Visual Short-Term Memory and Selective Attention in Individuals with Intellectual Disability

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Abstract

Individuals with a certain degree of intellectual disability (ID) are widely known for having deficits in some aspects of cognitive functions. This thesis focuses on visuospatial short-term memory (VSTM) and selective attention functions in people with ID compared to typically developed adults (TDA), aiming at the examination of the effect of ID on attentional orienting and visual short-term memory capacity. Participants with and without ID had to perform a simple computerized task, where images were displayed on the screen briefly. Afterwards, they had to recognize if the last image that appeared on the screen was one of the images presented earlier. Valid spatial attentional cues were sometimes presented before (pre - cues) or after (retro - cues) the array, to help individuals with the recognition task and their performance in these trials was compared with performance in neutral cue trials. Additionally, all participants completed the Raven's 2, a non-verbal intelligence test. Results showed that TDA adults had significantly higher d-prime scores in all conditions (precue neutral/ cued, retrocue neutral/cued) than individuals with ID. Also, TDA had greater attentional benefits than individuals with ID. Furthermore, there were no statistically significant differences between precue and retrocue blocks, neither in cued nor in neutral trials in individuals with ID. These results show that individuals with ID do not benefit from attentional cues to facilitate VSTM capacity. Lastly, correlation analyses indicated positive correlations between intelligence scores and d-prime cued scores as well as intelligence scores and VSTM capacity (Cowan's K), suggesting that as intelligence scores increase attentional benefits in service of VSTM increase.

Keywords: intellectual disability, mental retardation, visuospatial short-term memory, visuospatial selective attention

1. Introduction

1.1 Intellectual disability

Intellectual disability (ID) is portrayed by critical constraints in intellectual and adaptive functions that manifest before the age of 18 (AAIDD, 2008). ID is considered a developmental clinical condition (APA, 2013), affecting 1-3% of the population (Chelly et al., 2006). To be diagnosed, individuals with ID are compared to typically-developing individuals of the same chronological age in terms of their intellectual and adaptive functions (Merrill et al, 2003) and for diagnosis purposes, individuals with ID do not need to display impairments in all cognitive abilities (Merrill et al, 2003). The etiology of ID can be environmental pre-birth factors (i.e., malnutrition) or chromosomal malformations (i.e., rearrangements of chromosomes) and, notably, ID is the result of various syndromes (Chelly et al, 2006; Flint & Knight, 2003).

The term intellectual function, also known as intelligence, represents the person's general mental capacity (e.g., critical thinking, learning). To date, Intelligence Quotient (IQ) tests have been the most commonly used method to measure intellectual skills (i.e., reasoning ability) and distinct cognitive abilities (i.e., visuospatial and verbal abilities, short-term and long-term memory, attention, processing speed etc). IQ tests provide an overall standardized IQ score that allows comparing an individual's intellectual performance to the overall intellectual performance of other individuals at the same age. A person is considered to have ID when their IQ score is lower than 70. Based on IQ scores, the degree of disability is further distinguished into (a) mild ID (IQ scores between 50 and 70), (b) moderate ID (IQ scores between 35 and 50), (c) severe ID (IQ scores between 20 and 35) and (d) profound ID (IQ scores below 20). Additionally, there is the borderline category that reflects IQ scores between 70 to 80 (DSM-IV-TR; American Psychiatric Association 2000; ICD-10; World Health Organization, 2005).

Adaptive functions refer to the assortment of social, conceptual, and applied skills that are gained and used by individuals in their daily routines. Social skills allow an individual to interact and communicate with others effectively, for example, they include social duties, interpersonal abilities, being law-abiding etc. Conceptual skills refer to the abilities that allow an individual to understand complex ideas, such as language, reading and writing proficiency etc. Applied, otherwise practical, skills are these that an individual needs to independently perform daily functions, including skills related to healthcare, personal safety and so on (AAIDD, 2008). For diagnostic purposes, adaptive functions are divided into 10 sub-categories: utilitarian scholastics, home living, social aptitudes, recreation, occupation, wellbeing and security, correspondence, self-care, self-direction and community services. For a person to be diagnosed with ID, they must have at least two of the above abilities fundamentally restricted (Pulsifer, 1996) and the limitations of adaptive skills can be estimated with standardized tests (AAIDD, 2008). Previous research showed that some adaptive skills that can be developed through long repetition, such as daily living abilities, can be particularly strong in people with ID (Pulsifer, 1996). Nevertheless, adaptive skills related to working/short-term memory, such as socialization and communication abilities, were found to be weak in these individuals (Pulsifer, 1996).

1.1.2. Etiology of Intellectual Disability

Based on their etiology, ID syndromes are divided into two main categories; syndromic, usually related to underlying radiological, clinical, biological or metabolic causes, and non-syndromic (non-specific or idiopathic) where there is no known underlying cause and cognitive deficits are the sole indication of the disorder (Chelly, 1999; Chelly & Mandel, 2001; Chiurazzi et al, 2004; Frints et al, 2002; Ropers & Hamel, 2005).

From a neurobiological approach, ID can be a result of somatic or constitutive mosaic deregulation of hereditary information through three major processes (a) rearrangements of chromosomes, (b) deregulation of the engraving specific genes or genome regions and (c) failure of single genes (Chelly et al, 2006; Flint & Knight, 2003). Additionally, environmental pre-birth factors, in particular untimely birth, ecological neurotoxicity, malnutrition or liquor consumption during pregnancy, are major driving factors of ID syndromes (Gargiulo, 2009).

ID syndromic cases are primarily caused by prenatal causes, such as multifactorial sources, chromosomal malformations, metabolic disorders, maternal infections and environmental factors (e.g. alcohol) (Gargiulo, 2009; Hagberg et al., 1981; Blomquist et al., 1981). Perinatal factors that contribute to the occurrence of ID are gestational disorders (e.g. low birth weight, prematurity) and neonatal complications (e.g. anoxia), whereas postnatal factors include infections and intoxicants as well as environmental factors (e.g. low socioeconomic status, insufficient education, limited stimulation, poor household conditions, child abuse, child neglect, poverty and poor parent-child interaction) (AAMR, 2002; Gargiulo, 2009; Lipkin, 1991). Nevertheless, a significant number of ID cases were found to be non-syndromic and may have a multitude of underlying causes (Shree & Shukla, 2016; Gargiulo, 2009; McDonald, 1973; McLaren & Bryson, 1987). Moreover, ID syndromes have been proven to be comorbid with several neurological disorders. Most frequently, ID exists simultaneously with behavioral and/or psychiatric issues, brain palsy, epilepsy, sensory impairments, microcephaly and macrocephaly (McLaren & Bryson, 1987; Pulsifer, 1996).

Neuropsychological studies have revealed diverse cognitive profiles among individuals with ID of various etiology (Vicari et al., 2000). Individuals with ID develop different characteristics of behaviors, a phenomenon that occurs due to the variations in the origins of the disability and thus, each type of ID is associated with different combinations of behavioral and cognitive problems. Some types of ID have greater impairment in autonomous living abilities and efficient functionality than others and this correlates with the impaired brain region of the individual (Pulsifer, 1996). Due to damage in different brain regions in ID syndromes, individuals with ID will also show different levels of cognitive impairment. Nevertheless, neuroanatomical malformations in specific brain regions such as the hippocampus and the cerebellum are discovered in every ID-related syndrome and as a result, all categories of ID have common cognitive impairments, such as attentional problems and short-term memory deficits. Furthermore, cerebellar atrophy, described by a decreased volume of the cerebellum, characterizes Fetal Alcohol syndrome, Down syndrome and Fragile X syndrome, and cerebellar damage is usually present in Prader-Willi syndrome (Pulsifer, 1996).

To conclude, ID-related disorders and syndromes appear to have common biological and behavioral features among individuals. However, differentiation between the various ID syndromes highlights the diversity of neuroanatomical malfunctions that are responsible for the rich symptomatology of each syndrome. Brain abnormalities seem to be correlated positively with impairments in behavioral, cognitive, and/or adaptive skills, but this hypothesis is yet to be confirmed (Pulsifer, 1996). Evidently, more studies are needed to understand the actual brain-behavior relationships in each ID-associated disorder.

1.2. VSTM, STM, WM and their theories

Short-term memory (STM) refers to a memory system that is characterized by a limited retention capacity, visual and phonological coding and deterioration of mnemic trace in just a couple of seconds in the absence of repetition (Baddeley & Hitch, 1974; Basso et al., 1982; Cowan, 2001). STM can be measured with simple, visual or auditory, span tasks (Milner, 1971; Pulsifer,1996). Traditionally, the term STM is usually used to refer to situations where only the retention of information is needed, in contrast to the term working memory (WM), which is used in cases where both maintenance and active transformation of the information or engagement in a distracting activity during maintenance is needed (Jarrold & Brock, 2012). The characteristics of STM and WM are as follows: (1) small storage capacity "Magical number 7-/+ 2" items (Miller, 1956) or limited to 4 objects when presented simultaneously (Cowan, 2001), (2) short duration (can store information for few seconds, up to 18 seconds) (Luck, 2008; Peterson & Peterson, 1959), (3) data are encoded visually and acoustically (Conrad, 1964; Wickelgren, 1965), and (4) the capacity can be increased by the chunking method (Chase & Simon, 1973; Ericsson & Chase, 1982).

Visual short-term memory (VSTM) refers to a memory subsystem responsible for temporarily maintaining small amounts of visual information so it can be utilized in the assistance of ongoing cognitive tasks (Luck, 2008; Shimi & Scerif, 2017; Zerr et al., 2021). This subsystem can create mental representations instantly but its storage capacity is highly limited. Studying and measuring VSTM can be achieved through different "classes of tasks", where the most popular are (a) the Brook Matrix Task (Brooks, 1967), (b) the recall procedure and (c) the sequential comparison method and its successor the one-shot change-detection task (first developed by Phillips, 1974) (Luck, 2008).

The two most widely known WM models are Baddeley's model and Cowan's model. Baddeley's WM model (1974) is characterized as a multi-complex system, including a central control system, referred to as central executive, and two peripherals, the articulatory phonological loop and the visuospatial sketchpad. The two subsystems perform as basic short-term storage mechanisms, responsible for the preservation of verbal and visuospatial information respectively. The central executive acts as a coordinator for resources that are fundamental for the operation of the system and the manipulation of data (Baddeley, 1986; Baddeley & Hitch, 1974). The Phonological Loop is related to vocabulary and general language development (Baddeley et al., 1998; Gathercole & Baddeley, 1993) and the incoming data can be kept active through subvocal rehearsal. As for the visuospatial sketchpad, it is believed to be fundamental for mental imagery, spatial thinking (Baddeley, 1986; Engle et al., 1999; May & Einstein, 2013), and it has been associated with spatial arrangement abilities and geographical orientation (Logie & Logie, 1995). Baddeley (1986) assumed that STM for visuospatial and verbal information taps distinct memory stores. According to Baddeley's model, VSTM is viewed as the visual storage component of the more extensive working memory system, having momentary storage of data, even though working memory includes additional executive control and processing features (Baddeley, 1998; Jarrold & Brock, 2012; Luck, 2008). The "episodic buffer" is an impermanent store that coordinates information from the phonological loop, visuospatial sketchpad, and long-term memory. The central executive system is responsible for a wide scope of functions e.g., fluid intelligence (Duncan et al., 1996; Engle et al., 1999), judgment (Kyllonen & Christal, 1990), data retrieval, controlling the data flow and so on, as it is the expert component that facilitates activities among the phonological loop, visuospatial sketchpad, and episodic buffer (Baddeley, 1986; Engle et al., 1999; May & Einstein, 2013). Also, it is presumed to be mediated by the frontal lobes. As per the phonological loop model, the proficiency of rehearsal relies upon the speed with which data can be practiced (Baddeley et al., 1975).

On the other hand, Cowan's model (1988, 2005, 2011) supports that WM is an embedded-process within long-term memory. This model consists of four elements; the central executive system, the long-term memory, the active memory or working memory and the focus of attention. WM refers to a subset of long-term memory representations, with limited information capacity, that remains in an active state for the purpose of ongoing tasks (Cowan, 2017). A further subset of activated WM representations is believed to be in the focus of attention. The focus of attention refers broadly to processes involved in the active maintenance of stored representations in a limited-capacity memory system. As for the amount of simultaneously active representations in WM, it is still an issue of debate, whether they are unlimited in number or not (Cowan, 2008). Also, without rehearsing, it has been shown that representations remain active for about 10-20 seconds. Last, the active representations that fall within the focus of attention have a capacity limitation to 3-5 chunks, being immune to decay and interference (Cowan, 2001, 2008; Shimi et al, 2017).

Individuals with ID have deficits in explicit abilities, such as information coding for memorization, absence of union mnemic trace and decreased ability for data retrieval (Carlesimo et al.,1997; Katz & Ellis, 1991; McCartney, 1987; Spitz, 1966; Watkin, 1974; Winters & Semchuk, 1986). However, existing literature lacks data to support the hypothesis of deficits in implicit abilities in people with ID. Neuropsychological findings have shown inadequate development of the mnemic function in individuals with ID, depending on the levels of their speaking ability (Vicari et al., 2000). Through the years, numerous studies demonstrated a strong correlation between the capacity of WM and intelligence, otherwise known as the G factor (Colom et al., 2004; Conway et al., 2003; Kyllonen & Christal, 1990). Studies and theoretical models on human cognitive functioning concluded that WM capacity might be “the best predictor of intelligence” (Süß et al., 2002). Baddeley’s model (1986) has set the foundation for the relation between impairments in WM and ID. Furthermore, the executive part of WM can be positively associated with IQ differences amongst people with ID (Jarrold & Brock, 2012). WM is regularly estimated by complex span tasks, during which participants are asked to recall a set of items, after completing a subsidiary errand (Jarrold & Brock, 2012). Levels of sensitivity in tasks that evaluate components of WM may differ because of the intellectual ability (Engle et al., 1999) and the developmental level (Gathercole & Pickering, 2000) of the individual. Results from WM functioning evaluations showed that the brain structures of the WM system weren’t affected by ID (Jarrold et al., 1999; Wang & Bellugi, 1993).

In conclusion, memory is a cognitive function that has always intrigued researchers for further investigation in an attempt to understand its influence on the human brain. Baddeley and Cowan tried to set some guidelines and explanations about the subsystems of memory through their theories. In both theories, WM and STM are functions with highly limited capacity, strongly connected to the visual element. Through years of research, and by using Baddeley’s model, scientists concluded that WM skills are directly associated with intelligence, and a deficit in WM appears in people with ID. Engle and his colleagues (1999) pointed out that the activation of WM may rely on the participant’s IQ, age, mental level as well as the task itself. Also, based on Cowan’s theoretical model, it is considered that the activation of WM seems to be affected by the focus of attention (Cowan, 2001).

1.3. Selective attention and its relation to intellectual abilities

With regards to attention, it is a cognitive system distinguished into three main networks that together allow individuals to process and react to stimuli; i.e., alerting, orienting, and executive control (Callejas et al., 2004; Posner & Petersen, 1990). In the current study, attentional orienting (also referred to here as selective attention) was the main attentional process examined in individuals with ID. Attentional orienting includes voluntarily or involuntarily shifting of attention to the direction of an upcoming stimulus (Posner & Petersen, 1990).

Since the 1960s, researchers have been seeking to understand the relation between ID and attention deficits (Oka & Miura., 2008). Zeaman and House (1963) were the first to propose the theory of attention, suggesting that deficits of attention induce intellectual disabilities. However, an experiment by Brown (1966) found that intelligence was associated with the level of distractibility, and specifically, low intelligence was related to high levels of distractibility. Furthermore, a more recent study rejected the Zeaman and House (1963) hypothesis and approached the matter of attention deficiency as being one of the types of functional deficit in individuals with ID (Oka & Miura, 2008). Also, it was proposed that distractibility was more likely to result from external stimuli, rather than an inherent characteristic of people with ID (Zilgler, 1966). Stimuli that are important to the individual as well as light stimuli were found to cause more distractibility in individuals with ID or brain-injured patients (Cruse, 1961). Even though, in general, individuals with ID were found to have damage in attentional allocation function (Merrill & Peacock, 1994), no significant difference was found in attentional allocation between mild and moderate levels of ID (Oka & Miura, 2008). Lastly, a series of studies concluded that the learning difficulties of individuals with ID occur due to their attentional deficits (Denny, 1994; 1966; Luria et al., 1963; O’ Connor & Hermelind, 1963; Zeaman & House,1963; Zeaman, 1965).

1.4. Interactions between VSTM/WM and selective attention in typically-developing individuals

With regards to the interaction between VSTM and selective attention, researchers have carried out multiple studies with typically-developing individuals. Studies have shown that selective attention and VSTM are directly interrelated functions (Astle et al., 2012; Kuo et al., 2012; Shimi et al., 2014; Shimi et al., 2015; Shimi & Scerif, 2017; Lepsien, Thornton & Nobre, 2011). Selective attention can filter irrelevant information from entering VSTM and can, therefore, reduce the memory load to be retained in the limited-capacity VSTM (Downing, 2000). Furthermore, researchers have shown that attention can influence VSTM information through top-down processes (Astle et al., 2009; Griffin & Nobre, 2003; Sligte et al., 2010).

In order to study the interaction between VSTM and selective attention, researchers developed paradigms with attentional cues, which were presented either after or before stimulus presentation, to study the effects of attentional orienting on stimulus processing. Firstly, Sperling (1960) developed the “cueing partial-report paradigm” using iconic retro-cues, which guided attention to stimuli retained in iconic memory. Later, Posner (1980; Posner & Cohen, 1984) designed a paradigm including visuospatial cues that directed attention to the location of an upcoming target (pre-cues). Results from both paradigms showed that pre-cues and iconic retro-cues facilitate perceptual processing and iconic memory performance, respectively. Griffin and Nobre (2003) modified Sperling’s and Posner’s paradigms by adding both pre-cues and VSTM retro-cues; that is, visuospatial cues that appeared either before or after encoding information in VSTM respectively. They found that typically-developed adults’ VSTM benefited from attentional cues as adults were more accurate and faster in their responses in pre-cue and retro-cue trials compared to neutral trials (Griffin & Nobre, 2003). Therefore, this modified paradigm demonstrated the importance of attentional biases for VSTM performance and these results revealed the interaction between selective attention and VSTM. Similar findings were then found by other studies using this paradigm. For example, Sligte et al. (2008) found that retro-cues can have a positive effect on boosting impaired VSTM representations. In another study, attentional biases were found to help prioritize information at different processing phases and boosted the relevant to-the-task representations (Astle et al., 2009). Later, Shimi et al. (2014), showed that spatial STM and WM share control mechanisms with attentional orienting, i.e., orienting attention during maintenance protects mental representations from interference and decay (Shimi & Scerif, 2017).

Developmental studies with typically-developing children found that STM capacity increases enormously between 3 to 10 years old (Gathercole, 1999; Gathercole et al., 2004). Age was found to be associated with cue benefits in visuospatial memory, with older children and adults having larger attentional benefits than younger children (Shimi et al., 2014). This finding supported the suggestion that attentional refreshment mechanisms may affect differently STM/WM capacity, based on the individuals' developmental age (Barrouillet et al., 2009). In another study, Astle et al. (2012) found that even though children's VSTM was poorer than adults, children's VSTM capacity benefited from attentional cues. Also, children's attention cueing benefits during the maintenance process predicted VSTM and visual working memory (VWM) capacity, leading to the proposal that children's differences in visuospatial attention can explain developmental differences in VSTM capacity (Astle et al., 2012; Shimi et al., 2014; Shimi & Scerif, 2017). Lastly, these studies found that attentional orienting cues in service of encoding were more beneficial than attentional orienting cues in service of VSTM maintenance in young children, whereas adults had similar benefits (Astle et al., 2012; Shimi et al., 2014). Importantly, younger children benefited to a smaller degree from retro-cues compared to older children and young adults, leading to the suggestion that developmental differences during the maintenance process rely on age-related changes in using controlled voluntary visuospatial orienting, instead of being automatic (Shimi et al., 2014).

1.5. Impairments cognitive functions in ID- Associated syndromes

Individuals with ID not only demonstrate poorer cognitive, behavioral and adaptive abilities in comparison with individuals without ID, but they also differ in these abilities as a clinical group. Because of the variety of etiologies of ID-associated syndromes, there is also a plethora of symptoms and different combinations of defective skills.

Individuals with Down syndrome show deficits in auditory sequential memory and recalling auditory information verbal STM (Brener, 1940; Chapman, 1997; Laws & Bishop, 2004; Majerus & Van der Linden, 2003; Marcell & Armstrong, 1982; Thorn & Frankish, 2005; Varnhagen et al., 1987), lexical abilities (Brener, 1940; Caselli et al., 1998; Chapman, 1997; Fabbretti et al., 1997; Fowler, 1990; Jarrold & Brock, 2012; Majerus & Van der Linden, 2003; Thorn & Frankish, 2005; Vicari et al., 2000; 2004), coordinating skills (Down, 1866) and in explicit memory functions (Vicari et al., 2000; 2004). Jarrold and Cairns (2005), found a level of weakness in item recognition memory, but it must not be taken for granted. An important information that has to be pointed out is that DS exhibits strength in visuospatial memory (Grant et al., 1997; Pulsifer, 1996; Wang & Bellugi, 1994), nevertheless visual and verbal STM functions cannot be considered to be intact in individuals with ID relative to individuals with the same chronological age without DS (Jarrold & Brock, 2012). Individuals with Fatal Alcohol syndrome have been found to have slower reaction times (Jacobson & Jacobson, 1994), deficits in STM, abstract thinking, attention and problem-solving skills (Nanson & Hiscock, 1990; Russell et al., 1991; Streissguth et al., 1991) in relation to healthy individuals. Concerning Fragile X syndrome they demonstrate attenti2onal problems, difficulties in VSTM, arithmetic abilities, language and graphomotor skills (Freund & Reisis, 1993; Mazzocoo et al., 1993), social interactive skills and behavioral problems, like hyperactivity, impulsiveness and maladaptive behaviors (Dykens et al., 1989). Individuals with Prader- Willi syndrome illustrate deficits in auditory attention, data processing, VSTM and motor programming (Gabel et al., 1986; Curfs et al., 1991; Dykens et al., 1992; Warren & Hunt, 1981). However, there are conflicting information in long–term prognosis for cognitive functions for Prader-Willi syndrome. Associated strengths in individuals with Prader-Willi syndrome are showed in organizing skills, visual perception and visuospatial abilities (Curfs et al., 1991; Holm, 1981; Pulsifer, 1996). As for individuals with Angelman syndrome, appear to be characterized by nonverbal communication, brief attentional span and hyperactivity (Pulsifer, 1996; Williams et al., 2009). Individuals with Williams syndrome, show weaknesses in visuospatial STM, although they demonstrate strength in verbal STM (Brock et al., 2005; Farran & Jarrold, 2003; Grant et al., 1997; Mervis et al., 1999; Wang & Bellugi, 1994). Even though individuals with WS are considered to have strengths in verbal STM, it cannot be viewed as intact, compared to individuals of the same chronological age without WS (Jarrold & Brock, 2012). Individuals that consider to be within non-syndromic ID category show a general decrease in cognitive abilities (Hodapp et al., 1992), in which STM is generally damaged (Burack & Zigler, 1990). Even so, non-syndromic ID individuals have better visual STM abilities than syndromic ID individuals (Burack & Zigler, 1990).

Importantly, numerous distinctions have been found in skilled performance between individuals with and without ID of the same mental age (Courbois, 1996; Merrill & Mar, 1987; Merrill et al., 1987; Spitz & Borys, 1977). ID- associated syndromes have common deficits in iconic memory, STM acquisition, object and picture discrimination (Dobson & Rust, 1994) and visual information capacity (Hagen & Huntsman, 1971; Merrill & O’dekirk, 1994). Furthermore, visuospatial abilities were found limited in individuals with ID, but not in individuals with Down syndrome (Pulsifer, 1996). Selective attention processes were found to be impaired in individuals with ID compared to typically developed individuals (Fisher & Zeaman, 1973; Hagen & Huntsman, 1971; Zeaman & House, 1963; 1979), since individuals with ID present difficulties focusing in relevant information (Hagen & Huntsman, 1971), dysfunction in using top-down processes (Merrill & O'dekirk, 1994). Also, it was found that they use different operational neural systems of attention (Merrill & O'dekirk, 1994). Also, deficits were found in orienting their attention compared to typically developed individuals, as they have limited attention resources (Levén et al., 2011; Pulsifer, 1996; Nugent & Mosley, 1987). Additionally, studies have shown that order memory mechanisms are more vulnerable in ID (Jarrold & Brock, 2012). Last but not least, it was found that difficulties in VSTM abilities differ based on the degree of intellectual disabilities. Specifically, it was found that in mild-level ID, people presented difficulties in VSTM for visual objects, whereas in moderate-level ID, they show difficulties in visual memory for objects and location (Katz & Ellis, 1991). Also, individuals with mild ID recalled more pictures than those with moderate ID (Katz & Ellis, 1991).

In conclusion, ID-associated syndromes present differences in cognitive abilities between individuals with ID. At the same time, there are also differences between individuals with ID and individuals of the same mental age. These differences assist in identifying the weaknesses and strengths of each ID-associated syndrome. They also, highlight that specific deficits can arise from various reasons and cognitive mechanisms (Jarrold & Brock, 2012; Katz & Ellis, 1991), as different approaches may be needed for the better evaluation of these functions. Considering the above information, many ID-associated syndromes show general impairments to STM functions, however, some syndromes are considered to have strengths in verbal or visual STM. Lastly, selective attention seems to be greatly impaired in these syndromes.

1.6. Current study

This study focused on two key cognitive processes for adaptive functioning, i.e., VSTM and selective attention (here also referred to as attentional orienting), in people with ID. So far, attention and VSTM in individuals with ID have been studied separately. Therefore, the aim was to examine the effect of ID on attentional orienting and VSTM. To do so, the spatial cueing paradigm (with pre-cues and retro-cues) was used, setting two hypotheses. The primary hypothesis was that individuals with ID will have smaller cue benefits in service of VSTM in comparison to typically-developed adults (TDA). The second hypothesis was that individuals with ID will have poorer performance in neutral and retro-cue trials, compared to pre-cue trials.

2. Methodology

2.1. Participants

Twenty-five adults with ID (age range 19 – 63) and 22 typically-developed adults (aged 19 - 63) participated in the current study. Participants with ID were recruited from the "Christos Stelios Ioannou" foundation, which hosts, entertains, and provides treatments and employment to people with mild to moderate level ID. Inclusion criteria for participation of individuals with ID were 1) age above 18, 2) mild to moderate ID level, 3) ability to communicate verbally, and 5) absence of severe kinesiological deficits and visual-auditory problems. Inclusion criteria for TDA were 1) being chronologically matched with a participant with ID, 2) absence of severe kinesiological deficits and visual-auditory problems, and 3) absence of neurological impairments.

Of the twenty-five individuals with ID that participated in the study, only nineteen completed all tasks. Therefore, six participants with ID (2 males and 4 females) were excluded from the statistical analyses, because either they did not understand the Attentional

Orienting task or they were giving random answers or didn't want to continue the testing session. The final sample of nineteen adults with ID (8 males, 11 females, M=39.47) that completed all tasks of the study, were included in the statistical analyses as the ID group. More specifically, the final ID sample included five adults between 19 and 29 years of age, five adults between 30 and 40 years of age, five adults between 41 and 51 years of age, and four adults between 52 and 63 years old. The TDA group (11 males, 11 females, M=39.18) consisted of nine adults between 19 and 29 years of age, one adult 30 years old, seven adults between 41 and 51 years of age, and five adults between 52 and 63 years old.

The study was ethically approved by the Cyprus National Bioethics Committee. Typically-developed adults and parents or guardians of individuals with ID signed informed consent forms before participating in the study. Lastly, individuals with ID verbally assent to participate in the study.

2.2. Materials

The Attentional orienting task by Shimi et al. (2014) was used to assess the interaction between selective attention and VSTM. Also, individuals completed the Raven's 2 test that provided information on the intellectual abilities of the participants and the mental age of participants with ID.

Attentional Orienting Task: The Attentional Orienting task is an experimental paradigm, designed in E-prime v.2 (Psychological Software Tools, Pittsburgh, PA), and was presented on a laptop. Participants viewed an array of four different colored images (drawn from a set of seven color tones: green, red, blue, yellow, orange, white and pink) of familiar objects and animals on a black background. The array was followed by a single item, "probe", and participants responded whether the probe appeared in the previous array, by clicking the left mouse button as "yes" and the right mouse button as "no" for an answer. In half of the trials, visuospatial attention cues were shown briefly either prior to encoding (pre-cues) or during maintenance (retro-cues) of the array, guiding participants' attention to the likely location of the probe. The visuospatial attentional cues were always valid regarding the location of the probe, when this was present.

The task included two trial types: cued (pre - cue, retro - cue) and neutral trials. In pre - cue trials, a white arrow was presented as a visuospatial attention cue before the array, guiding the participant's attention to one of the forthcoming objects of the array (therefore, providing spatial information regarding the likely location of the probe). In retro - cue trials, the visuospatial attention cue appeared after the array, guiding the participant's attention to one of the already encoded objects. In neutral trials, a white square was shown before and after the array, to control for the nonspatial alerting benefits that pre - cues and retro - cues may have aroused. By this method, selective attention abilities in service of VSTM were measured. The neutral squares and the arrows were presented in the centre of the screen.

The task comprised two practice blocks, six trials each. After the practice blocks, participants had to complete four test blocks of 48 trials each, totalling 192 experimental trials. The first practice block was a slower version of the actual experiment to guarantee that participants completely understood the computerized task. The second practice block was adopted with the same time parameters as the actual experiment. Each test block included neutral trials and either pre - cues (two "pre - cue blocks") or retro - cues (two "retro - cue blocks"), in order to minimize any confusion that may arise from repetitively changing different types of visuospatial cues within a block. Block order was counterbalanced across participants. Two - thirds of trials were probe-present and one-third were probe-absent trials, where half were cued (equally probable to guide attention to one of the four potential spatial locations) and the other half were neutral. Participants received visual feedback about their performance (i.e., incorrect, correct, and no response) on every trial of the two practice blocks, whereas the number of the correct answers was presented on the screen after every 16 experimental trials and at the end of the experimental block.

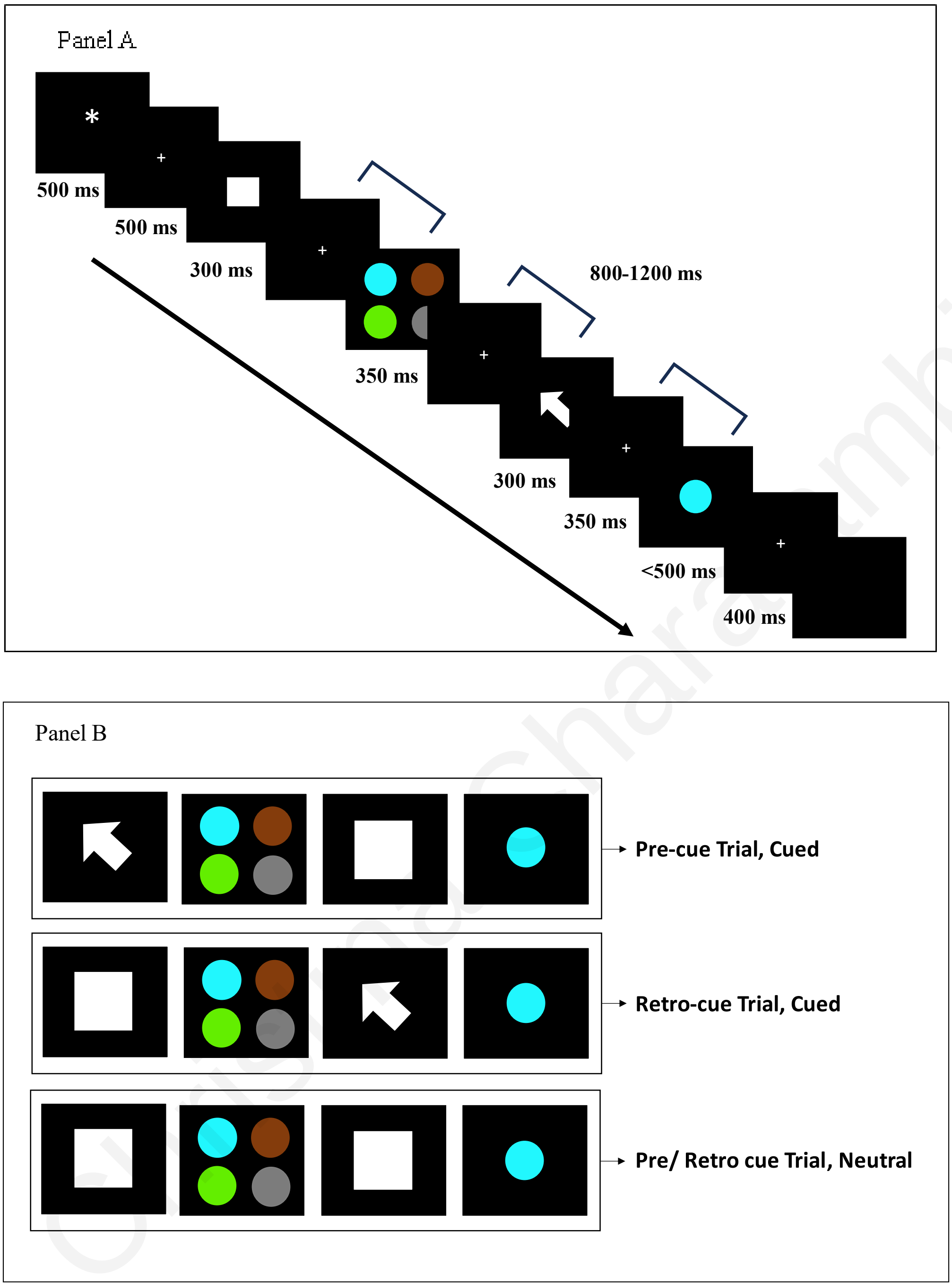

Figure 1 (figure adapted from Shimi et al., 2014): Panel A illustrates a retro-cue trial sequence. Panel B illustrates the two cue conditions (pre-cue or retro-cue) and the two trial types (cued or neutral).

Raven's 2 Progressive Matrices: The Raven's 2 Progressive Matrices (2018), designed by John C. Raven and published by NCS Pearson, is a nonverbal psychometric test assessing general cognitive functions, created to quantify educative skills (i.e., problem solving) of individuals from 4 to 90 years old. The general cognitive functions that it examines relate to visual attention and perception, fluid and broad visual intelligence, inductive reasoning, spatial skills, WM, classification abilities and simultaneous processing (McLeod & McCrimmon, 2020). Finally, Raven's 2 provides an Intelligence Quotient (IQ) score.

Raven's 2 comprises 60 visual units portraying a matrix of colorful geometrical illustrations (12 matrix per set; A – E sets) organized in 1 × 1, 2 × 2, 3 × 3, or 1 × 6 layouts. Every matrix contains an empty cell and six options for the examinee to choose from to complete a matrix. In the current study, participants with ID completed the short version, from A – C sets, having 30 minutes to finish the task. The typically-developed adult participants completed the long version, from B – E sets, with 45 minutes as a time limit. An important note for the test is that an administration is considered valid only when there are at least 16 items completed, discontinued criteria are met and/or the time limit (ranges up to 30 to 45 minutes, depending on the type) is reached (McLeod & McCrimmon, 2020).

Raven's 2 has very good psychometric properties ranging from good (.80s) to excellent (.90s) for internal reliability (Dimitrov, 2003) and good (.80s) for the test–retest stability. Moreover, it has strong content validity (Raven et al., 2018), as well as construct validity with Kaufman Brief Intelligence Test—Second Edition (KBIT-2; Kaufman, 2004), Naglieri Nonverbal Ability Test—Third Edition (NNAT3; Naglieri, 2015), and the Wide Range Achievement Test—Fifth Edition (WRAT5; Wilkinson & Robertson, 2017). Raven's 2 has a strong correlation with KBIT-2's nonverbal section (PF = .75) and moderate correlation with the verbal (PF = .50). Also, there has been a strong correlation between Raven's 2 and the NNAT3 (PF = .77).

Raven's 2 is a tool capable of measuring nonverbal cognitive abilities, making it useful to special populations and individuals with linguistic limitations. Also, because of the wide age range it possesses, it enables the examination of cognitive abilities across a broad age range of people. Raven's 2 was found to have more expansive test banks for the items than the previous version, it is easier to use, requires less training and understanding, as well as it has efficient administration time (McLeod & McCrimmon, 2020). Therefore, Raven's 2 is a suitable and valid tool for the assessment of general cognitive abilities in individuals with ID.

2.3. Procedure

Participants with ID were tested individually in a quiet room within the "Christos Stelios Ioannou" foundation. Typically-developed adults (TDA) were tested at the Memory and Attention Development Lab (MADLab) at the University of Cyprus. The examiner explained the trial and cue types of the Attentional Orienting task using printed schematic illustrations. Participants were constantly reminded to pay attention to the attention cues, when available, as they provided help. Participants were also encouraged to respond as quickly and accurately as possible while focusing their gaze on the fixation point throughout the trial. After completing every test block, participants with ID received stickers as well as a participation diploma at the end of the testing session, for encouragement and to increase motivation.

The Raven's 2 test was administered to individuals with ID on a different day at the "Christos Stelios Ioannou" foundation to avoid fatigue whereas it was administered to TDA on the same day, after the Attentional Orienting task. Before the Raven's 2 test, all participants were asked to do a sample trial in the presence of the examiner. They also received feedback during completing the practice trials, to ensure that they understood the task. Participants with ID pointed their responses for each matrix to the examiner, who then transferred their answers to the answer sheet. TDA participants wrote their responses on the answer sheet themselves. Finally, the examiner recorded the administration time using a timer that she started at the beginning of the task.

2.4. Statistical Design

There were two groups of participants, individuals with ID and TDA individuals. Two mixed-design Analyses of Variance were carried out on d-prime (accuracy) and Cowan's K. Cowan's K is a memory capacity measure, using the number of stored items in memory (Cowan, 2001; Pashler, 1988). Cue-condition (pre-cues, retro-cues) and trial-type (cued or neutral) were the within-subject variables and the group (ID, TDA) was the between-subject variable. Setting these factors, we were able to examine possible cue benefits in service of VSTM among participants with ID, as well as whether the magnitude of cue benefits differ between participants with ID and TDA. Unfortunately, an analysis of reaction times (RTs) could not be carried out as a few ID individuals had very low accuracy in a few conditions/trial-types that did not allow computing mean RT scores in all conditions. Pearson's r correlation analyses were carried out between the participants' total raw scores on Raven' 2 and the d-prime and Cowan's K scores for the different trial-types (pre-cued, retro-cued, pre-neutral, retro-neutral). Furthermore, partial correlation analyses were carried out between participants' total raw score in Raven's 2 and the cued trials for both pre-cue and retro-cue conditions while controlling for the neutral trials respectively, and for age.

3. Results

3.1. Accuracy – D-prime measurements

Analyses showed statistically significant main effects of cue-condition (F(1, 39) = 7. 33, p =.010, η_p^2 = .16), trial-type (F(1, 39) = 99. 73, p < .001, η_p^2 = .72) and group (F(1, 39) = 172,45, p < .001, η_p^2 = .82). There were, also, statistically significant interactions between cue-condition x group (F(1, 39) = 4.94, p=.03, η_p^2 = .11), trial-type x group (F(1, 39) = 81.28, p < .001, η_p^2 =.68) and cue-condition x trial-type x group (F(1, 39) =7.89, p= .008, η_p^2 = .17). The interaction of cue-condition x trial-type was not significant (F(1, 39) = 2.43, p= .13, η_p^2 = .06).

Analyses of simple main effects for the 3-way interaction showed that the TDA group had higher d-prime scores than the ID group across both cue conditions, pre-cue and retro-cue, and across trial types, cued and neutral trials (TDA: M=3.34 for pre-cue, M=1.66 for neutral trials in the pre-cue condition, M=2.66 for retro-cue, M=1.54 for neutral trials in the retro-cue condition, all ps<.001). Importantly, the TDA group had higher d-prime scores in cued than in neutral trials in both pre-cue (p<.001) and retro-cue conditions (p<.001), indicating both pre-cue and retro-cue benefits for TDA. In contrast, there were no significant differences between cued and neutral trials in either pre-cue (p=.96) or retro-cue (p=.24) conditions in the ID group, indicating the absence of cueing benefits for this group. Finally, the TDA group had higher d-prime scores in the cued trials of the pre-cue condition than in the cued trials of the retro-cue condition (p<.001), whereas their performance between the neutral trials across the two cue conditions did not differ (p=.26), suggesting larger pre-cue than retro-cue benefits. The ID group showed no significant differences in performance neither in cued nor in neutral trials between the two cue conditions (p=.83 for cued trials and p=.32 for neutral trials).

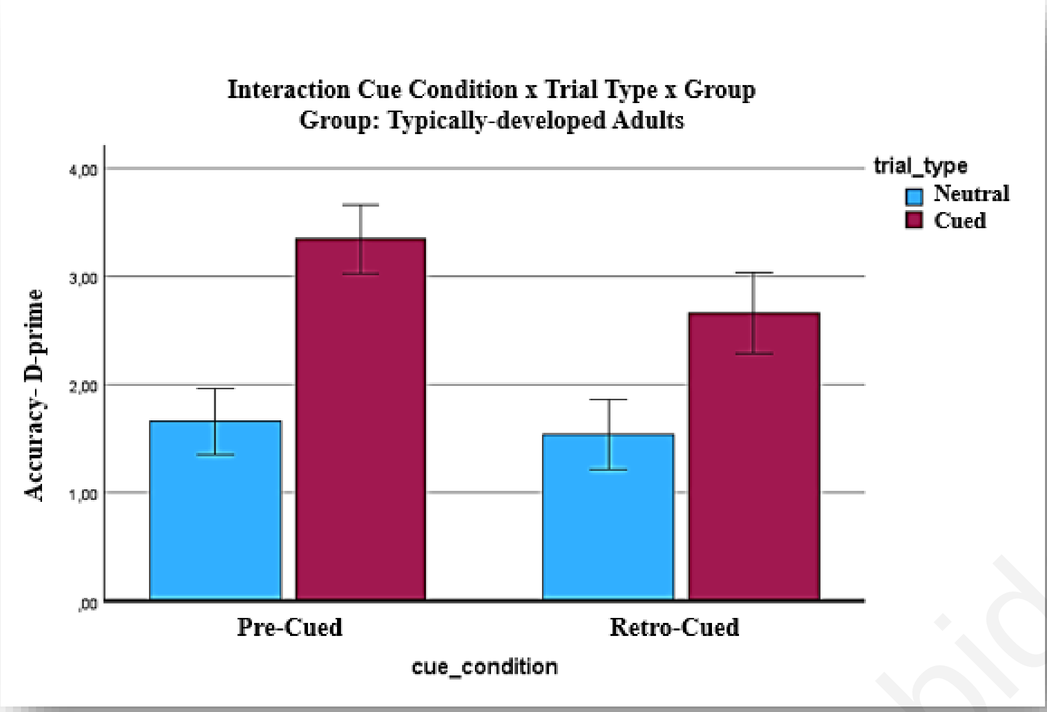

Figure 2: D-prime scores for pre-cued, retro-cued, and neutral trials of typically-developed adults. Error bars represent the standard error of the mean.

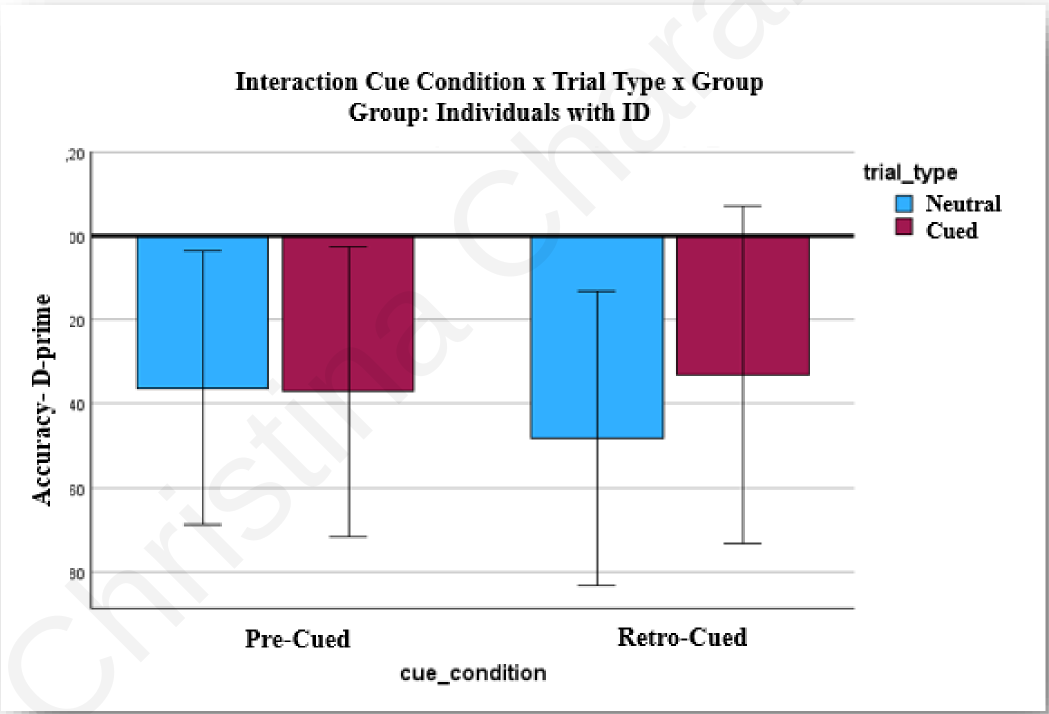

Figure 3: D-prime scores for pre-cued, retro-cued, and neutral trials of individuals with ID. Error bars represent the standard error of the mean.

3.3. Cowan's K

Analyses for Cowan's K showed similar results with d-prime analyses. There were statistically significant main effects of cue-condition ($F(1, 39) = 6.58$, $p = .01$, $\eta_p^2 = .16$), trial-type ($F(1, 39) = 57.01$, $p < .001$, $\eta_p^2 = .59$) and group ($F(1, 39) = 192.93$, $p < .001$, $\eta_p^2 = .83$). Also, the interactions of trial-type x group ($F(1, 39) = 35.60$, $p < .001$, $\eta_p^2 = .48$) and cue-condition x trial-type x group ($F(1, 39) = 3.95$, $p = .05$, $\eta_p^2 = .09$) were significant. In contrast, the interactions of cue-condition x group ($F(1, 39) = 2.09$, $p = .156$, $\eta_p^2 = .05$) and cue-condition x trial-type ($F(1, 39) = 0.51$, $p = .48$, $\eta_p^2 = .01$) were not significant.

Analyses of simple main effects for the 3-way interaction showed that the TDA group had higher K scores than the ID group across both cue conditions, pre-cue and retro-cue, and across trial types, cued and neutral trials (TDA: M=3.49 for pre-cue, M=2.12 for neutral trials in the pre-cue condition, M=3.05 for retro-cue, M=2.00 for neutral trials in the retro-cue condition, all ps<.001). Importantly, the TDA group had higher K scores in cued than in neutral trials in both pre-cue (p<.001) and retro-cue conditions (p<.001), indicating both pre-cue and retro-cue K benefits for TDA. In contrast, there were no significant differences between cued and neutral trials in either pre-cue (p=.68) or retro-cue (p=.17) conditions in the ID group, indicating the absence of cueing benefits in Cowan's K for this group. Finally, the TDA group had higher K scores in the cued trials of the pre-cue condition than in the cued trials of the retro-cue condition (p=.002), whereas their performance between the neutral trials across the two cue conditions did not differ (p=.30), suggesting larger pre-cue than retro-cue K benefits. The ID group showed no significant differences in Cowan's K neither in cued nor in neutral trials between the two cue conditions (p=.98 for cued trials and p=.23 for neutral trials).

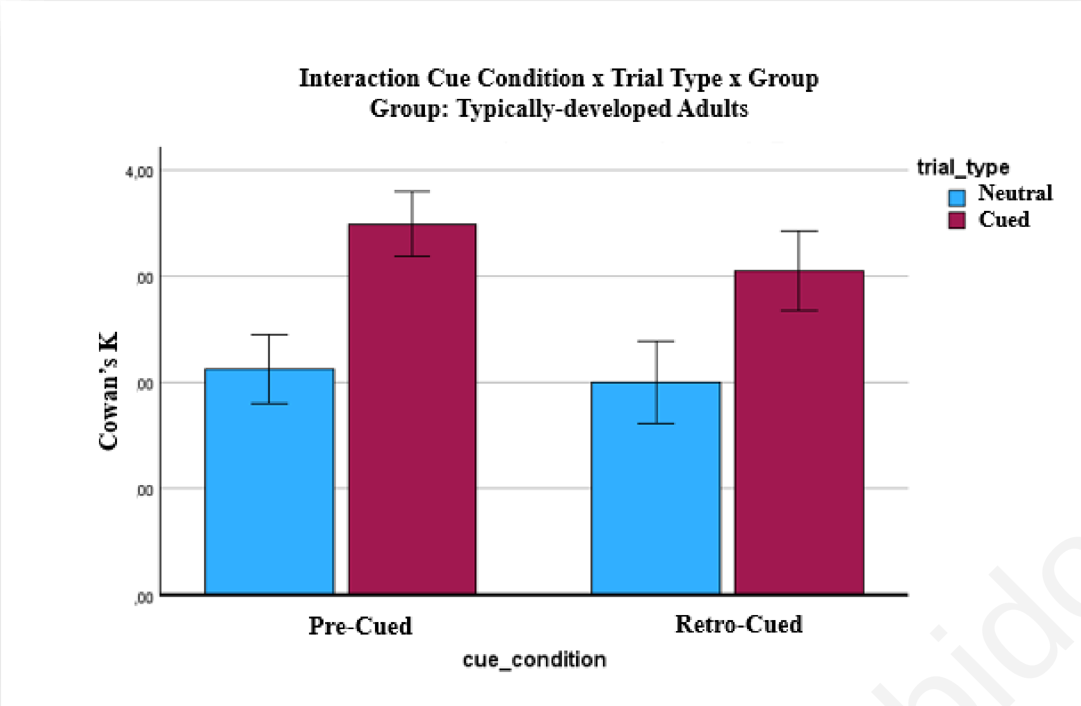

Figure 4: Cowan's K scores for pre-cued, retro-cued, and neutral trials of typically-developed adults. Error bars represent the standard error of the mean.

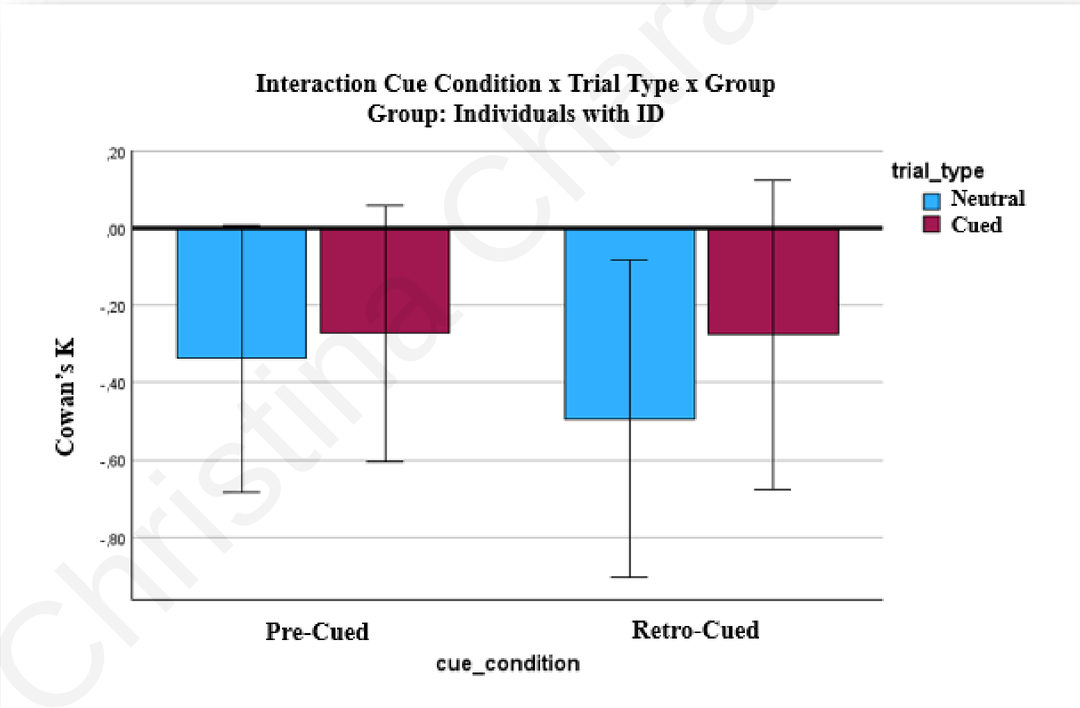

Figure 5: Cowan's K scores for pre-cued, retro-cued, and neutral trials of individuals with ID. Error bars represent the standard error of the mean.

3.4. Correlations

Pearson's r correlation analyses were carried out between the participants' total raw scores on Raven' 2 and the d-prime and Cowan's K scores for the different trial-types (pre-cued, retro-cued, pre-neutral, retro-neutral). It should be noted that the total raw score of ID participants in Raven's was lower than in the general population, confirming their intellectual disabilities. None of the individuals in the TDA group scored in the ID range. The total raw score in Raven's 2 was used as a continuous variable. The analyses showed very strong positive correlations between the total raw score in Raven's 2 and pre-cued, retro-cued, pre-neutral, and retro-neutral trials (all $ps < .001$ for both d-prime and Cowan's K). Table 1 shows results from the Pearson's correlation analyses.

Furthermore, partial correlations between the total raw score in Raven's 2 and the cued trials for both pre-cue and retro-cue conditions, controlling for the neutral trials, respectively, and for age showed again positive correlations for both pre-cue ($r(37) = .78$, $p<.001$) and retro-cue conditions ($r(37)=.52$, $p<.001$).

Variable	Raven's 2	Dprime precue-neutral	Dprime precue-cued	Dprime retrocue-neutral	Dprime retrocue-cued	Cowan's K precue-neutral	Cowan's K precue-cued	Cowan's K retrocue-neutral	Cowan's K retrocue-cued
Raven's 2	1								
Dprime precue-neutral	.85	1							
Dprime precue- cued	.94	.88	1						
Dprime retrocue-neutral	.82	.92	.87	1					
Dprime retrocue-cued	.86	.90	.91	.93	1				
Cowan's K precue-neutral	.88	.99	.91	.92	.92	1			
Cowan's K precue-cued	.94	.88	.99	.86	.92	.91	1		
Cowan's K retrocue-neutral	.83	.92	.88	.99	.93	.94	.88	1	
Cowan's K retrocue-cued	.89	.90	.93	.91	.99	.92	.95	.91	1

TABLE 1: This table presents the Pearson's correlation coefficients between the variables used in the analyses.

4. Discussion

The purpose of this study was to gain a better understanding of the interaction between selective attention and VSTM in individuals with ID, as well as of the differences between this clinical group of individuals and typically-developed adults (TDA) of similar chronological age. The primary hypothesis was that individuals with ID will have smaller cue benefits in service of VSTM in comparison to typically-developed adults (TDA). The second hypothesis was that individuals with ID will have poorer performance in neutral and retro-cue trials compared to pre-cue trials. In order to investigate these hypotheses, we used the Attentional Orienting Task that allowed us to study the influence of selective attention in encoding and maintaining information in VSTM.

Both d-prime and Cowan's K analyses showed that TDA had better performance than individuals with ID in both cued and neutral trials across both conditions (pre-cue, retro-cue). This finding is in agreement with our initial hypothesis that individuals with ID will demonstrate impairments in both selective attention and VSTM. Importantly, TDA had both pre-cue and retro-cue benefits, whereas individuals with ID showed no cueing benefits in either pre-cue or retro-cue conditions. This finding is in contrast with our second hypothesis that individuals with ID would benefit from pre-cues, but not from retro-cues.

Our findings from the TDA group are in agreement with previous studies showing that neurotypical adults can orient their attention to incoming perceptual stimuli and to internal representations to facilitate VSTM (Griffin & Nobre, 2003; Shimi et al., 2014; Shimi & Scerif, 2017). Our findings from the ID group are supported by past studies showing that individuals with ID have limited attentional resources (Levén et al., 2011; Nugent & Mosley, 1987; Oka et al., 2008) and deficits in attention selection and scanning processes (Oka et al., 2008; Zeaman & House, 1963;1979; Zeaman, 1965). Moreover, a past study showed that individuals with ID have poorer orienting reactions, which could cause non-efficient attentional separation of the relevant stimulus from the irrelevant stimuli (Luria et al., 1963), leading them to choose the irrelevant stimulus over the relevant ones. Also, another study showed that individuals with ID present higher levels of distractibility (Brown,1996). Similarly, our finding indicating that individuals with ID have poorer VSTM capacity in comparison to TDA agrees with past studies showing deficits in serial STM (Chapman, 1997; Laws & Bishop, 2004; Majerus & Van der Linden, 2003; Merrill & O'dekirk, 1994; Thorn & Frankish, 2005). Here, employing a simultaneous presentation of visual items, we demonstrate that individuals with ID have a much smaller VSTM capacity than 4 items, which is the average capacity of TDA (Cowan, 2001). Importantly, to our knowledge this is the first study showing a direct link between impaired selective attention and poor VSTM in individuals with ID.

Our novel finding is important because past research has shown that individuals with syndromic or non – syndromic ID have a variety of cognitive profiles and impairments in different processes of memory functions, such as information encoding process and deficits in information retrieval (Carlesimo & et al.,1997; Katz & Ellis, 1991; McCartney, 1987; Spitz, 1966; Watkin, 1974; Winters & Semchuk, 1986). In the present study, ID-etiology varied between participants, which may have contributed to the absence of interaction between selective attention and VSTM processes, as some ID–associated syndromes generally have impairments in VSTM processes (Burack & Ziglcr, 1990; Curfs et al., 1991; Dykens et al., 1992; Freund & Reisis, 1993; Gabel et al., 1986; Mazzocoo et al., 1993; Nanson & Hiscock, 1990; Pulsifer, 1996; Russell et al., 1991; Streissguth et al., 1991; Warren & Hunt, 1981).

The findings of our study, indicating that individuals with ID have smaller attentional benefits in the encoding and maintenance processes of VSTM compared to typically-developed adults, also align with the results of past developmental studies examining the interaction between attentional orienting and VSTM from early childhood to young adulthood. Previous studies that utilized the same AOT task in 6-7 year-old children and typically-developed adults found that young children exhibited smaller cueing benefits compared to adults (Shimi et al., 2014; Shimi & Scerif, 2017), consistent with our findings. However, our study revealed a surprising result, that is, individuals with ID had no cueing benefits in any of the two conditions (pre-cue and retro-cue), contradicting developmental studies that demonstrated attentional cueing benefits in 6-7 year-old children during encoding and maintaining VWM information, albeit smaller than adults, and larger pre-cue than retro-cue benefits. Specifically, previous studies showed that 6-7 year-old children benefited from attentional cues, particularly in the process of encoding (pre-cue condition), with younger children benefiting to a smaller extent from retro-cues compared to older children and young adults (Astle et al., 2012; Shimi et al., 2014; Shimi & Scerif, 2017). These findings led to the suggestion that developmental differences during the maintenance process rely on age-related changes in using controlled voluntary visuospatial orienting, instead of being automatic (Astle et al., 2012; Shimi et al., 2014; Shimi & Scerif, 2017). Based on the findings of developmental studies and our findings, we propose that maintenance processes rely on age-related changes and the intellectual abilities of the individual in using selective attention. Furthermore, since individuals with ID did not show any attentional benefits in the pre-cue condition while 6-7 year-old children did (Shimi et al., 2014; Shimi & Scerif, 2017), we demonstrate that individuals with mild and moderate-levels of ID may have poorer ability in encoding information in VSTM than 6-7 year-old children. Additionally, individuals with ID may have a smaller VSTM capacity compared to 6-7 year-old children. Indeed, the mental age of our ID participants using Raven's 2 revealed that the majority had a mental age of 4-year-olds. Future research could compare the abilities of mentally matched individuals with and without ID to examine further the attentional difficulties in service of VSTM of individuals with ID.

For the purpose of understanding the correlation between intellectual ability and cueing benefits (attentional benefits, VSTM capacity level and accuracy benefits) statistical correlations were performed; Pearson's r and partial. Based on Pearson's r correlation analyses, participants' total raw scores on Raven' 2 correlated positively with pre-cue and retro-cue performance, even after controlling for neutral baseline performance and age. These findings indicate that the better the attentional orienting ability in service of VSTM (i.e., for encoding and maintaining information in VSTM), the higher the fluid intelligence score. These correlations provide us with new information on selective attention in service of VSTM and the level of intellectual abilities, since this is the first study to our knowledge that shows a positive correlation between these variables.

Moreover, the results of the correlation analyses suggest that VSTM encoding and maintenance processes are positively related to an individual's fluid intelligence, which is supported by previous studies indicating that the activation and the capacity of WM and VSTM rely on the participant's IQ, age, mental level and the task itself (Engle et al., 1999; Collom & et al., 2004; Connway & et al., 2003; Kyllonen & Christal, 1990). Also, our results are consistent with previous studies that demonstrated WM capacity is positively correlated to IQ (Collom & et al., 2004; Connway & et al., 2003; Kyllonen & Christal, 1990). Furthermore, our results showed positive correlation between fluid intelligence and selective attention, a finding that is in agreement with previous studies indicating that low intelligence is related to the high levels of distractibility (Brown, 1966) and that individuals with ID have damage in attentional orientation (Merrill & Peacock, 1994; Oka & Miura, 2008).

Gathering insights into the interactions of selective attention and VSTM in individuals with ID is paramount, given that these cognitive processes are fundamental for effective learning. Such knowledge can pave the way for the development of more interactive learning methods and tools aimed at enhancing their adaptive abilities. Recently, there has been a growing interest in using Augmented Reality (AR) software to improve the skills of individuals with special needs, including those with ID, as it includes selective attention and visual memory skills. A recent review assessing the efficacy of AR applications has revealed promising outcomes, suggesting that AR could lead to the creation of a new learning method for independence skills, daily living skills and social skills (Cavus et al., 2021). The present study's findings shed light on how attentional deficits observed in individuals with ID impact the interaction between selective attention and VSTM encoding and maintenance processes, alongside highlighting their lessened VSTM capacity of four items. This understanding stands to significantly inform the development of more effective AR software tailored to the unique needs of individuals with ID.

The present study represents a first attempt to address the interaction between selective attention and VSTM encoding and maintaining processes in individuals with ID, incorporating comparisons with TDA, with whom they were chronologically matched. There are some potential limitations concerning the results of this study. One limitation is the lack of reaction time (RT) analysis, because participants with ID did not give responses to all the conditions of the experiment (precue-cued, precue-neutral, retrocue - cued, and retrocue – neutral), responses that are prerequisite for the analysis. Because of this, further information about time benefits due to attentional cues were not available, as well as in which extend selective attention influences VSTM encoding and maintaining processes in individuals with ID. Another limitation of the study is the lack of information about the etiology of ID among participants. Individuals with ID show a variety of cognitive dysfunctions based on their ID origin (Pulsifer, 1996) and therefore exhibit qualitative dissimilarities in cognitive operation (Katz & Ellis, 1991). Not knowing the diagnosis of our participants gives us a huge range of possible explanations for our findings as for multiple possible factors that may have affected the results.

Much work remains to be done before a full understanding of the interaction of visual attention with VSTM processes in individuals with ID is gained, as well as the actual brain-behavior relationships in each ID associated disorder. In terms of future research, it would be useful to embody matching mental age participants with and without ID. Including same mental age participants with and without ID can provide further understanding of selective attention and visual memory functions in individuals with ID, and allow observation of similarities and differences in interactions of selective attention with VSTM encoding and maintenance processes. In previous literature, participants with the same mental age as individuals with ID were children (Courbois, 1996; Dobson & Rust; 1994; Merrill & Marr, 1987; Merrill et al., 1987; Merrill et al., 2003; Spitz & Borys, 1977; Vicari et al., 2000).

The present study can be seen as a first step toward integrating two lines of research, visual selective attention and VTSM encoding and maintaining processes, in individuals with

ID. The present study stimulates further investigation of these cognitive functions in this population and highlights the need for further attention in this research niche. The findings of this study can contribute to the creation of more interactive and personalized to the needs of individuals with ID within the school units learning tools. In conclusion, our study suggests that individuals with ID do not use their selective attention efficiently to encode and maintain the goal-relevant information to boost their VSTM. It also indicated a positive correlation between intelligence scores and cueing benefits in accuracy and VSTM capacity. Lastly, it highlighted the differences in how visual attention interacts with VSTM functions between individuals with ID and TDA.

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