- **Name of the study**: Music Aptitude, Intelligence and Memory among Individuals with Intellectual Disability Compared to Individuals with Typical Development: Associations and Developmental Trajectories (Impaired, Parallel or Continuous Trajectory)
- **Year:** 2021
- **Catalog Number:** 890-194-2019
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- **Research Authority:** Submitted in partial fulfillment of the requirements for the Ph.D. degree in the
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Abstract

The main goal of the current study was to examine the developmental trajectories of musical aptitude among individuals with non-specific intellectual disability (ID), compared to individuals with typical development (TD) in two age cohorts: older adolescence (17-21) and young adulthood (25-40). Musical aptitude (tonal and rhythmic) was examined in light of a theoretical model of three possible developmental trajectories of intelligence and cognitive ability in the population with ID compared to the population with TD (Fisher & Zeaman, 1970; Lifshitz, 2020): Impaired, Stable or Continuous (Compensatory) Trajectory (see below). Another goal was to examine the association between crystallized and fluid intelligence, phonologic and visual-spatial working memory, episodic memory and musical aptitude in individuals aged 17-40 from these two populations, who had no musical training.

Associations between musical aptitude and learning, intelligence and cognitive skills in the population with TD is at the center of musical research (Sala & Gobet, 2017). Fluid intelligence is an innate ability, that includes understanding abstract relationships, spatial perception (McGrew, 2009) and processes that are manifested in short and long-term memory (Cattell, 1987; Horn, 1988). Musical aptitude is an innate ability (Talamini et al., 2018) that includes discrimination between frequencies which are organized in virtual space (in terms of pitch) (Levitin, 2012), **synchronization between the motor pattern and the beat extracted from the audio patterns** (in terms of rhythm) (Kotz et al., 2018) and based on short and long-

term musical memory (Talamini et al., 2017). Pitch representations are mainly associated with the frontal-temporal *lobe* (Peretz et al., 2009), whereas rhythm representations are associated with subcortical systems (Chen et al., 2006). A larger bilateral volume of the hippocampus, that is responsible for learning and memory, was found among musicians compared to non-musicians (Oechslin et al., 2013). Associations between phonologic-linguistic (Sallat & Jentschke, 2015), spatial (Swaminathan et al., 2017), phonologic and visual-spatial working-memory and long-term memory tasks (Talamini et al., 2017), and musical aptitude and learning, has been found. According to researchers (Besson et al., 2012), one of the explanations for these associations is the "transfer" effect (Thorndike & Woodworth, 1901), according to which different skills have common information processing processes. One of the goals of the present study was to examine whether, and to what extent, the patterns of relations between different measures of intelligence (crystallized and fluid) and memory (working memory and episodic memory) and musical aptitude found in the population with TD, also exist in the population with ID.

One of the questions that occupies researchers (Fisher & Zeaman, 1970; Lifshitz, 2020), is how intelligence and cognitive skills develop over the life cycle, in the population with ID compared to the population with TD. In the population with TD, there is a model according to which intelligence develops linearly until the age of 20, followed by a plateau, where decline begins between the ages of 50-60 (Kaufman, 2001). Fisher and Zeaman (1970) thus proposed a theoretical model of three possible trajectories for the development of intelligence in the population with ID compared to the population with TD: Impaired Trajectory - according to which intelligence reaches its peak at the age of 10-20, followed by stability, and decline begins at the age of 20-30; Stable Trajectory - according to which intelligence reaches a peak around the age of 20, followed by stability, and decline begins at the age of 50-60; Continuous [Compensatory] Trajectory - according to which intelligence may develop until the late 40s, with stability between the ages of 50-60, and decline begins at the age of 60 and above. In a series of studies conducted by Lifshitz et al. (Lifshitz et al., 2020; Chen et al., 2017), an increase in intelligence and memory was found among a population with ID at least up to the age of 40 and older. According to the “Compensation Age Theory” (Lifshitz, 2020), maturity and life experience contribute to cognitive development in old age. In light of this, another goal of the present study was to examine the developmental trajectories of musical aptitude in a population with ID compared to a population with TD. To the best of our knowledge, this is the first study to examine the developmental trajectories of musical aptitude from adolescence (17-21) to adulthood (25-40) among participants with TD as well as among participants with ID (where both groups had no musical training).

The participants included individuals with mild ID (N = 49, mean IQ = 62.31) and with TD (N = 48, mean IQ = 104.12) in two age groups (17-21, 25-40).

Tools: Crystallized intelligence refers to knowledge, understanding, conceptualization and verbal inference (McGrew, 2009). It was tested using the *Vocabulary* and *Similarities* tests (Wechsler, 2001). Fluid intelligence (see above) was tested using the *Block Design* test (Wechsler, 2001) and the *Raven Matrices* (1958). Working memory refers to short-term information storage and manipulation of information (Baddeley et al., 2011). It was tested using the *Forward Backward Digit Span* test (Wechsler, 2001) for phonologic working memory and by the *Forward Backward Spatial Span* test (Wechsler, 1997b) for visual-spatial working memory. Episodic memory refers to personal experiences according to the context and order in which they occurred (Tulving, 2002). It was tested using *Rey's Verbal Learning Test* (Rey AVLT; Vakil *Total Learning, Delayed :*& Blachstein, 1993, 1997). The measures produced from the test were *Recall* and *Retrieval Efficiency*.

Musical Tests: Due to the unique character of our study population and existing musical tests, musical aptitude, which includes discrimination between tonal and rhythms patterns, was tested using Gordon's tests (IMMA - 1986a, 1986b; MAP - 1995a, 1995b). Tonal aptitude was tested by the *Tonal Test, Melody Imagery* and *Harmony Imagery*. Rhythmic aptitude was tested by the *Rhythm Test, Tempo Imagery* and *Meter Imagery.* Each test included 15 items (out of 40 in the full version). A reliability *split half* test was therefore performed. The dependent variables were: (1) The achievement measure (between 0-15 points); (2) d' - (d prime) - the proportion of correct (Hit) versus false answers (FA - False Alarm). The Hit measure is the number of items in which the participant answered correctly and said "same / similar" when the correct answer was "same / similar"; And the FA measure is the number of items in which the participant answered an error and said "same / similar" when the correct answer was "different". Of the two variables, the d prime is the most "sophisticated" because it includes the proportion of correct versus false answers and thus prevents bias in scores following guesswork.

Results: The study results are presented below, with reference to the study's operative goals, hypotheses and questions:

Goal A: To examine the developmental trajectories of crystallized and fluid intelligence, phonologic and visual-spatial working memory and episodic memory, in a population with TD compared to a population with ID, in two age groups: older adolescence (17-21) and young adulthood (25-40).

For crystallized intelligence, we hypothesized that scores in the population with TD will be higher in adulthood (25-40) compared to adolescence (17-21), and in light of the "Compensation Age Theory" (Lifshitz, 2020), this will also be found in the population with ID. Regarding fluid intelligence, phonologic and visual-spatial working memory and episodic memory, stability was found in the population with TD in some of the studies (Cansino et al., 2013), while others found a decline (Hester et al., 2004) or an increase (Lezak et al., 2004). We therefore formulated research questions: What will be the scores tendencies in fluid intelligence, in phonologic and visual-spatial working memory and in episodic memory in the two study populations? Will the developmental trajectories be impaired, stable or continuous between adolescence (17-21) and adulthood (25-40)? Analyses of variance yielded parallel and differential lines between the two study groups and age:

Parallel lines: (1) Crystallized intelligence: The hypothesis was confirmed, and the findings indicate a continuous (compensatory) trajectory in both populations. Similarly to our study, an increase in scores from adolescence to adulthood was found in a population with TD (Chen et al., 2017). There was an increase also in the population with ID, which can be explained by the "Compensation Age Theory" (Lifshitz, 2020). **(2) Fluid intelligence:** Our findings indicate a stable trajectory from adolescence to adulthood in the population with TD, similarly to Schaie's (2013) findings, as well as a parallel stable trajectory in the population with ID. This finding is unique to our study. **(3) Visual-spatial working memory:** Our findings indicate a stable trajectory from adolescence to adulthood in the population with TD, similarly to Cansino et al. (2013), as well as among the population with ID, and are compatible with the findings of Lifshitz et al. (2020).

Differential lines: (1) Phonologic working memory: Regarding the population with TD, our findings indicate a stable trajectory in *Forward Digit Span*, similarly to Wisdom et al. (2012), and a continuous trajectory in *Backward Digit Span*, similarly to Lazek et al. (2004). Regarding the population with ID, our findings indicate a continuous (compensatory) trajectory in *Forward Digit Span*, similarly to Kilberg (2019 [Hebrew]). It should be noted that phonologic working memory represents crystallized intelligence (Brickman & Stern, 2009), and an increase in this domain was found, accordingly, in our study, which can be explained by the "Compensation Age Theory" (Lifshitz, 2020). In *Backward Digit Span*, a stable trajectory was found, similarly to Lifshitz et al. (2020). **(2) Episodic memory:** Regarding the population with TD, our findings indicate a stable trajectory, similarly to Vakil et al. (2010). Regarding the population with ID, our findings indicate a stable trajectory for *Total Learning* and *Delayed Recall* and a continuous (compensatory) trajectory for *Retrieval Efficiency*, similarly to Bustan

(2018 [Hebrew]).

Goal B: To examine the developmental trajectories of musical aptitude (total, tonal aptitude and rhythmic aptitude) in a population with TD compared to a population with ID, in two age groups: older adolescence (17-21) and young adulthood (25-40).

Differential lines in scores in musical aptitude, regarding study groups: We hypothesized that scores in musical aptitude (total) will be higher in the population with TD compared to the population with ID. Accordingly, we hypothesized that achievements and d' in tonal (*Tonal Test, Melody Imagery* and *Harmony Imagery*) and rhythmic (*Rhythm Test, Tempo Imagery* and *Meter Imagery*) tests will be higher in the population with TD. The hypothesis was confirmed, and musical aptitude (total, tonal and rhythmic tests) in the population with TD was found to be higher compared to the population with ID, similarly to Hooper et al. (2008b).

Parallel lines in the developmental trajectories of musical aptitude, regarding study groups and age groups: In the population with TD, musical aptitude (Trainor & Corrigall, 2010), visual-spatial working memory (Conklin et al., 2007) and episodic memory (Clark et al., 2006), stabilize in parallel, during middle adolescence, and at the latest at the age of 16. As mentioned, associations between musical aptitude, intelligence and memory (Talamini et al., 2017) were found, as were contradictions regarding the developmental trajectories from adolescence (16+) to adulthood. Due to the absence of theoretical information on the developmental trajectories of musical aptitude from adolescence (17-21) to adulthood (25-40) in the two populations (with TD and with ID) that had no musical training, we asked a research question: What will be the score tendency in achievements and d' measures in the musical aptitude (total, tonal and rhythmic tests) from adolescence (17-21) to adulthood (25-40) in the two populations? Will the developmental trajectory be impaired, stable or continuous? Our findings indicate a stable trajectory from adolescence to adulthood in both study groups, i.e., musical aptitude development represents the stable and parallel trajectory of fluid intelligence in the population with TD as well as in the population with ID, and musical aptitude is fluid in nature in both populations.

Pattern of answers in musical aptitude tests (tonal and rhythmic), regarding study groups and age groups: We asked whether a difference would be found (according to achievements measure) between study and age groups with reference to the musical aptitude tests. **Parallel lines:** In both study groups, the scores in the *Tonal Test* were significantly higher compared to the scores in the *Melody Imagery* and *Harmony Imagery* tests (p = .000). No differences were found in scores on rhythmic aptitude tests with reference to the type of test. No

differences were found in the scores with reference to age groups. The answers pattern suggests similar musical thinking in both populations and is consistent with the developmental approach (Hodapp & Zigler, 1997; Zigler, 1969; Zigler & Balla, 1982). **Differential lines:** The scores in *Melody Imagery* among the population with TD were higher than their scores in *Harmony Imagery* (p = .001). In contradistinction, no differences in scores were found between these two tests among the population with ID (p = .248).

Goal C: To examine the correlations between crystallized and fluid intelligence, memory (working memory and episodic memory) and musical aptitude, and to examine the contribution of background variables (age and gender), intelligence and memory to the explanation of the variance in musical aptitude in the two study groups. In this part, the analyses in the musical tests were conducted on the d'. Differential and parallel lines emerged between the study groups in the Pearson correlations and regression analyses:

Differential lines: **(1) Background variable:** In the population with TD, gender contributed to the explanation of the variance in musical aptitude (7.7%), in *Melody Imagery* (14.7%) and in *Harmony Imagery* (11%). The negative β coefficient indicated better musical aptitude among men compared to women. **(2) Correlations:** The size of the correlations (r = .28 – .44) in the memory tests (phonologic working memory, visual-spatial working memory and episodic memory) is similar in both populations. However, in the population with TD, few correlations were found between the memory and the tonal aptitude; Whereas in the population with ID many correlations were found between the memory and the musical-rhythmic aptitude. That is, the population with ID relies on memory more than the population with TD in order to perform musical-rhythmic tasks. Memory tests may have a mild to moderate cognitive load level (Kilberg, 2019 [Hebrew]; Lifshitz et al., 2016) relative to the population with TD, and therefore it relies less on memory. Hence, when examining correlations between cognitive and musical abilities, both the type of task (i.e., verbal or spatial memory) and the level of cognitive load should be considered. **(3) Regression analyses:** In the population with ID, *Backward Spatial Span* contributed (between 17-18%) to the explanation of variance in rhythmic aptitude and *Rhythm Test,* that is, the better the ability to change the movement, the better the ability to synchronize between motor pattern and beat (Kotz et al., 2018). *Total Learning* contributed (between 6.8-20.6%) to the explanation of variance in musical aptitude, *Harmony Imagery* and *Tempo Imagery,* that is, the better the ability of verbal-serial learning, so is the perception of harmony and the perception of time. Thus, the ability to change movement and verbal-serial learning are the basis of musical aptitude.

Parallel lines: A moderate correlation (*r* = .29 – .42) was found between fluid (but not crystallized) intelligence and musical aptitude in both populations, and fluid intelligence was found to contribute to the explanation of variance in musical aptitude. *Raven's Matrices* contributed (between 11.7-17%) to musical (total) and tonal aptitude and *Block design* contributed (between 7.1-14.2%) to rhythmic aptitude. It is possible that the *Raven* test is more related to tonal aptitude because it contains mainly spatial thinking while *Block design* test is more related to rhythmic aptitude because it also contains temporal-motor performance.

In conclusion, musical aptitude is similar in nature in the population with TD and in the population with ID, and musical aptitude in both populations behaves similarly to fluid intelligence with reference to developmental trajectories, correlations and regressions. The contribution of fluid intelligence and memory to the explanation of variance in musical aptitude indicates the importance of using the musical channel as a basis for the development of visual-spatial, motor, temporal and verbal skills. It is therefore recommended to adopt methods in musical education that combine movement and music, and to develop programs in which music serves as a means of improving the cognitive abilities of the population with ID.

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