

Working Memory Deficits in Individuals with Down Syndrome: The Role of the Phonological Loop

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What is Down Syndrome (DS)?

Cause:

Down Syndrome is caused by the trisomy of the twenty-first chromosome. It is the most common cause of intellectual impairment and occurs in 1/750-800 live births in the United States (Cleland, Wood, Hardcastle, Wishart & Timmins, 2010).

Characteristics:

- Approximately 85% of individuals with DS have a mild to moderate cognitive impairment (Cleland et al., 2010, p. 84).
- Roizen (1997) found that hearing loss is prevalent among individuals with DS (as cited in Cleland et al., 2010, p. 84).
- Miller & Leddy suggest that individuals with DS have difficulty making precise articulatory movements due to (as cited in Cleland et al., 2010, p. 84):
 - A small oral cavity
 - Hypotonia (less tension) of muscles surrounding the mouth
 - Fusion of lip muscles
- Expressive language deficits are commonly found and are typically more impaired than receptive language abilities (Lanfranchi, Jerman, Dal Pont, Alberti & Vianello, 2010, p. 309).
- Relatively intact visual and spatial abilities in comparison to the individuals cognitive functioning (Baddeley & Jarrold, 2007, p. 928; Lanfranchi et al., 2010, p. 309).
- Impaired phonological loop function is found in individual's with DS (Baddeley & Jarrold, 2007, p. 928). The phonological loop is commonly referred to as verbal working memory.
- Broad executive functioning impairments are found in individuals with DS (Lanfranchi et al., 2010, p. 308).

What is Working Memory (WM)?

Baddeley and Hitch (1974) established the first three-part model which describes the system responsible for the manipulation of incoming sensory information (as cited in Baddeley & Jarrold, 2007, p. 925). This model includes the central executive, phonological loop and visuospatial sketchpad as depicted in figure 1.

Central Executive

- This component is responsible for directing attention to the two sub-systems and has very limited capacity (Baddeley & Jarrold, 2007, p. 925).
- Miyake et al. (2000) hypothesized that this component is responsible for connecting working memory and inhibition as well as shifting and planning (as cited in Lanfranchi et al., 2010, p. 309).

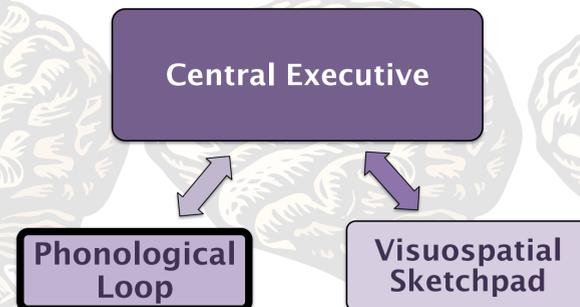
Phonological Loop

- This sub-component is responsible for storing incoming verbal information for a brief period of time. If this material is not rehearsed within a few seconds, it will decay rapidly (Baddeley & Jarrold, 2007, p. 925).
- Baddeley et al. (1998) hypothesized that over time the phonological loop has become an essential component for learning language (Baddeley & Jarrold, 2007, p. 926).

Visuospatial Sketchpad

- This sub-component is essential for controlling incoming visual and spatial information (Baddeley & Jarrold, 2007, p. 926).

Figure 1: Baddeley's Working Memory Model



What are Possible Causes of Phonological Loop Impairments in Individuals with DS?

1. Executive Dysfunction

1. There has been controversy whether **executive deficits** cause working memory impairments or that executive deficits are associated with individuals who have cognitive impairments caused by genetic disorders (Baddeley & Jarrold, 2007, p. 928).
 - A study has been conducted using participants with DS as compared to their typically developing (TD) peers. Tests were administered to both of the groups and measured different components of executive functioning (Lanfranchi et al., 2010, p. 308).
 - The results indicate that the individuals with DS performed significantly lower than the TD matched group in many areas including: planning, shifting between concepts and verbal WM (Lanfranchi et al., 2010, p. 316). Researchers also found that during the sustained attention task the individuals with DS were able to complete the same amount of tasks. However, the individuals with DS made more errors and showed limited to no strategy skills when solving the task (Lanfranchi et al., 2010, p. 308).
 - No conclusions have been reached that indicate executive dysfunction is the cause of WM deficits in individuals with DS.

2. Acoustic Difficulties & Inability to Rehearse

2. Evidence implies that the phonological loop of individuals with DS can not be explained by **acoustic difficulties or inability to rehearse sound-based information** (Baddeley & Jarrold, 2007, p. 929).
 - Most studies require that participants with DS have adequate hearing, therefore this would eliminate the decreased hearing ability as a causal factor.
 - In addition, TD children matched to DS individuals do not engage in the rehearsal of incoming information either (Lanfranchi et al., 2009, p. 410). However, the individuals with DS still performed lower on verbal working memory tasks.
 - Researchers have hypothesized that these difficulties are linked to a **decreased phonological capacity** (Lanfranchi et al., 2009, p. 410).

3. Inhibition

3. Recent evidence has found a link between inhibition and WM.
 - **Inhibition** is the ability to suppress or ignore information that is no longer relevant (Borella, Carretti, Lanfranchi, 2013, p. 66).
 - Researchers have hypothesized that individuals with DS have an "inefficient inhibitory mechanism," and as a result, information that is usually suppressed or forgotten stays within their WM (Borella et al., 2013, p. 70). In turn, this causes a limited WM capacity, because there is information present in their memory that is not pertinent to the current situation they are in (Borella et al., 2013, p. 70).

Implications for Future Research

- Researchers, Brock and Jarrold (2005) concluded that further research needs to be performed to determine whether the phonological loop in individuals with DS has a smaller capacity or the rate at which the information decays is quicker (as cited in Lanfranchi, 2009, p. 410).
- Individuals with DS and other chromosomal syndromes need to be further investigated in order to determine whether executive functioning is related to overall intellectual ability or some component of their genetic disorder syndrome (Lanfranchi et al., 2010, p. 316-317).
- Inhibition needs to be further researched to determine whether inhibition impacts solely verbal WM or other aspects of the WM model (Borella et al., 2013, p. 70).

References

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What Tests Assess Verbal WM in Individuals with DS?

Word span task: requires participants to recall words directly after they are presented in list form. The length of the list increases from two words to five (Lanfranchi et al., 2009, p. 404).

Non-word span: task requires the individual to remember non-words after they are presented in list form.

Selective span task: requires the individual to remember the first word in a series of lists. Each level of the task increases in difficulty depending on the amount of lists to remember and their length (Lanfranchi et al., 2009, p. 404).

Verbal double task: requires the individual to remember the first word in a list along with tapping the table when a target word is said (Lanfranchi et al., 2009, p. 404).

Digit span task: requires individuals to remember a sequence of numbers in the correct order they were presented (Byrne, MacDonald, & Buckley, 2002, p. 522)

What Effects do Phonological Impairments have on Individuals with DS ?

Difficulties retaining incoming acoustic and phonological information

Decreased reading performance especially longer sentences and paragraphs (Byrne et al., 2002, p. 527).

Baddeley et al. (1988) concluded that phonological impairments cause individuals to have difficulty learning new vocabulary words (as cited in Baddeley & Jarrold, 2007, p. 926).

Difficulties performing verbal tasks that require using the same modality (Lanfranchi, 2012, p. 163).