Global and local music perception in children with Williams syndrome

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Musical processing can be decomposed into the appreciation of global and local elements. This global/local dissociation was investigated with the processing of contour-violated and interval-violated melodies. Performance of a group of 16 children with Williams syndrome and a group of 16 control children were compared in a same–different task. Control participants were more accurate in detecting differences in the contour-violated than in the interval-violated condition while Williams syndrome individuals performed equally well in both conditions. This finding suggests that global precedence may occur at an early perceptual stage in normally developing children. In contrast, no such global precedence is observed in the Williams syndrome population. These data are discussed in the context of atypical cognitive profiles of individuals with Williams syndrome. *NeuroReport* 16:631–634 © 2005 Lippincott Williams & Wilkins.

Key words: Global/local; Music; Williams syndrome

INTRODUCTION

Williams syndrome is a rare genetic disorder characterized by a dissociated cognitive profile [1]. Persons with Williams syndrome present weaknesses in visuospatial, motor and arithmetic skills along with strengths in face perception, memory, sociability and selected aspects of language. Moreover, an increased interest in music has frequently been reported in people with Williams syndrome. A large number of parents and professionals believe that their children or patients have absolute pitch and report that they spend many hours listening to music or playing an instrument. Recent work on a large sample of young adults with Williams syndrome established that they displayed greater emotional responses to music and spent more time listening to music than the control group [2].

Although Williams syndrome persons often show remarkable ability in playing musical instruments, their musical perceptual competences have rarely been investigated. To date, most of the studies dedicated to exploring cognitive profiles of Williams syndrome individuals have focused on language [1] and, more recently, on visuospatial abilities [3].

A few studies evaluated music perception in individuals with Williams syndrome. Don *et al.* [4] compared a group of children with Williams syndrome with a group of normally developing children matched on receptive vocabulary. Their data showed that Williams syndrome children were similar to the control group on music tests, but that the former expressed greater liking of music and a greater range of emotional responses to music.

A more in-depth study of musical abilities compared a group of 14 children and adolescents with Williams syndrome with a 14-year-old matched control group [5]. Findings underlined that not all aspects of music were preserved in children with Williams syndrome. Although no difference was found between groups in a musical expressiveness task, the performance of children with Williams syndrome was poorer than that of the controls in pitch and rhythm discrimination tasks.

Finally, neural correlates of music and noise perception were explored in five adults with Williams syndrome and in five control participants [6]. Results showed that Williams syndrome individuals did not activate the same brain areas as the controls when listening to music. The superior temporal and middle temporal gyri were more activated by music than by noise in the controls, while the right amygdala was the only region that was more activated during the music condition versus the noise condition in the Williams syndrome population. These data underlined different neurofunctional organizations in the Williams syndrome pathology compared with the controls.

Music processing undoubtedly involves many neural subsystems for pitch, melody, contour, rhythm or timbre processing [7]. Interestingly, for our purpose, musical processing can also be decomposed into the appreciation of global/holistic and local elements [8]. According to this view, when hearing two successive melodies, a change in the direction of the pitch transition between two successive notes engenders a contour violation that disrupts the global property of the melody. In contrast, a change of the interval between two successive notes, without changing the direction, does not affect the contour and therefore does not affect the global properties but only the local properties of the melody. It is interesting to note that a change in the

global structure of a musical sequence (contour violated, CV) is more salient than a change in the local structure (interval violated, IV) [9]. Moreover, the concept of global and local musical processing seems to have a psychobiological validity insofar as brain lesion patients are differently impaired in the two types of processing, depending upon the side of the lesion [10].

However, no data are available, to our knowledge, on the global/local distinction in music perception in the Williams syndrome pathology. Such distinction would be of particular importance, however, insofar as it could be connected to the one found in the visuospatial domain. Several experiments have reported that the advantage found in normally developing children for the global configuration of visual stimuli compared with their local aspects is absent in children with Williams syndrome [3,11,12]. A lack of global advantage in the auditory domain would argue for a multimodal deficit of global processing in Williams syndrome.

Our study was thus aimed at further exploring musical abilities of children with Williams syndrome by evaluating the relative importance of the global and local aspects of musical perception. Note that stimuli and procedure were adapted from Mottron *et al.* [13].

MATERIALS AND METHODS

Participants: Sixteen participants with Williams syndrome (seven boys and nine girls) were included in this study. Pediatric geneticists established the Williams syndrome diagnoses. The children were all found to fulfill the criteria set out by Preus [14] for a diagnosis of Williams syndrome. All but two Williams syndrome individuals had been diagnosed with medical genetic testing (fluorescent in situ hybridization) that put forward a microdeletion on one copy of the gene for elastin on chromosome 7. Most of the Williams syndrome individuals were recruited via the Regional Williams Syndrome Association. They were aged from 8 years 7 months to 19 years 3 months (M=12 years 7 months, SD=4 years). At the time of testing, all the children were attending school or specialized centers for the educable mentally retarded. Mental ages, inferred from IQ measures (Wechsler Adult Intelligence Scale-III, WAIS-III [15]; Wechsler Intelligence Scale for Children-Revised, WISC-R [16] or Wechsler Intelligence Scale for Preschool and Primary Children-Revised, WPPSI [17] according to the participant's age), ranged from 4 years 2 months to 7 years 7 months (M=5 years 9 months, SD=1 year 8 months). IQ scores were within the range given for Williams syndrome individuals as reported by several recent studies [18]. Note that, in line with previous data [11,19], their scores in the verbal IQ subtest (M=62.5, SD=18.1) were found to be significantly higher than their scores at the performance IQ subtest (M=53.2, SD=12.2) (t[15]=2.7, $p<0.05$), which concords with data from previous studies.

A group of normally developing children was also tested in this study. Sixteen children (chronological age matches) were matched individually to each child with Williams syndrome for sex and chronological age, using a 5-month window (M=13 years 5 months, SD=3 years 7 months).

Children and adolescents of the two groups were also matched in their musical experience. None of them had extensive musical training.

Stimuli: Twelve melodies were built as a basic set of stimuli. Melodies were in the Western tonal idiom, starting and ending with the tonic. All melodies had the same tempo, rhythm and number of notes (N=9). The first eight notes were crotchets at a 170-bmp pace (350 ms ca.), while the last notes lasted more than twice as long (900 ms). All melodies underwent two types of modification: contour modification and interval modification. The contour modification created a CV melody, which was identical to the original melody except for a single pitch that modified the contour direction of the surrounding intervals. The interval modification created an IV melody, changing the same pitch as in the corresponding CV melody, but keeping the original contour. Note that the pitch modification was of diatonic type (without tonality change), and the serial position of the modified pitch varied across melodies. Although CV and IV are different stimuli, modifications took into account the following constraints: the average departures from the tonic were very similar (4.3 and 4.1, $p>0.3$); the average size for the intervals preceding and following the modified pitch were also very similar across CV and IV (M for preceding=3.5 and 3.5, p=1; M for following=4.1 and 4.2, $p>0.9$).

In order to increase variability of the material, we built 12 more stimuli, only to be used in the 'same' condition. A total of 48 experimental trials were used. Each trial began with a smiling face appearing on the screen to warn that a trial was going to begin. Then, a target melody was presented, followed after a 1.5-s pause by a comparison melody. Half of the trials were of 'same' type, using all the 24 melodies. The trials containing different melodies used only the first 12 melodies, followed by a CV (12 items) or by a IV (12 items) trial.

Procedure: Participants were tested individually in a quiet room of the CNRS in Marseille or at their home. Seated in front of a computer equipped with headphones, they were asked to listen to two successive melodies and then decide whether they were identical or slightly different. If they chose the 'same' answer, they had to press the 'a' keyboard button while they had to press the 'p' button for the 'different' answer. Different colored patches identified these buttons. Nine training trials were given prior to the experimental session. Trials were self-paced. All participants underwent a total of 48 trials, consisting of 24 'same' trials, 12 'CV' trials and 12 'IV' trials. The order of trial presentation was randomized for each participant.

RESULTS

The responses on different trials were classified as 'hits' if the participants answered 'different', and responses on 'same' trials were classified as 'false alarms' if participants answered 'different'. The mean proportions of hits obtained in each condition (CV or IV) and of false alarms for each of the experimental groups are presented in Fig. 1.

To replicate the procedure used by Mottron *et al.* [13], the proportion of false alarms was subtracted from the proportion of hits in each condition and for each participant. A single discrimination score was then obtained for the CV and IV conditions.

Data were subjected to an ANOVA with condition (CV/IV) as a within factor and group (Williams

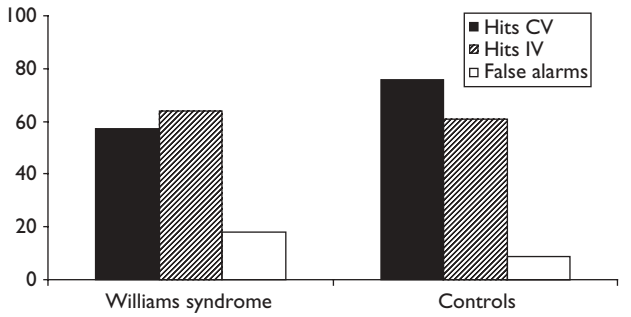

Fig. 1. Mean proportion of hits for the contour-violated (CV) and interval-violated (IV) conditions and false alarms in both Williams syndrome and control groups.

syndrome/chronological age matches) as a between factor. Analysis revealed a significant effect of group ($F[1,30]=9.05$, $p<0.005$), with children with Williams syndrome ($M=83.09$, $SD=36.8$) performing significantly poorer than those of the control group ($M=117.77$, $SD=22.7$). The main effect of the condition was not significant ($p>0.05$) but the group by condition interaction was significant ($F[1,30]=14.03$, $p<0.0008$). Indeed, the effect of the condition was not significant for the Williams syndrome group ($p>0.10$), but it was significant for the control group, with the IV harder than the CV condition ($t[1,15]=3.4$, $p<0.003$). Also note that while no difference between groups was evident for the IV condition ($p>0.05$), Williams syndrome children's performance was worse than that of the controls in the CV condition ($t(1,30)=4.05$, $p<0.0003$).

Scores were not correlated with the children's age in the Williams syndrome or in the chronological age-matched group (Spearman correlation test, $ps>0.7$).

DISCUSSION

The main aim of the present study was to evaluate the relative role of global and local aspects in music perception in Williams syndrome children. This study revealed two important findings.

First, a global analysis advantage in music perception is present in normally developing children. Hierarchical encoding of musical structures favoring the global structure has been supported by several studies using short musical sequences as the ones used in the present work. Our results are thus consistent with previous reports establishing that typically developing adolescents exhibited fewer errors in the contour-violated than in contour-preserved condition [19]. Additionally, electrophysiological evidence revealed that global processing of musical contour occurs at an earlier perceptual stage than local processing [20]. Taken together, these data strongly suggest that global precedence emerges at an early perceptual stage in the normally developing children. This confirms previous results obtained in the visual modality. Global precedence has frequently been reported in children, adolescents, adults and even in young infants when processing visual shapes [21].

Second, and most importantly, children with Williams syndrome do not present such a global advantage, possibly indicating an atypical auditory behavior in this pathology. Note, however, that their overall scores are below those of the controls. Although Williams syndrome children are able to understand and perform the task, their great receptivity to music does not seem sufficient to give rise to a 'normal' level of performance. This appears to contradict previous work showing that musical abilities of Williams syndrome children are commensurate with those of chronological age-matched normal children [2,22]. It is plausible that the task employed in our study is harder than the rhythm production and memory for music tasks used in Levitin and Bellugi [22].

However, it is unlikely that the differences encountered in the two groups in the emergence of global advantage may be explained by task difficulty. Indeed, performance of the Williams syndrome group differed from that of the controls in the CV but not in the IV condition, which was performed equally well by both groups.

Results of Williams syndrome children also depart from those found with the autistic patients by Mottron *et al.* [19]. Scores were better in the autistic population than in the comparison group for the detection of changes in the IV melodies that tap local processing. While scores of the Williams syndrome were never found to be better than those of the controls, they were significantly worse than those in the CV condition that pinpointed global processing. These findings possibly indicate a global integration deficiency in the Williams syndrome pathology, without better performance in local processing.

This pattern of results is reminiscent of the one obtained within the visuospatial domain. Difficulties in drawing global configurations and in assembling blocks to form a coherent whole have been reported in visuospatial tasks in this pathology [3,12]. Similar difficulties were observed in face and geometrical shape recognition tasks. Deruelle *et al.* [11] showed that children with Williams syndrome were less capable than controls in detecting changes that affect the spatial relationships between parts, while they are as able as them in detecting changes that affect the shape of the local elements.

Taken together, these results argue for a multimodal dysfunction of global information integration in the Williams syndrome population. Further studies focusing on the tactile domain, in which a dissociation between global and local aspects has also been described [23], would help to verify the hypothesis of a multimodal dysfunction.

In the visuospatial domain, the lack of global advantage observed in Williams syndrome was attributed to a specific impairment of the dorsal visual pathway, which is the cortical system believed to encode information about spatial relationships and visual control of action [24]. Recent neuroimaging findings are consistent with this hypothesis. Meyer-Linderberg and colleagues [25] showed that the parietal portion of the dorsal stream is not correctly activated when Williams syndrome persons are presented with a hierarchical visual stimuli task.

With respect to the auditory domain, neuropsychological data on normally developing persons point to a greater implication of the right hemisphere in contour processing and of the left hemisphere in interval processing [10]. In contrast, the unique electrophysiological study in the field [20] failed to show a different hemispheric lateralization for the two types of processing, but rather showed an early negative component peaking around 200 msec with a frontocentral distribution that was present only for CV melodies. These findings strongly suggest an automatic detection of musical information. Our results seem to indicate that this automatic detection is absent in the

Williams syndrome population. To understand whether this deficiency is connected to the different neurofunctional basis for music and noise processing recently shown between Williams syndrome and normally developing participants [6], further studies focusing on the neural structures involved in global and local music processing in this population are required.

CONCLUSION

These results are the first evidence of an atypical musical processing strategy in Williams syndrome. The atypical processing may be similar to the one observed within the visuospatial domain, which in return may suggest a multimodal atypical processing style.

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