RESEARCH ARTICLE

ACTA Vol. 10, No. 2, 2012, 259-269
NEUROPSYCHOLOGICA

Received: 15.01.2012
Accepted: 28.06.2012

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DIFFERENCES IN THE COGNITIVE FUNCTIONING OF PERSONS WITH WILLIAMS SYNDROME AND PERSONS WITH DOWN SYNDROME

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SUMMARY

Background The goal of this study was to produce a precise picture of the cognitive profile of persons with Williams Syndrome (WS), through a comparison to the characteristic profile of persons with Down Syndrome (DS), another genetic disorder.

Material/ Methods: We examined 35 persons with WS (average age 13.2 years) and a control group of persons with DS, matched for age and mental development. The research instruments used included Raven's Colored Matrices, the Brief Intelligence Test, three subtests from the Wechsler Intelligence Scale for Children – Revised (Similarities, Picture Arranging, and Digit Recall), Piaget's "left-right" test, a fragment from the MMSE, and a test of our own devising for recalling sensible verbal material.

Results: The WS group achieved better results than the DS group in respect to verbal intelligence, abstract thinking, cause-and-effect thinking, digit recall, and orientation in place and time.

Conclusions: WS has a significant impact on the affected person's cognitive level and profile. In order to improve rehabilitation, it would be worthwhile to base interventions on relatively well preserved cognitive functions (verbal intelligence and word memory, including name recall) and social-emotional functions.

Key words: genetic disorders, verbal intelligence, memory, cause-and-effect thinking

INTRODUCTION

Williams Syndrome (WS) is a rare genetic disorder involving multi-system disturbances, manifesting in a range of medical complications, with psychological consequences and a diversified degree of genotypic expression. It produces a specific profile of cognitive functioning. Persons with WS, despite intellectual disability, present many special abilities, especially linguistic and musical. They are characterized by a relatively good social development, which includes ease in making contact, sociability, and strong empathy.

WS is a relatively rare disorder: according to the most recent estimates the frequency of occurrence is 1 in 7500 live births (Stromme et al. 2002). It is caused by hemizygotic, submicroscopic deletions of DNA in the long arm of one of the chromosomes in the pair 7: 7q11.23. These deletions occur spontaneously, and are caused by crossing over between the homologous chromatids of chromosome 7 during meiosis (Hutyra et al., 2008).

A great deal of research has been devoted to the hypothesis that there persons with WS present a specific brain structure. Analyses of brain structure have pointed to a relatively enlarged frontal region in comparison to the rest of the brain. Part of the temporal lobes, the so-called “limbic region,” which is essential for normal affect, is relatively well developed (Reiss et al., 2001). Persons with WS also tend to have a larger cerebellum, especially the part known as the neocerebellum, responsible for language function, and partly also for motor and cognitive functions. The neocerebellum is richly connected to parts of the frontal cortex, which makes speech more fluent (Lenhoff et al., 1998).

In general, brain volume is 13% lower in comparison to healthy norms (Reiss et al., 2001). For the most part, the brain mass is somewhere between 800 grams and 1 kilogram, which is to say, about as much as in persons with Down Syndrome (DS). The two disorders differ, however, in respect to the shape of the brain. In contract to the brachycephaly that occurs in DS, individuals with WS will have smaller heads on the horizontal plane, especially in the posterior parts of both hemispheres (Galaburda & Bellugi, 2001).

WS is frequently accompanied by numerous health problems, especially cardiological defects. Generalized arteriopathies produce stenosis of the arteries in both the circulatory and pulmonary systems. Problems with the kidneys and the urinary tract affect 10-20% of persons with WS (Kaplan, 2006).

In terms of cognitive functioning, almost all persons with WS present with below-average intelligence. About 95% of the WS population is diagnosed with mild to moderate intellectual disability (Bellugi et al., 1994).

Among the greatest assets in school-age children with WS are:

- good verbal abilities;
- good memory;
- ability to learn by visual, auditory, and kinesthetic methods (based on their own personal experience);
- musical talent;

- a high level of enthusiasm, motivation, and engagement.

The greatest problems are caused by deficits in:

- abstract and cause-and-effect thinking;
- visuo-motor coordination;
- spatial thinking and imagination;
- planning and organization of complex activities;
- correct reading of non-verbal communication;
- separating the essential from the trivial;
- concentration;
- impulse restraint (Grejtak, 2002).

Persons with WS are endowed with excellent memory skills. They display exceptional abilities in the accurate, very precise and detailed reproduction of memorized stories, song lyrics, poems, and jokes, often successfully mimicking the facial expression and tone of voice of the original teller (Semel & Rosner, 2003).

Unfortunately, persons with WS also manifest certain memory deficits. From information gleaned from the parents of WS children it can be inferred that as many as 43% have difficulties in remembering. The greatest difficulties are encountered in remembering instructions, information, facts, and the location of objects on a map and in space (Tharp, 1986, cited by Semel & Rosner, 2003).

The majority of persons affected by WS display linguistic abilities. They usually display a rich vocabulary, good story-telling skills, and the ability to make interesting conversation. They use a rich spectrum of vocal expression. along with engagement and interest in the interlocutor, according to symptom formation theory (Brown & Pachalska 2003).

One of the characteristic features of the cognitive profile in WS is a low level of visuo-spatial skills, which are not only below average for their age, but also below their overall mental ability (Mervis, 1999). Persons with WS display weak spatial orientation, and the task of differentiating right from left or distinguishing other directions causes them particular difficulties (Semel & Rosner, 2003).

Another genetic disorder that will be discussed here is Down Syndrome (DS), which is among the most common chromosomal aberrations. The cause of DS is generally thought to be trisomy of chromosome 21, though at times the cause may be a regrouping of genetic material involving:

- structural changes in the form of duplication of only a given segment;
- inversions with duplication of the given segment or chromosome translocation (an exchange of segments between two chromosomes);
- karyotype crossover with partial trisomy of chromosome 21 (Midro, 2008).

Major organ and system defects, which include defects in the central nervous system, the sensory system, the cardiovascular system, the skeletal system, the respiratory system, and the digestive system, have a fundamental impact on all basic life functions in persons with DS (Sadowska et al., 2008).

All persons with DS show a generalized retardation of brain growth, which reaches a much lower volume (even up to 50%) and mass in comparison to healthy brains. The neocerebellum is also of smaller volume. There is reduced

neuronal density in DS (30—50% fewer neurons) and less volume of cerebral cortex in the frontal, temporal, and occipital regions (Sadowska et al., 2008).

As for cognitive development, DS children show a global retardation of development, deficits in speech and memory, and disorders of perception.

The thought processes of persons with DS are pictorial and concrete. They do not acquire reasoning skills or the capacity for abstract thinking (Pąchalska et al. 2010).

Intellectual disability and delayed psychomotor development constitute one of the most basic features of DS. Most of these children display mild or moderate intellectual disability (Sadowska et al., 2008).

Persons with DS have a specific profile of development and cognitive processing. Memory functions are on a low level, in terms of both capacity and accuracy (Zasępa, 2003; Rożnowska, 2007). Short-term memory is highly dependent on the material to be remembered: much shorter latency and greater accuracy can be observed in tests measuring visual memory than in the case of auditory memory. Persons with DA achieve much worse results in examinations of auditory memory than do persons with general intellectual disability in respect to memory for sentences and digits forward and back. Research conducted by Jarrold, Baddeley and Hewes (1999) on digit recall provided confirmation that persons with DS achieve lower scores than persons with WS.

The development of speech in DS children is mostly slower than in healthy children of the same age. Speech in DS is unclear, distorted, garbled. Their utterances feature an impoverished vocabulary and the use of a small number of concepts (Zasępa, 2003).

The available literature indicates clearly that the level of intellectual development in persons with WS is below the level considered normal for the given age group. There is a perceptible tendency in persons with WS to better performance of tasks based on verbal intelligence than non-verbal intelligence (Mervis, 1999; Bellugi et al., 2001). Individuals with WS display particular difficulties with abstract and cause-and-effect thinking, spatial imagination and orientation, and temporal orientation (Mervis, 1999; Grejtak, 2002). Moreover, they often display difficulties in committing information to memory (Bellugi et al., 1994; Lukacs, 2005; Semel & Rosner, 2003).

There is very little information in the literature on the comparison of the functioning of persons with WS and those with other genetic disorders. The research conducted by Bellugi et al. (2001) demonstrated that persons with WS use more complex and grammatically correct sentences than do persons with DS, whose utterances are characteristically short and simple. Persons with WS also show greater interest in the interlocutor and more empathy. In the case of tasks requiring spatial organization, however, persons with WS tend to focus on details, and thus fail to notice the overall appearance of the copied figure. Persons with DS show the opposite tendency: they typically copy only the general outline, without marking smaller elements. The information derived from the research conducted by Klein and Mervis (1999) indicates that persons with WS achieve

better results in tests measuring digit recall than do persons with DS. Spatial orientation does not differentiate these two groups.

The goal of our study was to examine the profile of cognitive development that is normal for persons with DS, and to determine which functions develop relatively well, and which not, thus requiring intervention. The research question was this: what are the differences in the cognitive functioning of persons with WS and DS?

MATERIAL AND METHODS

The research was done on an individual basis, and took place as part of comprehensive medical and psychological research organized by the Society to Aid Persons with Williams Syndrome, and also in homes and schools attended by WS children. The research was done in 2008-2009.

The experimental group (WS) was composed of children, youth, and adults who had a diagnosis of WS confirmed by genetic testing. This group counted 35 persons, with an average age of 13.2 years (standard deviation 3.34). The control group (DS) included 16 persons with DS (average age 12.5±3.93). There were no statistically significant differences between the two groups in respect to age: t=0.66, p=0.51. The two groups also displayed marked similarity in intellectual development, as measured by Raven's Colored Matrices: t=1.70, p=0.09.

The research instruments included the following:

- Raven's Colored Matrices;
- The Brief Intelligence Scale;
- three subtests from the WISC-R (Similarities, Picture Arranging, Digit Recall);
- Piaget's "right-left" test for spatial orientation;
- a portion of the Mini-Mental State Examination (MMSE);
- an authorial test of recall of sensible verbal material.

RESULTS

The first aspect of cognitive functioning that we subjected to empirical verification was verbal intelligence. In view of the better performance by persons with WS in tasks based on verbal material rather than non-verbal material, we assumed that the WS group would have better scores than the DS group on verbal intelligence, as measured by the Brief Intelligence Test. The results actually achieved by the two groups on this test are shown in Table 1.

Table 1. Results from the two research groups on the Brief Intelligence Scale

		WS	DS
Brief Intelligence Scale	M	16.2	6.75
	SD	6.26	3.17

There are important differences between the scores in the WS and DS research groups, as confirmed by the t-Student test. The WS group did in fact achieve significantly higher results than did the DS group: t=5.73, p=0.00. This result would seem to be particularly interesting, in that the two groups showed an approximately equal level of functioning in respect to non-verbal intelligence.

We also assumed that the WS group would achieve higher scores than the DS group in abstract thinking. In order to measure this parameter, we used the Similarities subtest from the WISC-R. Table 2 presents the results achieved by the two research group. The differences between groups are statistically significant (t=5.37, p=0.00).

Once we had established the nature and extent of the differences in respect to abstract thinking, we decided to test for differences in cause-and-effect thinking. The instrument used for this purpose was the Picture Arranging subtest from the WISC-R. The hypothesis was that persons with WS would achieve higher results than would persons with DS.

A preliminary analysis of the data contained in Table 3 shows that there are significant differences between the two groups (t=3.44, p=0.00), confirming the hypothesis that the scores in the WS group for cause-and-effect thinking would be significantly higher than those obtained by the DS group.

Memory is a very important aspect of cognitive functioning. In order to measure possible differences in this respect between our two research groups, we formulated the hypothesis that persons with WS would have better memory scores than persons with DS. Memory functions were measured by means of tools based on verbal and numerical material. Upon comparing the results achieved by both groups (see Table 4), we found that there were significant differences only in the digit tasks (t=4.19, p=0.00), while in the case of word recall the differences were almost negligible (t=0.02, p=0.98). However, regardless of the material used to test memory function, most of the subjects in the WS group had higher scores than their counterparts in the DS group.

Table 2. Results from the two research groups on the Similarities subtest

		WS	DS
Similarities	M	10.1	3.75
	SD	4.34	2.96

Table 3. Results from the two research groups on the Picture Arranging subtest

		WS	DS
Picture Arranging	M	10.03	4.69
	SD	5.93	2.57

Based on a review of the literature, we also hypothesized that there would be no between-group differences in respect to orientation in space, location, and time. Orientation in space (right and left) was measured using Piaget's test, as pertains to orientation in respect to one's own body, the researcher sitting opposite the subject, and three objects lying on the table in front of the subject.

Our hypothesis was that the the WS group's results would be comparable results to those of the DS group in respect to spatial orientation, and this was confirmed: there were no significant differences between the two groups in this respect (t=-0.15, p=0.88; see Table 5).

As to orientation in place and time, the results turned out to be surprising, in that the data failed to confirm our hypothesis that there would be no difference between the two groups in this respect. The results indicate that the WS group achieved significantly better scores than did the DS group (t=3.98, p=0.00; see Table 6).

A careful analysis of the cognitive profiles of both groups drew our attention to an interesting dependency. In the set of words used to measure word memory there were two tasks based on memory: for names and for concrete words. Our subjects dealt with these tasks at a different level. An analysis of the relation between memory for words and names and group was conducted, using analysis of variance with repeated measures. The inter-group factor was the research group, and the type of word memory was the repeated measure factor. The results confirmed the supposition we had made: F(1,54)=11.265, p=0.00. The DS group achieved higher scores on the task requiring memory for concrete words than for names, while the profile for the WS group was the opposite: they more easily remembered names than words. The differences were statistically significant (F=23.74, p=0.00).

These results may be related to the relatively good social development and empathy characteristic for persons with WS, who are very sociable, enjoy making

Table 4. Results from the two research groups on the memory tests

		WS	DS
Digit Recall	M	4.94	1.81
	SD	2.73	1.76
Word Memory	M	6.71	6.69
	SD	4.62	2.77

Table 5. Results from the two research groups on the Piaget test

		WS	DS
Piaget	M	10.8	11.0
	SD	4.99	2.5

Table 6. Results from the two research groups on the Mini-Mental State Examination

		WS	DS
MMSE	M	5.83	3.06
	SD	2.31	2.29

new friends, and have a large social network (see also Pachalska et al., 2012). It is probably for this reason that they performed better on the task based on memory for names, as opposed to the task that required them to remember words.

DISCUSSION

Researchers working on Williams Syndrome are unanimous regarding the associated intellectual disability. Our research also confirmed this observation.

Mervis (1999) and Bellugi et al. (2001) called attention to the tendency of persons with WS to perform better on tasks requiring verbal intelligence than nonverbal intelligence. In our research we observed this same tendency.

Both Mervis (1999) and Grejtak (2002) have pointed out the particular difficulties that are posed for persons with WS by abstract thinking. However, the results we obtained from the Similarities subtest indicate that these difficulties are even greater for persons with DS.

The aforementioned authors add that person with WS also display deficits in respect to cause-and-effect thinking. Our research, using the Arranging Pictures subtest from the WISC-R, showed that persons with WS function at a higher level in this respect than do persons with DS.

Another question that has not been completely resolved is the comparison of short-term auditory memory in WS and DS. Bellugi, Wang, and Jernigan (1994) and Klein and Mervis (1999) reported that WS children have much better memory than DS children. Confirmation was also provided by Jarrold, Baddeley, and Hewes (1999), who studied digit recall; their WS subjects achieved an average score of 13.93±3.38, whereas the DS subjects had only 9.68±3.37. The Digit Recall subtest from the WISC-R was also used by Wang and Bellugi (1994), whose WS subjects had higher scores than the DS subjects in both tasks, digits forward and digits back. Between-group differences in digit recall – $t(12)2.7$, $p<0.01$ – were also reported by Klein and Mervis (1999). Our own results were consistent with these data, so far as digit recall is concerned. The task that used diverse verbal material, on the other hand, indicated that the DS subjects were functioning on very nearly the same level as the WS subjects. These data contradict the results reported by Klein and Mervis (1999), who also required their subjects to remember words. These authors reported that their WS subjects had higher scores than their DS subjects: $t(12)=2.7$, $p<0.01$.

Some surprising information was provided by the analysis of results from the task measuring verbal recall. The WS group, in contrast to the DS group, had

better memory for names than for concrete words. The difference can be explained in terms of the characteristic features of social development in persons with WS, especially sociability, which causes persons with WS to have a wide circle of friends, and inclines them to make contact with other people, including strangers.

Our research demonstrated that persons with WS and those with DS show a similar level of functioning in respect to spatial orientation. There can be little doubt that poor orientation in space is characteristic for WS. The literature contains research results from which it can be concluded that WS is associated with problems in recognizing directions correctly. Difficulties involving body scheme and spatial orientation, including the inability to differentiate left from right and basic directions, have been reported by Semel and Rosner (2003). Our research also confirmed the information reported by Klein and Mervis (1999) regarding the lack of difference in this respect between WS and DS. Our subjects with WS obtained higher scores in tasks measuring orientation in time and place, however, than did those in the DS group. In the literature we found no data regarding this observation. The difference between the level of spatial orientation shown by the WS group in the Piaget test and the MMSE tasks can be explained in terms of the additional skills involved in correct solutions to these problems. In the case of left-right orientation, an appropriate level of abstract thinking is required, while the questions concerning orientation in time and place are based on consciousness of one's own self, since they require reference to oneself and one's own perceptions.

The information we collected and the results of our research justify the conclusion that persons with WS display a different profile of cognitive functioning when compared to persons with DS. Thus the very existence of a genetic defect does not predetermine a specific model of cognitive development. Functioning in the domains of overall mental acuity, verbal intelligence, abstract and cause-and-effect thinking, memory, and spatial orientation is dependent not so much on the intellectual disability caused by a genetic disorder, as by the type of disorder.

CONCLUSIONS

Our research indicated that the level of cognitive functioning significantly differentiated a group of persons with WS from a group with DS. The WS group achieved better results than the DS group in verbal intelligence, abstract thinking, cause-and-effect thinking, digit recall, and orientation in place and time.

Our results, backed up by a review of the literature on the subject, suggest that WS exerts a major impact on the cognitive level and profile of persons suffering from this disorder.

A clear picture of the characteristic features of functioning in persons with WS can contribute to the construction of adequate methods to teach WS children and support their development. In order to achieve better outcome in rehabilitation, it seems worthwhile to base intervention on the strong and relatively well

preserved functions of cognitive development (verbal intelligence, word memory, including memory for names) and social-emotional development.

In building programs to support the development of persons with WS, it is necessary to bear in mind that these individuals, despite the fact that they have been affected by the same genetic disorder, may differ from each other. The deletion in chromosome 7 can affect about 20 genes, but in particular cases the number and configuration of genes may be quite different, which can be a source of differences in cognitive and social-emotional functioning. For this reason it is essential to remain cautious in analyzing and generalizing results for the entire population of persons with WS.

Our research suggests that in integrative classes, special classes, and school support centers, teachers should adapt their programs and teaching materials correspondingly for particular pupils, who may indeed present a similar level of mental impairment, but their profile of cognitive, social, and emotional development can be quite diverse, as demonstrated here.

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