2013

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

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What is Down Syndrome (DS)?

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 (Clendaniel, Wood, Hardcastle, Wishart & Timmins, 2010).

Characteristics:
- Approximately 85% of individuals with DS have a mild to moderate cognitive impairment (Clendaniel et al., 2010, p. 84).
- Rosenier (1997) found that hearing loss is prevalent among individuals with DS (as cited in Clendaniel et al., 2010, p. 84).
- Miller & Ledyard suggest that individuals with DS have difficulty making precise articular movements due to (as cited in Clendaniel 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 impairing than receptive language abilities (Lanfranchi, Jeronimo, Dal Pont, Alberti & Vianello, 2009, p. 309).

What is Working Memory (WM)?

Baddeley and Hitch (1974) established the first three-part model which describes the system responsible for manipulating and storing information (as cited in Baddeley & Jarrold, 2007, p. 926). 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 a 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 visual and spatial information for a brief period of time. If this material is not rehearsed, it will decay rapidly (Baddeley & Jarrold, 2007, p. 925).
- Baddeley et al. (1988) concluded that the phonological loop has become an essential component for learning language (Baddeley & Jarrold, 2007, p. 926).

Visuospatial Sketchpad
- This sub-component is responsible for controlling incoming visual and spatial information (Baddeley & Jarrold, 2007, p. 926).
- Impaired phonological loop function is found in individuals with DS (Baddeley & Jarrold, 2007, p. 928).
- The phonological loop is commonly referred to as verbal working memory.

Brain structures required for verbal WM in DS:
- Broad executive functioning impairments are found in individuals with DS (Lanfranchi et al., 2010, p. 308).

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

1. Executive Dysfunction
   - There has been controversy whether executive dysfunction causes the working memory impairments or that executive dysfunction is associated with individuals who have cognitive impairments caused by genetic disorders (Baddeley & Jarrold, 2007, p. 925).
   - 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. 310).
   - Researchers also found that during the planning task, the individuals with DS were able to complete the same amount of tasks. However, the individuals with DS made more errors and needed twice as many attempts to solve 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
   - Evidence implies that the phonological loop of individuals with DS cannot be explained by acoustic difficulties or inability to rehearse (Baddeley & Jarrold, 2007, p. 929).
   - Studies that examine 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., 2010, p. 410). However, the individuals with DS still performed lower on verbal working memory tasks.
   - Researchers have hypothesized that the difficulty may be attributed to decreased phonological capacity (Lanfranchi et al., 2009, p. 410).

3. Inhibition
   - Recent evidence has found a relationship between inhibition and WM.
   - Inhibition is the ability to suppress or ignore information that is no longer relevant (Borella et al., Lanfranchi, 2013, p. 60).
   - Researchers have hypothesized that inhibition dysfunction in DS has an “inefficient inhibitory mechanism,” and as a result, information that is usually suppressed or forgotten within their WM (Borella et al., 2013, p. 70).
   - In turn, this could lead to a limited WM capacity, because there is information present in their working memory that is not pertinent to the current situation they are in (Borella et al., 2013, p. 70).

What Effects do Phonological Loop Impairments have on Individuals with DS?

Difficulties retaining incoming acoustic and phonological information

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

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

Reduced performance verifying that task requires using the same modality (Lanfranchi, 2012, p. 163).

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 et al., 2009, p. 410).
- Individuals with DS and other chromosomal syndromes need to be further investigated in order to determine which other executive functioning is related to overall intellectual ability or specific deficits in 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).