FROM LOW TO ROUTINE EXPERTISE: CASES OF DYSMUSIA WITH DEFICITS IN VISUO-SPATIAL AND COMPUTATIONAL SKILLS

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***Abstract**: Aiming at developing a more integrated frame of mental faculties (*intelligence *and* metacognition*) correlated with types of* expertise *(learning and achieving), this paper looks at the* ability-disability dissociation *within musical intelligence displayed by individuals with a genetic disorder called* Williams syndrome *(*WS*). Despite the innate musicality that marks many individuals with* WS*, their inability to read spatially and computationally oriented Western musical notation requires them to depend on oral transmission for learning of the repertoire. They have* dysmusia *without having* amusia*. We attribute dysmusia in WS to their deficiency in mathematical and visuospatial abilities. However, their ability to well comprehend the isochronal sound quality of* mora-timed *languages support the hypothesis that they could potentially read Western musical notation if it were re-oriented to be linear and non-computational. This paper demonstrates how this hypothesis is borne out and argues that the musical notation devised offers a case in which 'disability' (low expertise) can be turned to 'ability' (routine expertise). The new type of expertise broadens the conventional frame of mental faculties accordingly.*

***Keywords**: dysmusia, Williams syndrome; types of expertise; metacognition; frame of mental faculties; multiple intelligences.*

Introduction

The general objective of our research is to form an integrated frame of **mental faculties** (**intelligence and metacognition**) correlated with **types of expertise**. Intelligence has been taken as some entity that can be objectively majored and reduced to an **IQ score.** Metacognition (MC), a term attributed to Flavell [Flavell, 1979], is taken as higher-order thinking that enables learning (and hence survival). In general, MC is understood as forming a center for intelligence, thus is positively correlated with IQ. However, the ability to use MC is a separate entity [Veenman, et al., 2006]. Relevant here are two types of expertise: (a) classical **routine expertise (RE)** which involves mastering procedures so that they become highly efficient and accurate and (b) **adaptive expertise (AE)**, posited by [Hatano & Inagaki, 1986], which involves conceptual understanding that allows the "expert" to invent new solutions to problems and even new procedures for solving problems. Table 1 shows correlations among IQ, MC, and types of Expertise; (1) typically developing individuals with normal IQs (thus with age appropriate

MC) are adaptive experts if they possess the ability to use MC; otherwise, (2) they are routine experts who yet may reach adaptive experts by training. It is not difficult to place atypically developing individuals with mental disorder as type (3) low expertise; they are unable to use MC since their MC is low.

An issue is raised as to whether these three types are exhaustive or not. Based on the cognitive profile of a genetic disorder called Williams syndrome, this paper proposes that there is another type of expertise, type (4) in Table 1: **low expertise**, but which may reach routine expertise if **cognitively sensible unique training** is provided.

Table 1. IQ-MC-Expertise Correlations

Types of population	Intelligence (IQ)	Metacognition (MC)	Ability to use MC	Types of Expertise
(1)	normal	age appropriate	+possed	*adaptive expertise*
(2)	normal	age appropriate	–possed	*routine expertise*, but reach adaptive expertise by training
(3)	low	low	–possed	*low expertise*
[(4)] *unattested	low	low	α possed	low expertise, but can reach routine expertise through cognitively sensible training

We will confirm the relevance of the notion of *Inclusive Education* (*IE*), whose fundamental spirit is to respect and meet educational needs specific to individual students, regardless of whether they are disabled or not. *IE* is a relatively new, globally developing standard notion. We recognize with interest that it is in harmony with a long-running educational slogan “If the students don’t learn the way we teach, we teach the way they learn.”

Multiple intelligences in Williams syndrome

Williams syndrome (WS), also known as **Williams-Beuren syndrome** named after two cardiology groups in the early 1960s, [Williams, et al., 1961] and [Beuren, et al., 1962], is a hemizygous multisystem disorder caused by microdeletion of 26 to 28 genes, most notably the elastin gene (ELN), from chromosome #7 (the region labeled 7q11.23). Estimated to occur 1 in 7,500 to 10,000 live births [cf., Strφmme, et al., 2002], the deletion links to physical anomalies including narrowing of the aorta (often fatal), slow physical growth, and specific facial appearances.

Individuals with WS are also predisposed to certain cognitive difficulties; they are at large marked by mild to moderate retardation with IQ ranging from 40 to 100; they have a severe deficiency in mathematical and spatial abilities; their fine motor control skill is severely affected. The onset of speech is significantly delayed; however, the end-state of language development in WS is not only relatively spared but often shows large vocabulary. Their oral language is quite expressive, letting them be known as good story tellers. They are apparently sociable, and show empathy to other people. Moreover, the majority of them show excellent affinity for music; some of them even possess absolute pitch perception. A number of these physical and behavioral similarities suggest that at least some of the fairies in the early yarns were modeled on people with Williams syndrome [Lenhoff, et al., 1997].

The nativists' view of such cognitive dissociations (i.e., peaks and valleys in cognitive abilities) in *WS* posed a possibility of a modular organization of human brain functions [Bellugi, et al., 1988]. Although such a proposal has been challenged as inappropriate by *neuroconstructivists* such as Karmiloff-Smith [Karmiloff-Smith, 1992], it is clear that the aforementioned simple frame of IQ-MC-Expertise, in which only the three population types (1), (2) and (3) in Table 1 are accommodated, does not suffice for the understanding of an individual as an integrated human being. Cognitive dissociations in *WS* may be better accommodated by broader frames of mind that have been disseminated as **multiple intelligences** [Gardner, 1993; 2009].

In the theory of multiple intelligences, people's capabilities are grouped into the following eight comprehensive categories [Gardner, 2009: 6-7], though these multiple intelligences are interrelated and thus these groupings are not necessarily so clear-cut.

- *Linguistic* (i.e., the capacity to use words effectively, whether orally or in writing),
- *Logical-mathematical* (i.e., the capacity to use numbers effectively and to reason well),
- *Spatial* (i.e., the ability to perceive the visual-spatial world accurately and to perform transformations upon those perceptions),
- *Bodily-kinesthetic* (i.e., expertise in using one's whole body to express ideas and feelings and facilitate in using one's hands to produce or transform things),
- *Musical* (i.e., the capacity to perceive (e.g., as a music aficionado), discriminate (e.g., as a music critic), transform (e.g., as a composer), and express (e.g., as a performer of musical forms),
- *Interpersonal* (i.e., the ability to perceive and make distinctions in the moods, intentions, motivations, and feelings of other people, including sensitivity to facial expressions, voice, and gestures),
- *Intrapersonal* (i.e., self-knowledge and the ability to act adaptively on the basis of that knowledge),
- *Naturalist* (i.e., expertise in the recognition and classification of the numerous species (the flora and fauna) of an individual's environment).

Cognition in Williams syndrome may be characterized as follows. Strengths are in linguistic, musical, interpersonal, and perhaps naturalist categories; weaknesses are in logical-mathematical, spatial, intrapersonal, and bodily-kinesthetic categories in the sense that fine motor control is severely defected. Among them, linguistic and musical intelligences as abilities and logical-mathematical and spatial intelligences as disabilities are relevant to the purpose of this paper.

In WS, logical-mathematical intelligence is severely affected; they have difficulties with simple addition or subtraction. Mental computation of basic arithmetic operations is beyond their reach. They also face difficulties with spatial skills. Figure1 drawn from Katada [Katada, 2015] shows that they are unable to perform a task of drawing double-strata characters; they see the details of the character, but do not grasp its whole. Figure 2 (taken from *Science Mystery* broadcast by Fuji TV, 2003) shows that their capacity for comprehending three-dimensional figures is severely limited.

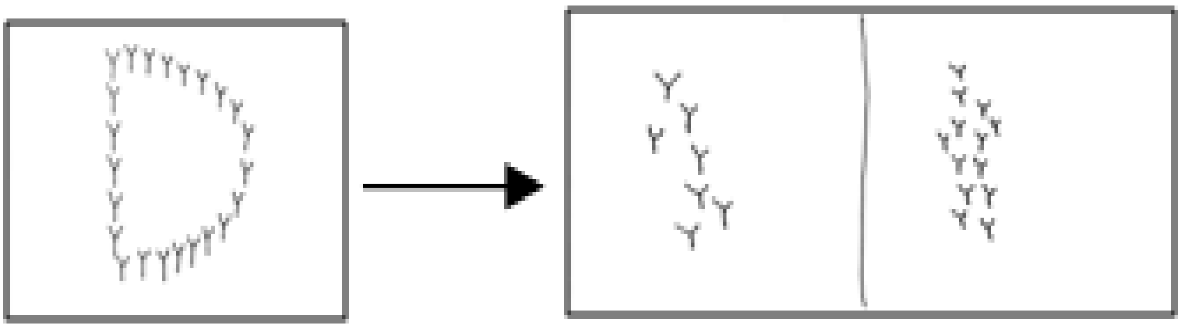

Figure 1. Drawing of characters in double strata

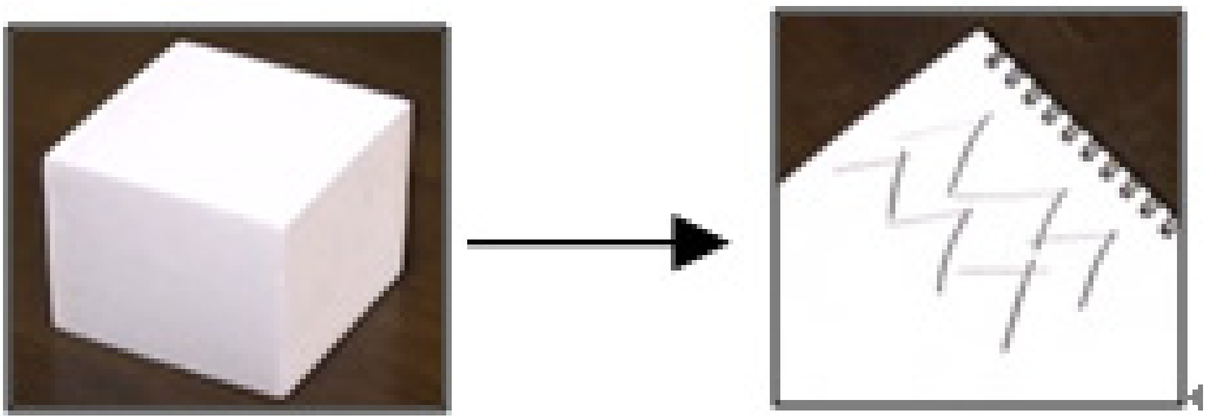

Figure 2. Drawing of 3-dimentinal figures

Figure 3 and Example 1 below are taken from Lenhoff, et al [Lenhoff, et al., 1997]. They together show a clear contrast between defected spatial skills and expressive oral language skills in WS. The same subject (14 year-old, female, IQ 49) demonstrates a limited drawing of an elephant, but quite expressive oral skill for describing the same animal, although it should be noted that their verboseness is often far beyond their level of comprehension.

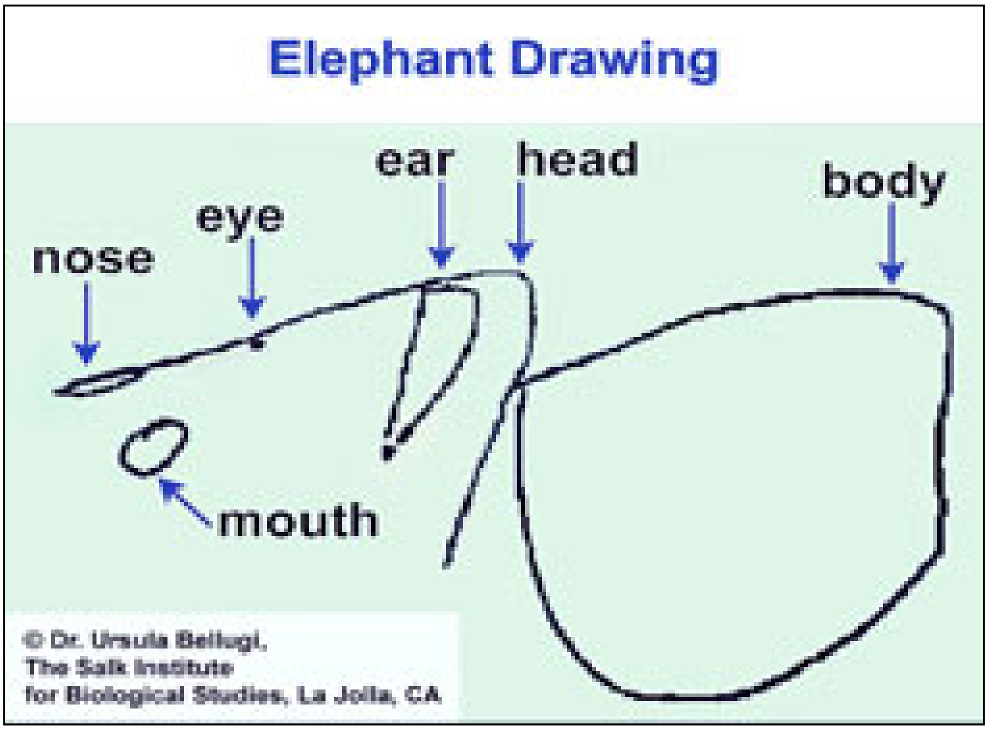

Figure 3. Drawing of an elephant

What an elephant is, it is one of the animals. And what an elephant does, it lives in the jungle. It can also live in the zoo. And what it has, it has long, gray ears, fan ears, ears that can blow in the wind. It has a long trunk that can pick up grass or pick up hay. If they're in a bad mood, it can be terrible. If the elephant gets mad, it could stomp; it could charge. Sometimes elephants can charge. They have big long tusks. They can damage a car. It could be dangerous. When they're in a pinch, when they're in a bad mood, it can be terrible. You don't want an elephant as a pet. You want a cat or a dog or a bird.

Example 1. Oral description of elephants

Equally strong as their oral linguistic skill is their musical intelligence. The affinity they show for music has been well reported in the literature. Many of them have perfect pitch perception without being trained and some even have musical expertise [Lenhoff, et al., 2001]. Their musical intelligence, however, is limited by nature to oral and aural facets.

Dysmusia but not amusia in Williams syndrome

Despite the innate musicality that marks many individuals with Williams syndrome, most of them have difficulties in reading Western musical notation. For singing or playing musical instruments, they depend on auditory transmission for learning of the repertoire; that is, they neither find printed music for themselves nor perform it without having it played or sung to them in advance. Furthermore, despite the fact that many of them compose their own songs orally or instrumentally, they are unable to transcribe the music by themselves.

There is a term ***amusia***, attributed to Knoblauch [Knoblauch, 1888]; it denotes an impaired capacity for musical activity, which appears mainly as a defect in processing pitch. ***Dysmusia***, on the other hand, is a relatively recent term attributed to Gordon [Gordon, 2000], who proposed the idea of ***musical dyslexia***, an inability to read musical notes. Clearly, cases of Williams syndrome are not amusia but dysmusia. The field of research on WS has paid much attention to their innate musicality but the fact that the affected individuals are dysmusical seems to be so given that research reports of dysmusia in WS are very rare. It should be noted in this connection that reports of dysmusia are in general rare. This fact may be due to a sociological reason; in most of the cultures worldwide, dysmusia is not taken as a serious disorder for life.

Phenomenologically, dysmusia or musical dyslexia (the inability to read musical scores) in Williams syndrome is akin to ***developmental dyslexia*,** an inability to read and write text, which manifests not in the dyslexics' oral language but only in their reading and writing. Cognitively, however, there is a sharp difference. Developmental dyslexia is characterized as a failure to reach age appropriate reading abilities, despite adequate intelligence, educational opportunities, socioeconomic possibilities, and in the absence of any cognitive problems such as poor vision or obvious brain damage [Vellutino, 1979]. Dysmusia in WS is likewise developmental in the sense that it is innately present in affected individuals. Unlike developmental dyslexia, however, dysmusia in WS involves deficient cognitive facilities such as weak logical-mathematical and spatial intelligences. In addition, Gordon [Gordon, 2000] reports that, although the skills of learning to read words and music do overlap, they appear to involve different areas of the brain. These commonalities and differences are summarized in Table 2.

Table 2. Dyslexia-dysmusia comparison and contrast

	Developmental Dyslexia	Dysmusia (musical dyslexia) in WS
+affected facilities	skills for reading and writing	skills for reading and writing music
–affected facilities	skills for hearing and speaking	skills for listening and singing music
+ innate	innately with dyslexics	innately with dysmusics
cognitive deficiencies	no obvious anomalies	obvious anomalies
areas of the brain involved (X ≠ Y)	X	Y

We suspect possible cause-effect correlations between cognitive deficiencies and dysmusia in WS.

Cognitive load on reading musical notation

Musical melodies in Western music are typically notated in the fashion illustrated in Figure 4. Melodies are continuous; however, they are written down as if they were a series of discrete units or scores called *rhythm*. Western musical notation, in other words, is a highly evolved coding system. With notes proceeding down and up, the musical coding system relies heavily on spatial orientation in order to differentiate pitches on the musical staff arranged on five lines.

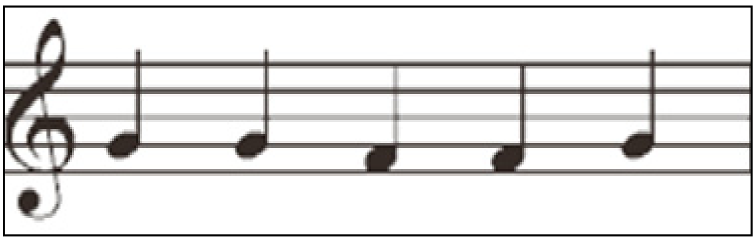

Figure 4. Western musical notation

Furthermore, with a quarter note denoting one beat, one must do *mental computation* quickly, automatically, and unconsciusly as melodies proceed. In Figure 5, for example, two quarter notes (1 beat each) are added together to create a half note, which is twice long over 2 beats without rearticulating the sound.

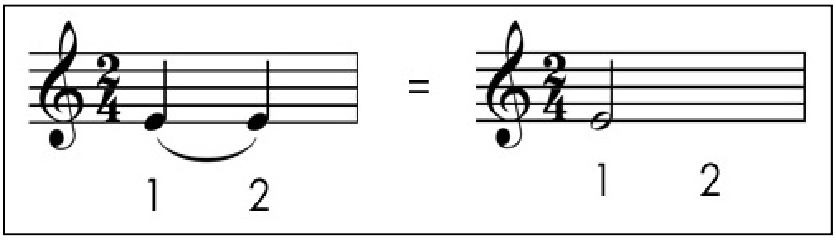

Figure 5. Mental addition in reading music

Conversely in Figure 6, a quarter note (1 beat) breaks down into two eighth notes, each being half length, rearticulated twice.

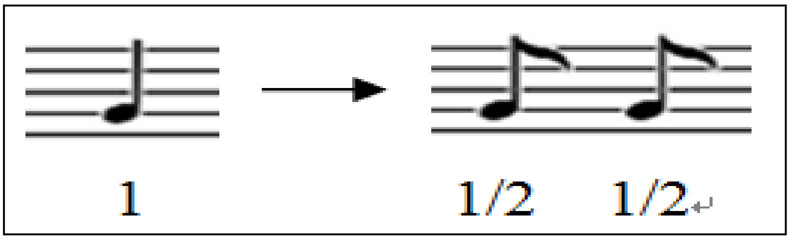

Figure 6. Mental division in reading music

The cognitive workload for reading musical notation is then at least dual; it takes spatial skills and mathematical computation skills. When the rhythm becomes more advanced, as in Figure 7, the cognitive workload for reading music gets heavier and heavier.

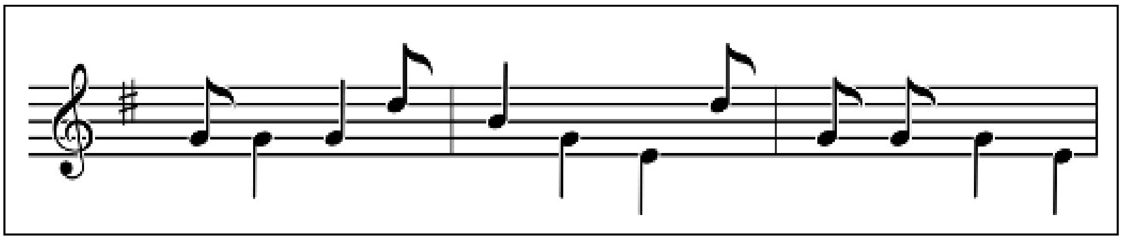

Figure 7. More advanced rhythmic transcription

Due to not only the spatial challenges they usually face but also their deficiencies in computational, mathematical skills, it is not surprising if comprehending spatially and computationally oriented rhythmic transcription is beyond the reach of most individuals with Williams syndrome.

Moraic linguistic rhythm and solfège

Solfège is an exercise in singing using solmization, associating each note of a scale with a particular syllable (do, re, mi, fa, …). We hypothesize that solfège could serve as foundations for pitch orientation in musical notation, and thus can be used to devise musical notation that is comprehensive for individuals with Williams syndrome. There are a few pieces of linguistic evidence that would support this hypothesis.

First, a rhythm is a regular, repeated pattern of sounds which is associated with *isochronism*. In terms of what psychologically real linguistic entities function as **isochronal** (i.e., equally timed), the languages of the world may be classified into three types. In **stress-timed languages** including English, Russian, Arabic, German, etc., each phrase with a phrase-final stressed syllable is isochronal. In **syllable-timed languages** including French, Italian, Spanish, Yorba, etc., each syllable (CVC) is isochronous. In **mora-timed languages** including Japanese, Tagalog, Javanese, Ganda, Kiribati, Ancient Greek, etc., each mora (CV) is isochronal. Among the three types of linguistic rhythms, isochronism is most apparent and complete in mora-timed rhythm. In other words, moraic (CV) linguistic rhythm is closest to solmization where each note stands for CV (i.e., do, re, mi,…). In addition to the above fact, the experiments conducted at the WSA music and enrichment camps for young adults with Williams syndrome (Michigan, USA) have shown that shadowing words and phrases was most smooth in some of the mora-timed African languages such as Swahili and Berber [Katada, 2015]. Furthermore, Katada [Katada, 2008] reported a rare ability of word-reversing ***ludling*** (< Latin *ludas* 'game' + *lingua* 'language') in the mora-timed Japanese by a subject with Williams syndrome.

Relevant to this font are the following facts indicating that a linguistic unit 'mora' is basic [cf. Katada, 1990]. First, early child-language behavior is marked by an over-reliance of CV units and absence of rhyme units (VC), as we see in contrastive pairs of CVC-based adult language and CV-based child language, such as [dog] vs. [doggy], [mum] vs. [mummy], and [dad] vs. [daddy]. Second, nascent readers blend CVC words more efficiently as CV+C than C+VC [Cassady & Smith, 2004]: e.g., for the word *cat* [CVC], *ca+t* [CV+C] is preferred over *c+at* [C+VC]. Also noted is that **phonological dyslexia** is marked by overproduction of CV units and absence of rhyme units VC [Katada & Schneider-Zioga, 2010], which would explain a mysterious gap in surface prevalence between two languages: 15-20% in the rhyme (VC)-based English speaking world, but 1-2% in the mora (CV)-based Japanese speaking world.

In short, the ability to fully comprehend the moraic quality of language in Williams syndrome supports the hypothesis that individuals with WS could be well trained for solmization and could potentially read musical notation under the following conditions:

– the spatial property of the notation is eliminated (i.e., no requirement of visuospatial recognition), and
– the note value (length) is kept constant (i.e., no requirement of mental computation).

The invented notation is expected to reduce or eliminate the aforementioned cognitive workload on both spatial challenges and mental computation challenges they face when reading proper musical notation.

Musical notation devised: from spatial-computational to linear noncomputational approaches

The devised musical notation is illustrated below. First, to represent the pitch degrees of solfège, the system of shaped-note singing is adopted (Figure 9) especially for younger individuals. The spatial property of the notes is eliminated here; thus, there is no requirement of visuospatial recognition.

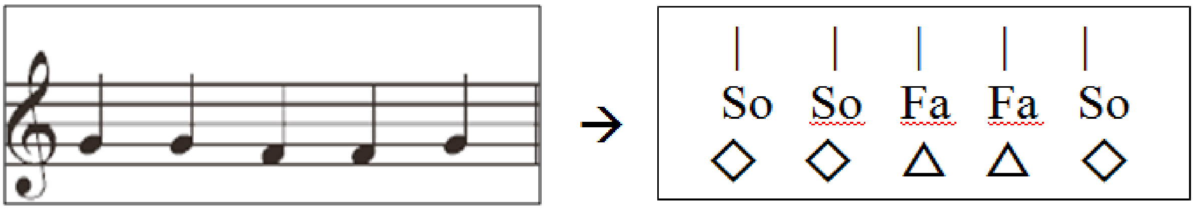

Figure 8. From spatial orientation to linear orientation

Second, to express an extension of pitch length, dashes (----) are used as in Figure 9. The note value is kept constant here and the computational nature of the standard musical notation is eliminated. This would free the individuals with WS from the heavy mental computation challenge.

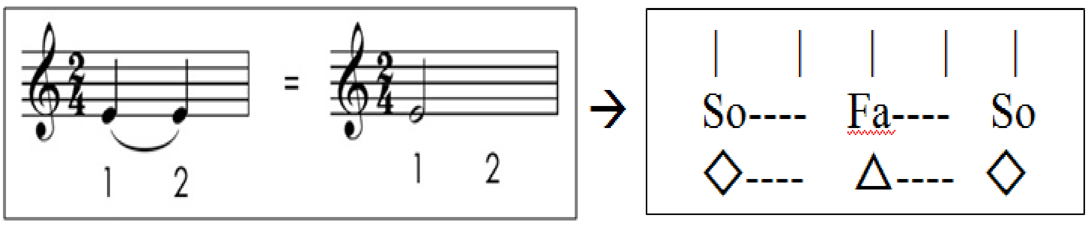

Figure 9. From computational approach to non-computational approach

An experiment was conducted in Japan in 2013, attended by six individuals with Williams syndrome (age 6-16 years old). Five of them have shown almost 100 percent accuracy at reading impromptu melodies transcribed in like manner as linear and non-computational approach. (One 7 year-old with hyper activation was unable to pay enough attention to the lesson.) The linear quality of the beat denoted by (|), the non-computational nature of the pitch length using (----), and solfège with moraic quality do not seem to overload the cognitive processing system of WS.

Conclusion

This paper analyzed properties of standard Western musical notation that is spatial and computational in nature, and developed a new notation that is linear and non-computational in nature. It also looked at the cognitive weaknesses and linguistic strengths of dysmusics with Williams syndrome. The devised musical notation offered a case in which 'unable to read' can be turned to 'able to read' when the cognitive workload behind dysmusia is circumvented. Conclusions drawn from this paper are dual: theoretical contributions and educational implications.

Theoretically, **a fourth type of expertise** is attested, which is added to Table 1 as (4): individuals with low intelligence and low metacognition, thus should be 'low expert', yet may reach 'routine expert' when cognitively sensible unique training is provided. This has broadened a frame of mental faculty correlations.

Educationally, the continuum (spectrum) nature of 'disability' is confirmed. The notion of disability is a matter of degree and thus applies to everyone. The subjects of the study presented in this paper are dysmusics with Williams syndrome; however, the devised notation should work as well for any individuals with similar cognitive difficulties and even for typically developing abled individuals. ***Inclusive education (IE)*** is a relatively recent educational notion, which aims to meet individuals' learning needs and include everyone, regardless of whether they are disabled or not. In *IE*, this paper saw a link to the classical educational slogan: *If students do not learn the way we usually teach, we teach the way they learn.*

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When SM are designed by different stakeholders, such parameters as time, scale, repr, miller and unique are changed (4). Parameter prec depends on the complicity of concrete SM type notation [UML 2.5, 2012].

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