

**Meta-analysis of Working Memory and Implicit
Memory Studies in
Populations with Intellectual Disability:
Nonspecific Etiology, Down Syndrome and
Williams Syndrome, in Comparison with
Typically Developing**

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Abstract

Divided into two parts, the meta-analysis in this study examined memory studies among populations with intellectual disabilities. While the first, deals with a meta-analysis of Working Memory (WM) the other investigates the Implicit Memory system (IM). The study population consisted of three groups of subjects, all of whom with intellectual disability (ID): participants with a Non-specific etiology, Down Syndrome or Williams' Syndrome.

In many research fields, particularly social research, it is necessary to organize a vast amount of accumulated data, all the while attempting to provide an explanation of the results, and clarify the contradictions that are sometimes obtained from similar studies. Thus, there is a great importance in compiling the various studies and drawing aggregate conclusions (Hunter & Schmidt, 2000). Meta-analysis was developed as a possible solution for this problem. It is a statistical method that integrates the findings of independent studies that share the same conceptual assumption, or processes to achieve common research goals (Borenstein, Hedges, Higgins, & Rothstein, 2009; Cooper & Rosenthal, 1980). Meta-analysis, unlike a literature review, can "review" the findings available through quantitative statistical analysis, and provide statistical dimensions to the research questions (Borenstein *et al.*, 2009, 2011; Ellis, 2010; Hunter, Schmidt, & Jackson, 1982).

This study's primary purpose was to examine any differences in both the working memory (WM) and implicit memory (IM) functioning, between those individuals with an intellectual disability (ID), and those with typical development (TD). With this main goal, the following main questions were examined:

Question 1: Do demographic variables of subjects (Age and Etiology), and task variables (Memory components, Type of task, Level of control, and Modality), comprise moderators that may explain the differences between results of studies on WM and IM among populations with intellectual disabilities?

Question 2: Are there differences in the effect sizes of memory functioning between population with intellectual disabilities as compared to those with typical development, between and within the various system components?

The database of the meta-analysis included studies from the 1990's, as a consequence of the enhanced interest during this period in the research of various etiologies of mental disabilities derived from a conceptual approach that considered intellectual disability as a separate cognitive profile that can be described in a qualitative and quantitative manner. In addition, the 1990's saw significant change in the terminology and general knowledge pertaining to the field of short-term and long-term memory. Short-term memory was incorporated into a multi-component framework (Conceptualized as Working Memory) that enables simultaneous information storage and processing. Long-term memory has been found constructed from subsystems (explicit and implicit memory) as part of the process utilized for direct and conscious learning and information retention and for subconscious memory and recall skills and processes, respectively.

The combination of changes and accumulated knowledge in both these areas, led to a large number of cognitive studies including those pertaining to memory, providing mixed and even contradictory results

concerning various memory functioning in populations with intellectual disabilities (Schuchardt, Gebhardt, & Mäehler, 2010; Van der Molen, Van Luit, Jongmans, & Van der Molen, 2009). Hence, the present study was conducted utilizing a meta-analysis method in order to achieve generalized conclusions concerning working memory and implicit memory functioning in population with intellectual disabilities, including identification of specific developmental processes involved in creating a cognitive profile of different groups with intellectual disabilities.

A previous meta-analysis conducted by the author of this current study (Shtain, 2009; Lifshitz, Shtain, Weiss, Vakil, & 2011), focused solely on explicit memory functioning, that is only a single component of the memory system, among populations with intellectual disabilities. The present study sought to expand the scope and therefore focused on conducting a meta-analysis of studies that examined working memory (WM) and implicit memory (IM), in three different populations with intellectual disabilities (NSE, DS, WS), compared to subjects with typical development (TD). The review of pertinent literature has shown, to the best of our knowledge, that this is the first meta-analysis that focuses on working memory and implicit memory functioning in people with intellectual disabilities, while observing the differences between and within the different memory systems.

The process for constructing a database for each of the two meta-analyses (working memory and implicit memory) began by locating appropriate studies conducted between 1990 - 2012, according to content and statistical inclusion criteria. The present meta-analysis pertaining to working memory consists of 60 articles that included 72 different studies. The meta-analysis concerning implicit memory consists of 18 articles, including 22 different studies.

The meta-analytical procedure for the research and all its cross-sections used a designated statistical software "Comprehensive Meta-Analysis" (Borenstein *et al.*, 2005), and consisted of four main stages. 1. Calculating weighted effect size (d), based on the random effects model, along with a 95% confidence interval height and statistical significance (p). 2. Calculating homogeneous statistics (Q), including its size (I^2) and its distribution (Tau). 3. A 'Categories' model which yielded two results: within-classification effect (Q_w) and between-classification effect (Q_b). 4. Examination of a given variable as a moderator.

We now present the following **research questions, hypotheses and findings**, separately for each of the individual memory systems.

Working Memory System – Operational Questions

Memory studies that were conducted amongst populations with the aforementioned intellectual disabilities and, accordingly, the current meta-analysis, were based largely upon the Baddeley's model of components (Baddeley, 2000a, 2000b, 2003) that includes a Central Executive, assisted by two secondary 'slave system storage units: phonological loop and Visuo Spatial Sketchpad. Moreover, the current meta-analysis examined the studies conducted according the Cornoldi's Continuum Model (Cornoldi, Carretti, & De Beni, 2001; Cornoldi, Rigoni, Venneri, & Vecchi, 2000; Cornoldi & Vecchi, 2003) that examines variables related to task control level and modality. According to this model, working memory tasks are to be tested by referring to two dimensions; the **horizontal dimension** as

related to task modality, and the **vertical** one as reflecting the level of control required for task performance in linkage to its demands.

A. A General Question Pertaining to Working Memory:

Does the effect size with respect to working memory functioning would indicate differences between populations with intellectual disabilities and with typical development?

Hypothesis: Effect size would indicate a large difference between groups, leaning in favor towards the typical development population. This hypothesis was assumed since various studies found a link between working memory functioning and intelligence indices (Gathercole, 1999; Gathercole *et al.*, 2004, 2006; Yuan *et al.*, 2006). In addition, 60% of the studies in the current meta-analysis found that performance of a variety of working memory tasks is lower among the population with intellectual disabilities, as compared to those with typical development.

Results: The results of this meta-analysis showed that effect size ($d = 0.92$) and confidence interval (LCI =0.76; UCI=1.10) indicated large differences between the groups. Therefore, the research hypothesis was confirmed. WM functions among the intellectual disabilities population were significantly impaired in comparison to those with typical development. However, the homogeneity test (Q) showed a large heterogeneity between studies; indicating they do not share similar results. Hence, in order to reach homogeneity between the studies, and identify moderators that may explain the inconsistency among studies; studies were classified according to several variables.

B. Operational Questions Related to Potentially Demographic Moderators:

Question 1: Are there differences in effect sizes of working memory functioning amongst the intellectual disability population as compared to the typical development population according to the age variable (MA, CA)?

Hypothesis: Differences in effect sizes between groups according to Mental and Chronological age would be found. This is based upon studies that found an influence of chronological age on various memory functioning (Kemper *et al.*, 2010; Lifshitz *et al.*, 2011; Shtain, 2009).

Results: Results of the meta-analysis indicated there are significant differences between working memory functions amongst the intellectual disabilities population and typical development population, both when the comparison was made upon the basis of mental and chronological age criteria. However, the differences between working memory functioning compatible with mental age are **largely and significantly reduced** when compared with chronological age. Hence, the hypothesis was confirmed. However, given the large degree of heterogeneity between the studies in each category (CA, MA), the age variable was not found to be a moderator, namely, it cannot explain the differences between the studies.

Question 2: Are there differences in effect sizes of working memory functioning amongst the intellectual disabilities population as compared to the typical development population according to etiology (NSE, DS, WS)?

Hypothesis: In light of the different profiles of people with different syndromes (particularly between Williams Syndrome and Down Syndrome) (Breckenridge *et al.*, 2013; Carney, *et al.*, 2013; Kittler, *et al.*, 2008; Lanfranchi, *et al.*, 2002;; Vicari, & Carlesimo, 2006b), it was hypothesized that effect sizes differences would be found concerning working memory functioning between the intellectual disabilities population and those with typical development according to the variable etiology.

Results: The results of the meta-analysis indicated significant differences between mean effect sizes that refer to the working memory functioning of different groups with intellectual disabilities as compared to with those with typical development. In other words, there are different cognitive profiles concerning working memory according to different etiologies, even with similar levels of damage between etiologies. Therefore, the research hypothesis was confirmed. However, given the large degree of heterogeneity between the studies in each category (NSE, DS, WS), a variable etiology was not found as a moderator.

C. Operational Questions Pertaining to Task-Related Variables that may be Moderators:

Question 1: Are there differences between effect sizes in the functioning of population with intellectual disabilities as compared to that of the typical development population between working memory system components (Phonological Loop, Visuo Spatial-Sketchpad, Central Executive)?

Hypothesis: Many studies conducted on subjects with the various types of aforementioned disability syndromes used Baddeley's model (Baddeley, 2000a, 2000b, 2003) to demonstrate that impaired functioning of the memory maybe specific to a single component, while the functioning of other components remain intact (Gathercole & Alloway, 2006; Henry & Winfield, 2010; Martinussen *et al.*, 2005; Mosse & Jarrold, 2010; Purser & Jarrold, 2005; Trezisea *et al.*, 2014). Therefore, it was hypothesized that effect size would indicate differences in the working memory functioning of a population with intellectual disabilities as compared to those with typical development in various memory components.

Results: The results of the meta-analysis based upon components Baddeley's model of components (Baddeley, 2000a, 2000b, 2003), indicated significant differences between mean effect sizes, relative to functioning of the population with intellectual disabilities and as compared to those population with typical development with according to memory component variable. In addition, discernible heterogeneity in the performance pattern was found to exist between groups in various components of the working memory system. In addition, an examination of the interaction between etiology and task component variable contributed to the identification of the distinctive performance pattern of each group with intellectual disabilities.

Hence, the research hypothesis was confirmed. However, given the large degree of heterogeneity between the studies in each category (Phonological Loop, Visuo Spatial-Sketchpad, Central Executive) memory component variable is a moderator.

Question 2: Are there differences between effect sizes with regard to the functioning of the population with intellectual disabilities as compared to those with typical development within the components of the working memory system according to task type variable, control levels and modality?

Hypothesis: Based on various studies that found differences between subjects with intellectual disabilities and with typical development only in some of phonological loop and visuo-spatial sketchpad tasks (*e.g.*, Numminen *et al.* , 2002; Van der Molen *et al.*, 2009, 2010), it was hypothesized that a difference between the intellectual disabilities and typical development populations would be found in effect sizes **within** the components of the functioning of working memory system. Furthermore, it was hypothesized that these differences would be found concerning the Central Executive component, consistent with the working memory model proposed by Cornoldi (Cornoldi *et al.* 2000, 2001, 2003).

Results:

A. The results of the meta-analysis showed no differences between mean effect sizes relating to a type of task (Word span, Digit span, Non-word repetition task and General task) within the phonological loop component. The functioning of the population with intellectual disabilities was found to be significantly impaired in comparison to the typical development population in each one of the verbal categories. However, the results of the meta-analysis relating to Visuo Spatial-Sketchpad component indicated significant differences between mean effect sizes related to type of task (Visual task and Spatial task). In comparison to the typical development population (MA), the functioning of the intellectual disabilities population was relatively preserved in regards to visual tasks, whereas spatial tasks were found to be moderately impaired. Task type variable, too, was not found to be a moderator, both in regards to the phonological loop or the spatial component of the visuo-spatial sketchpad.

B. The results of the meta-analysis pertaining to task variables (control level and modality) in the Central Executive component found no differences between the mean effect sizes relating to level of control (Level 1, Level 2, Level 3). The functioning of the intellectual disabilities population was impaired compared to the typical development population in all three levels of control. Similarly, no differences were found between the mean effect sizes relating to modality (Verbal Task, Visuo-spatial Task and Dual Task). However, when examining the interaction between modality and mental age variables, the functioning of people with disabilities in visual-spatial task was found to be relatively preserved in comparison with the typical development population while the gap between groups in verbal tasks was reduced. Level of control and modality were not found to be moderators.

In conclusion, the distinctive pattern of performance enhanced the assumption that a working memory system consists of distinct parts, anatomically and functionally speaking, and therefore supports the Baddeley's model of components. This model was found useful in identifying a distinctive working memory profile among different groups with intellectual disabilities, especially between the phonological loop component and Visuo Spatial-Sketchpad. Additionally, an examination of the working memory functioning in the population with intellectual disabilities, in relation to the Cornoldi *et al* sequence model (2000, 2003), has provided evidence that the Central Executive component is not monolithic. On the one hand, the present study shows no proof that the difficulties of inherent in intellectual disability (NSE, DS) are increased by performing memory tasks according to the required level of control. On the other

hand, an evidence of the importance of dividing the Central Executive component, in relation to the variable modality was found.

In the current meta-analysis, none of the variables related to subjects or task were found to be moderators, and therefore cannot explain the inconsistency between the studies. Only the interaction between task-related and subjects-related variables significantly reduced the heterogeneity between studies and allowed observing differences between the groups (ID, TD).

Implicit-Memory System Operational Questions:

A. General question: Would the effect size of the implicit memory functioning indicate differences between the population with intellectual disabilities and those with typical development?

Hypothesis: As reflected in the present database, previous studies of implicit memory functions among populations with intellectual disabilities were influenced by the premise outlined by Reber (Reber, 1993; Reber *et al.*, 1991), that in contrast to explicit learning, implicit learning should reveal small changes as a function of individual differences in age and maturity, and it should be relatively unimpaired by neurological or psychological disorders. Accordingly, irrespective of variables of etiology, age, and type of task, it was hypothesized that effect size would indicate small differences in implicit memory functioning between the population with intellectual disabilities and those with typical development.

Results: The results of the meta-analysis (20 studies), showed that effect size ($d = 0.43$) and confidence interval (LCI = 0.25; UCI=0.62) indicated significant and moderate differences between the groups. Hence, the research hypothesis was not supported; implicit memory functioning amongst the population with intellectual disabilities was found moderately impaired relative to the population with typical development. In addition, a test of statistical heterogeneity (Q) showed a large heterogeneity between studies, indicating that they do not share similar results.

B. Operational Questions Related to Demographic, Potentially Moderating Variables:

Question 1: Are there differences in effect sizes of implicit memory functioning between the population with an intellectual disabilities as compared with those with typical development according to age variable (MA, CA)?

Hypothesis: In the absence of studies concerning the effect of the age variable on the functioning of implicit memory in population with an intellectual disability no hypothesis was assumed *a priori*, only a question was formulated.

Results: The results of the meta-analysis indicated there were no differences in the mean effect size according to the age variable. People with intellectual disabilities have moderate to significant gaps in implicit memory functioning, both in comparison to those with typical development matched according to chronological and in comparison to those matched according to mental age. Consequently, the age variable is not a moderator.

Question 2: Are there differences concerning the effect size of implicit memory functioning in the intellectual disability population as compared to those with typical development, according to etiology (NSE, DS, WS)?

Hypothesis: In light of studies that have described different capacities of implicit learning among individuals with Down syndrome and those with Williams Syndrome (Vicari *et al.*, 2000, 2001, 2007), it was hypothesized that in contrast to Reber's theory (1993), effect size would indicate differences in implicit memory functioning, between the different etiologies.

Results: The results of the meta-analysis indicated significant differences between the mean effect sizes relating to etiology. Effect size in regard to those with intellectual disabilities without a specific etiology, indicated preserved memory functioning in comparison to those with typical development, while the effect size of implicit memory functioning in those with Down and Williams syndromes indicated impaired functioning in comparison to the typical development population. It should be noted that this meta-analysis extends the evidence concerning patterns of cognitive functioning, which are qualitatively different, amongst the various etiologies, to the implicit memory domain. In other words, people with different etiologies do not share the same set of weaknesses and capabilities. As a consequence of these results and the homogeneity between studies in each category, etiology was found to be a moderator that might explain the inconsistency between the results of the various studies.

C. Operational Questions Related to Task-Related Potentially Moderating Variables:

Question 1: Are there differences in the effect sizes of implicit memory functioning of population with intellectual disabilities as compared with population with typical development, according to type of task (Priming and procedural tasks)?

Hypothesis: In light of the results of studies that found a difference in the performance levels of individuals with Williams syndrome between priming and procedural tasks (Vicari *et al.*, 2001), and in light of the uneven functioning of study subjects with Down syndrome and those with intellectual disabilities without a specific etiology in various priming tasks (*e.g.* Komatsu *et al.*, 1996; Mattson *et al.*, 1999), it was hypothesized that differences in effect sizes relating to implicit memory functioning within the intellectual disabilities population would be found in different types of tasks..

Results: The results of this meta-analysis indicated there were no differences between the mean effect sizes according to type of task variable. Implicit memory functioning in individuals with intellectual disabilities, as is expressed in both priming and procedural tasks, is moderately impaired compared to those with typical development. In contrast, when an examination was conducted concerning the differences in implicit memory functioning of each intellectual disability group separately (NSE, DS, WS), between their performance of priming and procedural tasks, in comparison with those typical development population, a heterogeneous pattern of performance was found, suggesting a differing level of functioning of each of the various tasks. Nevertheless, the type of task variable was not found to be a moderator.

In conclusion, this meta-analysis extends the evidence regarding patterns of cognitive functioning that differ in qualitative terms, amongst the various etiologies to the implicit memory domain. Unlike Reber's premise, the findings of this study suggest that implicit capabilities of those with intellectual disabilities, may vary as a function of individual differences and task type.