Learning and Individual Differences 40 (2015) 27–40

Contents lists available at ScienceDirect

Learning and Individual Differences

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

Auditory intelligence: Theoretical considerations and empirical findings

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ARTICLE INFO

Article history:
Received 3 May 2014
Received in revised form 15 January 2015
Accepted 28 March 2015

Keywords:
Auditory intelligence
Academic intelligence
Musical training
BIS model

ABSTRACT

In the last few years, auditory intellectual abilities have received increased attention in different fields of research. However, most intelligence models have yet to include an auditory factor. This paper aimed to replicate the general auditory factor and examined whether and how the hierarchical and faceted Berlin Intelligence Structure model (BIS; Jäger, 1982) should be extended by adding an auditory dimension. Two studies included 126 students (Study 1) and a heterogeneous group of 175 adults (Study 2). Participants took a broad auditory intelligence test and the BIS test and provided a self-report of musical training. Confirmatory factor analyses revealed two separate auditory content factors: nonverbal and speech. Auditory nonverbal ability was clearly distinct from academic intelligence, whereas auditory speech ability could be completely subsumed under verbal reasoning. We suggest that auditory ability – as represented by auditory nonverbal tests – needs to be added to the BIS as an additional content dimension.

1. Introduction

Researchers tend to accept the assumption of a general auditory intelligence factor (cf. Zajac, Burns, & Nettlebeck, 2012; see findings reported by Carroll, 1993; Kidd, Watson, & Gygi, 2007; McGrew, 2009; Stankov & Horn, 1980) but only modestly agree about the structure and nature of auditory intelligence (Kidd et al., 2007) and its relations to other broad ability constructs (Zajac et al., 2012). Some well-known intelligence models (e.g., Carroll, 1993; Horn & Noll, 1997; McGrew, 2005) and tests (e.g., Schrank, McGrew, Mather, & Woodcock, 2014) include auditory intelligence, but this construct has been given less attention than visual intellectual abilities, and our understanding of it lags behind our understanding of visual processing (e.g., Carroll, 1993; Horn & Stankov, 1982; Lotto & Holt, 2011; Shuter-Dyson & Gabriel, 1981). This is surprising because auditory intelligence plays an important role in conversations (e.g., on the phone), performance bottlenecks (e.g., while driving a car or piloting a plane), impaired sight (e.g., at night), musical performances, the acquisition of foreign languages (i.e., pronunciation), reading and language disorders (e.g., Gathercole, 2006), and others. Meanwhile, in the last few years, research on auditory abilities has expanded into other disciplines, particularly into cognitive psychology and neuropsychology with topics such as phonological awareness, nonword repetition research, temporal processing, reading and language disorders, and musical training (e.g., Bailey, 2010; Conway, Pisoni, & Kronenberger, 2009; Gathercole, 2006; Bailey, 2010; Panagiotidi & Samartzi, 2013; Roden et al., 2014; Strait & Kraus, 2011; Tierney & Kraus, 2013). However, in psychometric research, auditory intelligence is rarely included in tests and there is a need to answer questions about the factor structure of auditory intellectual abilities, the role of such abilities within intelligence models, and their relations to variables such as musical experience. The answers to these questions could add to the findings obtained in the aforementioned disciplines. Against this background, the general aims of this paper were to: (a) replicate the general auditory factor and investigate aspects of its structure, (b) examine whether and how the Berlin Intelligence Structure Model (Jäger, 1984) should be extended by adding an auditory dimension, and (c) investigate how musical training is related to auditory intelligence.

This introduction is organized as follows: First, auditory intelligence will be defined and distinguished from related constructs such as musical and speech comprehension and phonemic awareness. Second, the structure of auditory intelligence and related empirical findings as proposed and investigated in different streams of research will be addressed, that is, work in the Cattell–Horn–Carroll (CHC) tradition as well as research based on auditory discrimination abilities and their respective empirical findings with regard to other broad academic intelligence[1] constructs. These topics will be complemented by the suggestion that auditory intelligence may be related to the constructs in the

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[1] We use the term "academic intelligence" instead of "general intelligence" in order to clearly distinguish it from "new intelligence constructs" such as emotional and practical intelligence. In our view, "general intelligence" or "g" is ambiguous with regard to how it involves these "new intelligence constructs." By using academic intelligence, we refer to abilities that are required in academic contexts (e.g., school, university) such as the operations reasoning, memory, and speed as applied to verbal, numerical, and figurative–spatial material.

http://dx.doi.org/10.1016/j.lindif.2015.03.029
1041-6080/

Berlin Intelligence Structure Model (BIS Model; Jäger, 1982), which does not yet include an auditory factor. Third, we will address the effect of musical training on auditory intelligence and finally summarize the aims and hypotheses of this paper.

1.1. Definitions of auditory intelligence

Within the tradition of Gf–Gc theory, Stankov (1994, p. 157) defines auditory abilities[2] in the broadest sense as cognitive abilities that depend on sound as input and on the functioning of our hearing apparatus, which encompasses simple sensory processes and the abilities required to solve complex (nonverbal or speech) problems.

In his comprehensive reanalysis, which resulted in the Three-Stratum Theory, Carroll (1993, p. 364) reported a "broad auditory perception factor" (Ga), which he described as the individual's capacity to apprehend, recognize, discriminate, or even ignore the characteristics of auditory stimuli, independent of the individual's knowledge of structures in language or music.

The CHC theory (McGrew, 1997, 2005) integrates the extended Gf–Gc theory and the Three-Stratum Theory and defines auditory processing (Ga) as the ability to analyze, synthesize, and discriminate auditory stimuli, including the ability to process and discriminate speech sounds that may be presented in distorted conditions. More recently, this definition was revised by Schneider and McGrew (2012) who see auditory processing (Ga) as the ability to detect and process meaningful nonverbal information in sound (p. 131). In comparison with the latter definition, we specify the term "process." We also adopt the view of the earlier CHC theory and include speech units and environmental sounds in our definition of auditory stimuli. Thus, in this paper, auditory intelligence is defined as the ability to discriminate, remember, reason, and work creatively (on) auditory stimuli, which may consist of tones, environmental sounds, and speech units (Seidel, 2007).

1.2. Distinguishing auditory intelligence from related constructs

1.2.1. Musical/speech comprehension

In our view and as suggested by Carroll (1993), auditory intelligence should be distinguished from musical appreciation and speech comprehension. According to Franklin (1956) and Kurth (1931), auditory intelligence refers to single units (e.g., tone or speech units), whereas in musical abilities, a whole sequence (e.g., melody) is considered. Correspondingly, in auditory speech tasks, single units are analyzed, discriminated, or memorized, whereas in verbal comprehension tasks, the whole process of comprehension is relevant. This distinction is often not made on auditory and musical tests. For instance, pitch discrimination on the Seashore (1919) can be considered an auditory subtest, whereas the chord decomposition subtest reported by Stankov and Horn (1980) is rather musical. The recently developed Musical Ear Test (Wallentin, Nielsen, Friis-Olivarius, Vuust, & Vuust, 2010) was designed to measure musical abilities in musicians and amateurs. Participants have to judge whether two short musical phrases (either rhythm or melody) are identical or not. Although the test clearly involves musical material, the melodic/rhythmic sequences are mostly very short, involving only a few tones, and are comparable to the following Stankov and Horn (1980) auditory tasks: "Detection of repeated tones," "Tonal analogies," and "Tonal figures." Thus, the test will be treated as an auditory test in this paper.

The related field of musical abilities has a rather long research tradition (Drake, 1933; Seashore, 1919), but studies have not yet succeeded in providing a clear structure of musical abilities (Carroll, 1993). Although musical abilities are expected to share variance with auditory intelligence as they both rely on the same (auditory) perception channel, these findings have rarely been integrated into intelligence research.

[2] The term "auditory abilities" is used interchangeably with the term "auditory intelligence." Because the construct is considered to be an intelligence construct, we prefer the term "auditory intelligence."

1.2.2. Phonological and phonemic awareness

Phonemic awareness can be defined as the ability to abstract and manipulate segments of spoken language (i.e., phonemes; Bentin, 1992) or as the conscious awareness that spoken words comprise individual sounds (Snider, 1997). Phonological awareness is the ability to detect and manipulate sounds in spoken language (Liberman & Shankweiler, 1985; Wagner & Torgesen, 1987) and includes the manipulation of larger sound units such as onsets, rhymes, and syllables; thus, phonemic awareness can be viewed as a subconstruct of phonological awareness. There have been different opinions about the size of the word units. However, there is a consensus that phonological awareness is a unitary construct that manifests itself in different skills (e.g., the acquisition of literacy) throughout a person's development (Anthony & Francis, 2005). Phonological awareness is essential for successful reading development (e.g., Melby-Lervag, Halaas-Lyster, & Hulme, 2012; Sodoro, Allinder, & Rankin-Erikson, 2002). Phonemic awareness and phonological awareness are both similar to auditory intelligence as they all focus on basic processes and single units. Moreover, they all require discrimination. However, auditory nonverbal intelligence focuses on tones, whereas phonemic/phonological awareness addresses language units; thus, auditory nonverbal intelligence can be clearly discriminated from the awareness measures. Auditory speech intelligence involves both acoustical and language features, but the acoustical aspects are more central. Whereas phonemic/phonological awareness involves only discrimination, we maintain that auditory intelligence involves memory and reasoning processes that go beyond discrimination with respect to auditory material. But in the current CHC theory, phonemic awareness is included as a narrow ability within general auditory processing (Ga; Schneider & McGrew, 2012).

1.3. Previous work in the field of auditory intelligence: its structure and empirical findings with respect to academic intelligence

1.3.1. Cattell–Horn–Carroll (CHC) tradition

Most of the work on auditory intelligence in psychometrics has been done in the CHC tradition, which goes back to Stankov and Horn's (1980), and Horn and Stankov's (1982) early work. Stankov and Horn (1980) aimed to develop auditory tasks that corresponded to the visual domain and that made use of basic stimuli, such as pure tones, chords, and voices. In constructing such auditory tests, intensity and pitch were used as the main elements that were analogous to the elements of line and shape on visual tests. Stankov and Horn (1980) included music and speech perception ability tasks and based the development of these tasks on findings from the fields of musical abilities (e.g., Drake, 1939; Seashore, Lewis, & Saetveit, 1960; Shuter, 1968; Wing, 1948) and listening comprehension (Fleishman, Roberts, & Freidman, 1958; Hanley, 1956; Karlin, 1941; Solomon, Webster, & Curtis, 1960). Classified into the extended theory of fluid intelligence (Gf) and crystallized intelligence (Gc; Horn, 1994; Horn & Noll, 1997), a general auditory factor (Ga) was located on the second level (i.e., broad abilities) next to the broad visual ability factor (Gv) and considered to be an indicator of either Gf or Gc depending on the corresponding auditory task. Ga subsumed seven primary auditory ability factors (i.e., narrow abilities) that were interpreted as (a) tonal memory, (b) speech perception under distraction, (c) auditory verbal comprehension, (d) immediate memory, (e) cognition of relationships, (f) discrimination among sound patterns, and (g) maintaining/judging rhythm (Stankov, 1983; Stankov & Horn, 1980; Stankov & Spilsbury, 1978). Temporal tracking was suggested as an additional ability. It was assumed to affect the understanding of language with an extremely high or low tempo and to be related to working memory capacity (Stankov, 1983). Stankov and Horn's (1980) findings were consolidated in several later studies (Dun, 2000; Horn & Stankov, 1982).

In his Three-Stratum Theory, Carroll (1993) located the broad auditory perception factor in the second stratum next to Gf, Gc, Gv, and others. In contrast to Horn and Noll (1997), he assumed a general factor on the third stratum. Carroll subsumed 12 primary auditory abilities on