1
aɪ	p	1	aɪ	p	1	0
aɪ	r	0	aɪ	r	1	1
aɪ	k	1	aɪ	k	2	-1
aɪ	əʊ	0	aɪ	əʊ	1	-1
aɪ	s	0	aɪ	s	1	-1
aʊ	ə	1	aʊ	ə	0	1
aʊ	d	0	aʊ	d	1	-1
aʊ	k	0	aʊ	k	1	-1
b	ə	3	b	ə	3	0
b	ɒ	2	b	ɒ	1	1
b	æ	2	b	æ	1	1
b	ʌ	1	b	ʌ	0	1
b	ɪ	1	b	ɪ	1	0
b	aɪ	1	b	aɪ	1	0
b	l	0	b	l	1	-1
b	r	2	b	r	0	2
b	e	1	b	e	4	-3
b	ɑː	0	b	ɑː	1	-1
b	d	0	b	d	1	-1

b	ɜː	0	b	ɜː	1	-1
b	ɔː	0	b	ɔː	1	-1
ɔː	n	2	ɔː	n	1	1
ɔː	b	1	ɔː	b	0	1
ɔː	d	1	ɔː	d	0	1
ɔː	g	0	ɔː	g	1	-1
ɔː	t	1	ɔː	t	1	0
ɔː	ə	0	ɔː	ə	1	-1
ɔː	k	0	ɔː	k	1	-1
d	ɪ	3	d	ɪ	1	2
d	əʊ	1	d	əʊ	1	0
d	e	1	d	e	0	1
d	ɒ	1	d	ɒ	2	-1
d	ə	1	d	ə	0	1
d	r	1	d	r	1	0
d	ʌ	0	d	ʌ	1	-1
d	iː	2	d	iː	3	-1
dʒ	æ	1	dʒ	æ	1	0
dʒ	e	1	dʒ	e	0	1
e	l	11	e	l	11	0
e	t	3	e	t	2	1
e	r	1	e	r	2	-1
e	θ	1	e	θ	0	1
e	s	2	e	s	3	-1
e	d	1	e	d	1	0
e	ŋ	1	e	ŋ	1	0
e	k	1	e	k	2	-1
e	n	3	e	n	3	0
e	tʃ	0	e	tʃ	1	-1
e	m	1	e	m	4	-3

ə	r	10	ə	r	9	1
ə	n	12	ə	n	11	1
ə	l	15	ə	l	17	-2
ə	t	6	ə	t	6	0
ə	s	8	ə	s	8	0
ə	k	4	ə	k	3	1
ə	p	4	ə	p	3	1
ə	m	5	ə	m	4	1
ə	z	2	ə	z	1	1
ə	f	3	ə	f	4	-1
ə	g	1	ə	g	1	0
ə	v	1	ə	v	0	1
ə	b	2	ə	b	3	-1
ə	d	0	ə	d	1	-1
ɜː	t	1	ɜː	t	1	0
ɜː	f	0	ɜː	f	1	-1
ɜː	m	0	ɜː	m	1	-1
ɜː	g	0	ɜː	g	1	-1
ɜː	p	0	ɜː	p	1	-1
eə	r	1	eə	r	0	1
eɪ	t	7	eɪ	t	8	-1
eɪ	k	1	eɪ	k	0	1
eɪ	d	1	eɪ	d	0	1
eɪ	n	2	eɪ	n	2	0
eɪ	s	1	eɪ	s	0	1
eɪ	ʃ	2	eɪ	ʃ	1	1
eɪ	b	0	eɪ	b	1	-1
eɪ	ə	0	eɪ	ə	1	-1
eɪ	θ	0	eɪ	θ	1	-1
əʊ	ə	0	əʊ	ə	0	0

əʊ	p	2	əʊ	p	1	1
əʊ	n	2	əʊ	n	0	2
əʊ	z	1	əʊ	z	0	1
əʊ	k	1	əʊ	k	0	1
əʊ	m	1	əʊ	m	1	0
əʊ	r	0	əʊ	r	1	-1
əʊ	t	1	əʊ	t	3	-2
əʊ	tʃ	0	əʊ	tʃ	1	-1
f	ɪ	1	f	ɪ	1	0
f	l	2	f	l	0	2
f	əʊ	1	f	əʊ	0	1
f	æ	0	f	æ	1	-1
f	ʌ	1	f	ʌ	1	0
f	ɜː	1	f	ɜː	1	0
f	iː	1	f	iː	2	-1
f	ə	2	f	ə	1	1
f	ɑː	0	f	ɑː	1	-1
f	eɪ	0	f	eɪ	1	-1
f	e	0	f	e	2	-2
f	r	0	f	r	1	-1
g	ə	6	g	ə	4	2
g	e	0	g	e	2	-2
g	l	2	g	l	1	1
g	j	1	g	j	1	0
g	ɪ	1	g	ɪ	1	0
g	r	1	g	r	1	0
g	eɪ	1	g	eɪ	0	1
g	ɑː	1	g	ɑː	1	0
g	w	1	g	w	0	1
g	v	0	g	v	1	-1

g	æ	0	g	æ	2	-2
g	s	0	g	s	1	-1
h	æ	2	h	æ	1	1
h	ɒ	1	h	ɒ	0	1
h	ɑː	1	h	ɑː	0	1
h	e	1	h	e	1	0
ɪ	k	6	ɪ	k	6	0
ɪ	g	4	ɪ	g	2	2
ɪ	t	7	ɪ	t	7	0
ɪ	n	5	ɪ	n	5	0
ɪ	l	4	ɪ	l	4	0
ɪ	f	1	ɪ	f	0	1
ɪ	d	2	ɪ	d	1	1
ɪ	s	2	ɪ	s	1	1
ɪ	ə	1	ɪ	ə	0	1
ɪ	eɪ	1	ɪ	eɪ	0	1
ɪ	tʃ	1	ɪ	tʃ	0	1
ɪ	f	1	ɪ	f	1	0
ɪ	r	1	ɪ	r	1	0
ɪ	z	1	ɪ	z	0	1
ɪ	ʃ	1	ɪ	ʃ	0	1
ɪ	ʒ	1	ɪ	ʒ	0	1
ɪ	v	1	ɪ	v	0	1
ɪ	p	0	ɪ	p	1	-1
ɪ	b	0	ɪ	b	1	-1
iː	ə	3	iː	ə	3	0
iː	n	3	iː	n	3	0
iː	eɪ	1	iː	eɪ	1	0
iː	əʊ	0	iː	əʊ	1	-1
iː	eə	0	iː	eə	0	0

iː	g	0	iː	g	1	-1
iː	l	1	iː	l	0	1
iː	t	1	iː	t	1	0
iː	s	0	iː	s	1	-1
iː	b	0	iː	b	1	-1
iː	z	0	iː	z	1	-1
iː	v	0	iː	v	1	-1
ɪə	r	1	ɪə	r	1	0
j	ʊ	3	j	ʊ	3	0
j	uː	1	j	uː	1	0
k	æ	7	k	æ	7	0
k	ə	7	k	ə	9	-2
k	ɔː	3	k	ɔː	2	1
k	eɪ	3	k	eɪ	2	1
k	t	4	k	t	3	1
k	j	2	k	j	1	1
k	ɒ	1	k	ɒ	1	0
k	ɑː	1	k	ɑː	1	0
k	aɪ	0	k	aɪ	1	-1
k	əʊ	1	k	əʊ	0	1
k	ɪ	1	k	ɪ	2	-1
k	e	1	k	e	3	-2
k	l	0	k	l	1	-1
k	r	1	k	r	1	0
k	ʌ	1	k	ʌ	1	0
k	ʃ	1	k	ʃ	0	1
k	iː	1	k	iː	2	-1
l	ɪ	8	l	ɪ	7	1
l	ə	10	l	ə	10	0
l	eɪ	2	l	eɪ	4	-2

l	aɪ	3	l	aɪ	3	0
l	uː	2	l	uː	1	1
l	ɒ	1	l	ɒ	0	1
l	ɑː	0	l	ɑː	1	-1
l	æ	1	l	æ	1	0
l	k	2	l	k	2	0
l	e	1	l	e	2	-1
l	əʊ	1	l	əʊ	0	1
l	s	0	l	s	1	-1
l	ʃ	0	l	ʃ	1	-1
l	tʃ	1	l	tʃ	1	0
l	aʊ	1	l	aʊ	0	1
l	iː	1	l	iː	2	-1
l	ɔː	0	l	ɔː	1	-1
l	ɜː	0	l	ɜː	1	-1
l	t	1	l	t	2	-1
m	ʌ	3	m	ʌ	1	2
m	ɒ	3	m	ɒ	2	1
m	æ	3	m	æ	1	2
m	e	2	m	e	2	0
m	ɪ	4	m	ɪ	3	1
m	əʊ	1	m	əʊ	0	1
m	ɑː	2	m	ɑː	1	1
m	iː	1	m	iː	0	1
m	b	1	m	b	1	0
m	p	1	m	p	0	1
m	ə	2	m	ə	4	-2
m	uː	0	m	uː	2	-2
n	ɔː	0	n	ɔː	1	-1
n	ə	4	n	ə	5	-1

n	əʊ	3	n	əʊ	2	1
n	ɒ	2	n	ɒ	1	1
n	ɪ	2	n	ɪ	1	1
n	d	1	n	d	0	1
n	ɑː	1	n	ɑː	0	1
n	uː	1	n	uː	0	1
n	r	1	n	r	0	1
n	v	2	n	v	0	2
n	iː	1	n	iː	3	-2
n	t	1	n	t	2	-1
n	æ	1	n	æ	1	0
n	k	0	n	k	2	-2
n	l	0	n	l	1	-1
n	s	1	n	s	3	-2
n	ʃ	0	n	ʃ	1	-1
ŋ	ə	1	ŋ	ə	0	1
ŋ	g	2	ŋ	g	2	0
ŋ	k	1	ŋ	k	0	1
p	ə	6	p	ə	7	-1
p	e	3	p	e	2	1
p	æ	2	p	æ	0	2
p	ɪ	3	p	ɪ	2	1
p	ɒ	2	p	ɒ	2	0
p	l	1	p	l	0	1
p	r	1	p	r	0	1
p	t	1	p	t	1	0
p	aɪ	1	p	aɪ	1	0
p	aʊ	0	p	aʊ	1	-1
r	iː	9	r	iː	9	0
r	e	5	r	e	3	2

r	ə	6	r	ə	5	1
r	uː	3	r	uː	1	2
r	æ	1	r	æ	1	0
r	aɪ	3	r	aɪ	2	1
r	ɪ	3	r	ɪ	3	0
r	ʊ	1	r	ʊ	0	1
r	eɪ	2	r	eɪ	3	-1
r	əʊ	2	r	əʊ	3	-1
r	ɑː	1	r	ɑː	3	-2
r	ɔː	1	r	ɔː	0	1
r	ʌ	1	r	ʌ	1	0
r	aʊ	0	r	aʊ	1	-1
r	ɒ	0	r	ɒ	2	-2
s	ə	7	s	ə	6	1
s	eɪ	0	s	eɪ	1	-1
s	t	4	s	t	4	0
s	iː	0	s	iː	1	-1
s	ɪ	3	s	ɪ	2	1
s	k	3	s	k	1	2
s	e	2	s	e	2	0
s	h	1	s	h	0	1
s	n	1	s	n	1	0
s	ʌ	0	s	ʌ	1	-1
s	p	1	s	p	1	0
s	ɑː	0	s	ɑː	1	-1
s	æ	0	s	æ	2	-2
s	f	0	s	f	1	-1
s	uː	1	s	uː	3	-2
s	ɜː	0	s	ɜː	1	-1
s	m	0	s	m	1	-1

s	l	0	s	l	1	-1
ʃ	æ	0	ʃ	æ	1	-1
ʃ	ə	5	ʃ	ə	5	0
ʃ	r	1	ʃ	r	0	1
ʃ	t	0	ʃ	t	1	-1
t	ə	18	t	ə	20	-2
t	r	8	t	r	10	-2
t	ɪ	3	t	ɪ	1	2
t	e	3	t	e	2	1
t	əʊ	2	t	əʊ	0	2
t	s	2	t	s	1	1
t	ɑː	1	t	ɑː	2	-1
t	eɪ	2	t	eɪ	0	2
t	æ	1	t	æ	1	0
t	k	1	t	k	0	1
t	j	0	t	j	1	-1
t	ɪə	1	t	ɪə	1	0
t	iː	0	t	iː	2	-2
t	uː	1	t	uː	2	-1
t	ɜː	0	t	ɜː	1	-1
t	ɔː	0	t	ɔː	1	-1
t	ʌ	0	t	ʌ	2	-2
tʃ	əʊ	1	tʃ	əʊ	0	1
tʃ	eə	1	tʃ	eə	1	0
tʃ	iː	0	tʃ	iː	1	-1
tʃ	r	0	tʃ	r	1	-1
tʃ	ə	0	tʃ	ə	1	-1
tʃ	ɪ	0	tʃ	ɪ	1	-1
ʊ	l	2	ʊ	l	1	1
ʊ	s	1	ʊ	s	0	1

ʊ	z	0	ʊ	z	1	-1
ʊ	ə	1	ʊ	ə	1	0
uː	d	1	uː	d	0	1
uː	t	1	uː	t	0	1
uː	θ	1	uː	θ	0	1
uː	m	1	uː	m	1	0
uː	n	2	uː	n	3	-1
uː	l	0	uː	l	1	-1
uː	r	0	uː	r	1	-1
uː	s	0	uː	s	1	-1
v	ə	3	v	ə	3	0
v	æ	1	v	æ	0	1
v	eɪ	1	v	eɪ	0	1
v	aɪ	1	v	aɪ	0	1
v	ɒ	1	v	ɒ	0	1
v	ɪ	2	v	ɪ	1	1
ʌ	m	2	ʌ	m	1	1
ʌ	t	1	ʌ	t	0	1
ʌ	ŋ	1	ʌ	ŋ	0	1
ʌ	z	1	ʌ	z	1	0
ʌ	ʃ	2	ʌ	ʃ	2	0
ʌ	n	1	ʌ	n	2	-1
ʌ	s	0	ʌ	s	2	-2
ʌ	k	0	ʌ	k	1	-1
w	ɪ	2	w	ɪ	0	2
w	iː	1	w	iː	0	1
w	ɔː	1	w	ɔː	0	1
z	ə	3	z	ə	3	0
z	iː	1	z	iː	0	1
ʒ	ə	1	ʒ	ə	0	1

θ	ə	2	θ	ə	1	1
θ	b	1	θ	b	0	1
Total		**582**			**582**	

26. Appendix 26

Breakdown of factors within each predictor for Snodgrass words used in RWPM, SPN and SR tasks

Predictors		Number of cases	Percent
Syllables	1	5246	54.00%
	2	3225	33.20%
	3	946	9.70%
	4	301	3.10%
No. of phonemes in the target word	1	86	0.90%
	2	731	7.50%
	3	2838	29.20%
	4	2150	22.10%
	5	1892	19.50%
	6	817	8.40%
	7	774	8.00%
	8	172	1.80%
	9	258	2.70%
Position of stress (single syllable 0, initial stress 1, stress on second syllable 2, final stress 3)	0	5160	53.10%
	1	3913	40.30%
	2	344	3.50%
	3	301	3.10%
Target present (No = 0, Yes = 1)	0	5289	54.40%
	1	4429	45.60%
location of traget (0 no target, 1 end of the first syllable, 2 within the word, 3 end of the word)	0	5289	54.40%
	1	1032	10.60%
	2	1462	15.00%
	3	1935	19.90%
Target sound	B	817	8.40%
	D	817	8.40%
	F	817	8.40%
	K	817	8.40%
	L	817	8.40%
	M	817	8.40%
	N	774	8.00%
	P	817	8.40%
	R	817	8.40%
	S	817	8.40%
	SH	817	8.40%
	T	774	8.00%

27. Appendix 27

Syntax used for the generalised estimating equation (GEE) used to analyse the accuracy data in the RWPM, PMSR, SPN tasks.

```
* Generalized Estimating Equations.
GENLIN Correct (REFERENCE=LAST) BY Targetsound No.ofphonemes
   locationoftraget0notarget1endofthefirstsyllable2withintheword3en (ORDER=ASCENDING)
  /MODEL Targetsound No.ofphonemes
locationoftraget0notarget1endofthefirstsyllable2withintheword3en
   Targetsound*No.ofphonemes Targetsound*
   locationoftraget0notarget1endofthefirstsyllable2withintheword3en
   No.ofphonemes*locationoftraget0notarget1endofthefirstsyllable2withintheword3en
INTERCEPT=YES
 DISTRIBUTION=BINOMIAL LINK=LOGIT
  /CRITERIA METHOD=FISHER(1) SCALE=1 MAXITERATIONS=100 MAXSTEPHALVING=5
PCONVERGE=1E-006(ABSOLUTE)
   SINGULAR=1E-012 ANALYSISTYPE=3(WALD) CILEVEL=95 LIKELIHOOD=FULL
  /EMMEANS SCALE=ORIGINAL
  /REPEATED SUBJECT=Participant SORT=YES CORRTYPE=INDEPENDENT ADJUSTCORR=YES
COVB=ROBUST
   MAXITERATIONS=100 PCONVERGE=1e-006(ABSOLUTE) UPDATECORR=1
  /MISSING CLASSMISSING=EXCLUDE
  /PRINT CPS DESCRIPTIVES MODELINFO FIT SUMMARY SOLUTION (EXPONENTIATED)
WORKINGCORR.
```

28. Appendix 28

Syntax used for the generalised estimating equation (GEE) used to analyse the RT data in the PMSR and SPN tasks.

```
* Generalized Estimating Equations.
GENLIN Reactiontime BY Targetsound Tragetpresent
    Positionofstresssinglesyllable0initialstress1secondarystress2fin (ORDER=ASCENDING)
  /MODEL Targetsound Tragetpresent Positionofstresssinglesyllable0initialstress1secondarystress2fin
    INTERCEPT=YES
 DISTRIBUTION=NORMAL LINK=IDENTITY
  /CRITERIA SCALE=MLE PCONVERGE=1E-006(ABSOLUTE) SINGULAR=1E-012 ANALYSISTYPE=3(WALD)
CILEVEL=95
    LIKELIHOOD=FULL
  /REPEATED SUBJECT=Participant SORT=YES CORRTYPE=INDEPENDENT ADJUSTCORR=YES
COVB=ROBUST
  /MISSING CLASSMISSING=EXCLUDE
  /PRINT CPS DESCRIPTIVES MODELINFO FIT SUMMARY SOLUTION.
```