Neuropsychologia 54 (2014) 28–40

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

The enigma of dyslexic musicians

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ARTICLE INFO

Article history:
Received 7 July 2013
Received in revised form
14 November 2013
Accepted 10 December 2013
Available online 19 December 2013

Keywords:
Dyslexia
Frequency discrimination
Musical training
Working memory
Anchoring
Auditory perception
Perceptual learning

ABSTRACT

Musicians are known to have exceptional sensitivity to sounds, whereas poor phonological representations (or access to these representations) are considered a main characteristic of dyslexic individuals. Though these two characteristics refer to different abilities that are related to non-verbal and verbal skills respectively, the recent literature suggests that they are tightly related. However, there are informal reports of dyslexic musicians. To better understand this enigma, two groups of musicians were recruited, with and without a history of reading difficulties. The pattern of reading difficulties found among musicians was similar to that reported for non-musician dyslexics, though its magnitude was less severe. In contrast to non-musician dyslexics, their performance in pitch and interval discrimination, synchronous tapping and speech perception tasks, did not differ from the performance of their musician peers, and was superior to that of the general population. However, the auditory working memory scores of dyslexic musicians were consistently poor, including memory for rhythm, melody and speech sounds. Moreover, these abilities were inter-correlated, and highly correlated with their reading accuracy. These results point to a discrepancy between their perceptual and working memory skills rather than between sensitivity to speech and non-speech sounds. The results further suggest that in spite of intensive musical training, auditory working memory remains a bottleneck to the reading accuracy of dyslexic musicians.

1. Introduction

Developmental dyslexia is defined as a specific deficit in reading acquisition that cannot be accounted for by low IQ, poor educational opportunities, or an obvious sensory or neurological damage (World Health Organization, 2008). There is a wide consensus that dyslexia is a neurological disorder with a genetic origin. The most influential account for reading difficulties is the phonological hypothesis which suggests that dyslexia is characterized by deficits related to phonological representations or access to these representations. These deficits pose a bottleneck to efficient learning of grapheme to phoneme correspondences, which are the basis of alphabetical writing systems (Shaywitz, Mody, & Shaywitz, 2006; Snowling, 2000; Wehner, Ahlfors, & Mody, 2007). Although this hypothesis is influential (see Ramus, Marshall, Rosen, & Lely, 2013, for a multidimensional account), other theories either challenge it (e.g. "The anchoring deficit hypothesis" (Ahissar, Lubin, Putter-Katz, & Banai, 2006; Ahissar, 2007)), or assert that it only addresses some aspects of a broader deficit, and perhaps not the basic deficit. For example, several researchers claimed a general deficit in processing rapid sequences of stimuli, both in the auditory (Tallal, 1980) and in the visual modalities ("The magnocellular theory", Stein, 2001). Others suggested a general deficit in the acquisition of automaticity (cerebellar or procedural deficit, Nicolson, Fawcett, & Dean, 1995, 2001; Nicolson, Fawcett, Brookes, & Needle, 2010; Lum, Ullman, & Conti-Ramsden, 2013), or a sluggish attentional system (Hari & Renvall, 2001; Lallier et al., 2009). Given that reading is a challenging visual task, other researchers focused on visual attentional skills (Lacroix et al., 2005; Valdois, Bosse, & Tainturier, 2004; Vidyasagar & Pammer, 2010).

A key tenet of the phonological deficit hypothesis is that it assumes a domain specific impairment. It is specific even with respect to the auditory modality, where it claims that dyslexics′ deficits relate only to speech components. However, a series of studies reported broader auditory deficits. In a pioneering study, Tallal and colleagues found that dyslexics have a deficit in identifying fast, briefly presented auditory stimuli (Tallal & Piercy, 1974). A series of subsequent studies documented impairments in a range of simple perceptual tasks, including tasks that did not challenge the rate of dyslexics′ identification, but rather the accuracy of their auditory discrimination in spectral (Ahissar

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0028-3932/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.neuropsychologia.2013.12.009

et al., 2006; Ahissar, Protopapas, Reid, & Merzenich, 2000; Amitay, Ahissar, & Nelken, 2002; Baldeweg, Richardson, Watkins, Foale, & Gruzelier, 1999; France et al., 2002; Oganian & Ahissar, 2012; Santos, Joly-Pottuz, Moreno, Habib, & Besson, 2007) and temporal (Corriveau, Pasquini, & Goswami, 2007; Goswami et al., 2002; Huss, Verney, Fosker, Mead, & Goswami, 2011; Vandermosten et al., 2010) dimensions. Other studies pointed to sensory-motor difficulties, particularly when temporal accuracy was required, as in the case of synchronized tapping (e.g. Thomson, Fryer, Maltby, & Goswami, 2006; Wolff, 2002). Importantly, the sensitivity of dyslexics to non-speech sounds was found to be correlated with their reading proficiency as well as with their verbal memory scores (Banai & Ahissar, 2004, 2009). Additional studies documented impaired performance among dyslexics when hearing speech in noise (Chandrasekaran, Hornickel, Skoe, Nicol, & Kraus, 2009; Ziegler, Pech-Georgel, George, & Lorenzi, 2009). Taken together, these studies suggest that dyslexia is characterized by a broader auditory deficit, and more specifically, dyslexics′ difficulties are related to mechanisms that are common to speech and non-speech stimuli. This conjecture has been further supported by recent studies, which found that activity in auditory areas, including auditory brainstem (Hornickel & Kraus, 2013), auditory thalamus (Díaz, Hintz, Kiebel, & von Kriegstein, 2012), and the auditory cortex (Lehongre, Ramus, Villiermet, Schwartz, & Giraud, 2011), is impaired in dyslexia.

Additional support for the idea that general auditory skills are associated with linguistic skills comes from many studies among children at various ages. Some studies show that cortical responses to speech and non-speech stimuli already at birth are significant predictors of later lingusitc and reading abilities (Choudhury & Benasich, 2011; Leppänen & Hämäläinen, 2010; Molfese, 2000). Other studies show that musical skills at pre-reading stages predict subsequent phonological and reading skills (Anvari, Trainor, Woodside, & Levy, 2002; Bolduc & Montésinos-Gelet, 2005; Degé & Schwarzer, 2011; Moritz, Yampolsky, Papadelis, Thomson, & Wolf, 2012). Indeed, among young readers (first grades of school), auditory and reading related skills are correlated (Forgeard, Schlaug, & Norton, 2008; Grube, Kumar, Cooper, Turton, & Griffiths, 2012; Loui, Kroog, Zuk, Winner, & Schlaug, 2011), particularly among those who had no musical training (Banai & Ahissar, 2013; Corrigall & Trainor, 2011; Forgeard, Winner, Norton, & Schlaug, 2008; Tsang & Conrad, 2011). In a complementary manner, 'tone deaf' individuals who have difficulty in auditory frequency discrmination, have significant deficits in phonemic awareness (Jones, Lucker, Zalewski, Brewer, & Drayna, 2009).

Overall, these findings suggest that an individual is either sensitive to both verbal sounds and non-verbal sounds, or is insensitive to both. Pitch and duration form the basic auditory dimensions that underlie the melodic and rhythmic patterns of musical tunes. Not surprisingly, musicians have exceptionally high sensitivity to pitch (Kishon-Rabin & Amir, 2001; Micheyl, Delhommeau, Perrot, & Oxenham, 2006; Schellenberg & Moreno, 2009) and duration of non-verbal stimuli (Banai, Fisher, & Ganot, 2012; Montagni & Peru, 2012; Rammsayer, Buttkus, & Altenmueller, 2012; Rammsayer & Altenmuller, 2006). However, both pitch and duration are also linguistically relevant, both for phonological identifications and for extracting prosodic information (e.g. Astésano, Besson, & Alter, 2004; Böcker, Bastiaansen, Vroomen, Brunia, & Gelder, 1999; Eckstein & Friederici, 2005). Musicians are expert in pitch processing in linguistic contexts, e.g. when differentiating between syllables (Chobert, Marie, François, Schön, & Besson, 2011; Kühnis, Elmer, Meyer, & Jäncke, 2013; Ott, Langer, Oechslin, Meyer, & Jäncke, 2011; Sadakata & Sekiyama, 2011) or words (Besson, Schön, Moreno, Santos, & Magne, 2007; Bidelman, Hutka, & Moreno, 2013; Deguchi et al., 2012; Wong, Skoe, Russo, Dees, & Kraus, 2007). Musicians are also expert in duration processing in linguistic contexts, e.g. identifying metrically congruous or incongruous syllables or words (Chobert, Clément, Jean-Luc, & Mireille, 2012; Marie, Magne, & Besson, 2011). In addition, musicians are more sensitive to emotions conveyed by speech prosody (Thompson, Schellenberg, & Husain, 2004).

In line with the reported behavioral findings, musicians′ brains show differences compared to non-musicians′, both structurally (e.g. Herdener et al., 2010; Imfeld, Oechslin, Meyer, Loenneker, & Jancke, 2009; Oechslin, Imfeld, Loenneker, Meyer, & Jäncke, 2009; Schneider, Scherg, & Dosch, 2002; Steele, Bailey, Zatorre, & Penhune, 2013), and functionally, at the cortical level (e.g. Fujioka, Trainor, Ross, Kakigi, & Pantev, 2005; Kuchenbuch, Paraskevopoulos, Herholz, & Pantev, 2012; Seppänen, Hämäläinen, Pesonen, & Tervaniemi, 2012; Trainor, Shahin, & Roberts, 2009), and at sub-cortical levels (e.g. Bidelman, Krishnan, & Gandour, 2011; Musacchia, Sams, Skoe, & Kraus, 2007; Parbery-Clark, Strait, & Kraus, 2011; Strait, Kraus, Parbery-Clark, & Ashley, 2010). These changes probably reflect the combined contribution of an initially elevated sensitivity and prolonged musical training (Baeck, 2002; Hyde et al., 2009; Schlaug et al., 2009).

Taken together, the pattern of musicians′ auditory skills and their elevated brain responses to auditory stimuli look like the opposite of that reported for dyslexic individuals. Thus, one would not expect to find individuals who are both musicians and dyslexics. Yet some musicians including very famous ones (e.g. John Lennon and Nigel Kennedy, http://www.dyslexia.com/famous.htm), have claimed that they were dyslexic.

One possible solution to this seeming inconsistency is that the sensitivity of dyslexic musicians to both speech and non-speech sounds is indeed enhanced, as expected for musicians, and their reading difficulty stems from a non-auditory or phonological deficit (e.g. visual attention; Franceschini, Gori, Ruffino, Pedrolli, & Facoetti, 2012; Gabrieli & Norton, 2012; Zorzi et al., 2012). Alternatively, dyslexic musicians may have excellent sensitivity to non-speech sounds, but poor sensitivity to speech sounds. Such a profile would challenge the claim that there are common mechanisms for processing speech and non-speech sounds (Kraus & Chandrasekaran, 2010; Salamé & Baddeley, 1989; Schendel & Palmer, 2007; Williamson, Baddeley, & Hitch, 2010). The third alternative is that dyslexic musicians exhibit the typical dyslexic profile but do not manifest the typical musicians′ profile. Namely, their difficulties may include non-verbal sounds, either at the perceptual or at the working memory processing stage, or both.

The current study was aimed to resolve this enigma, by assessing the reading, memory and auditory skills of self-reported musician dyslexics. We recruited professional musicians from the Music Academy of the Hebrew University of Jerusalem who reported difficulties in reading (including, but not specific to, reading musical notes) throughout their school years, and still have reading difficulties, as measured in the lab. We composed their control group from their musician peers with no reading difficulties, who were matched for age, musical education (years and self-reported amounts of practice) and reasoning skills. In order to further assess the severity of their reading and phonological deficits, we compared their performance to that of their non-musician peers matched for age, general education and reasoning abilities (who participated in an earlier study; Oganian & Ahissar, 2012).

We found that most of the musicians who reported having reading difficulties were indeed slow and/or inaccurate readers with poor phonological skills compared with their musician peers. Their decoding and phonological skills were well below those of non-musician controls, though, in average, they were less impaired than those of non-musician dyslexics.

We systematically characterized musicians′ psychoacoustic skills with simple tones and with verbal stimuli. We found that psychoacoustic thresholds and sensory-motor accuracy of dyslexic musicians were similar to those of their non-dyslexic musician peers. Namely, they were superior to those of the general population.