Music Training, Dance Training, and Multitasking

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1 Introduction

Many skills and abilities have the potential to produce improvements in seemingly unrelated tasks. For example, some evidence exists that bilinguals have greater task-switching ability than monolinguals (Gunnerud et al. 2020). Training in Tai Chi Chuan has shown multitasking benefits (Wu et al. 2018), as has video game training (Pallavicini et al. 2018). Any number of skills might be associated with, or cause, multitasking improvements. The goal of this review is to investigate two acquired skills: music and dance.

Theorists have posited similarities between language and music structures (Feld 1974; Jackendoff 2009). Likewise, language and dance share structures (Hanna 2001), as do music and dance (Hanna 1982). Given that bilinguals seem to show improved multitasking performance (Gunnerud et al. 2020), and given the similar skills involved in bilingualism, music, and dance, one might expect to see multitasking benefits because of music and dance training. On the other hand, evidence exists that bilingualism is not, in fact, associated with improved multitasking performance (Moradzadeh et al. 2015), and thus one might not expect to see music and dance training benefits to multitasking. Nonetheless, all three constructs involve fine motor control skills, ability to parse and generate content within a prescribed structure, and connection between visual, auditory, and kinesthetic systems.

Music is the art of producing and combining sounds to produce an aesthetic or emotional effect. Music expertise takes many forms, as there are myriad instruments: woodwind, brass, string, percussion, vocal, and computer-generated sound. Learning each instrument involves the development of a set of technical skills over a long period of time. Thus, calling someone a musician indicates that the individual has some degree of music expertise in some subset of all possible music skills.

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Individuals develop expertise in specific genres of music, and each genre has its own set of rules (with a between-genre overlap in some skills and other genre-specific skills). Thus, like bilingualism, music expertise is heterogeneous, with wide variation in which skills are trained.

Recent meta-analyses investigated whether music training benefits cognitive skills (Cooper 2020; Gordon et al. 2015; Sala and Gobet 2019, 2020). The conclusion of these reviews is that music training rarely benefits performance across a wide range of cognitive tasks and that benefits of music training are small in magnitude. These reviews left out the literature on task-switching and dual-task performance, leaving open the question of whether multitasking benefits from music training. This omission is surprising because multitasking is at the core of music performance and thus is more likely than other cognitive skills to become highly trained during learning of music skills.

1.1 Skills Involved in Musical Performance

1.1.1 Shifting Attention

Musicians regularly shift attention between musical elements, including notes, rhythms, keys,[1] tempos, and dynamics (Moradzadeh et al. 2015). A core skill of musicianship is shifting attention between these and other performance elements. The confluence of which notes are sounded, when, and how loudly they are sounded form the basis of music. In a sense, each piece of music is a different task, containing its own combination of key, tempo, rhythm, and melody.

In music-making, attentional shifts take place using both internal and external sources (stylistic choices and memory of the piece; auditory feedback and bandmate cues). This is similar to task-switching paradigms (holding in mind when a task change should take place; visual cues to change task). Musicians maintain mental representations of the music (McPherson 2005), which is similar to the maintenance of task sets in computerized task-switching paradigms. Musicians must gracefully recover from mistakes, using auditory feedback, as occurs in many task-switching paradigms.

In many ways, attentional shifts between musical elements are unlike a typical task-switching paradigm. Musicians attend to these elements simultaneously, making music performance a form of simultaneous multitasking. Switching between songs does not involve an independent set of skills since the same core set of musical elements is involved. Unlike a typical laboratory task-switching paradigm, music performance involves lengthy practice (although musicians perform and learn many new, initially unpracticed pieces of music, so not all musical performance is highly practiced).

[1] Music involves a set of notes that, in relation to each other, sound more harmonic or dissonant. Western music is based on musical keys, which are a prescribed set of standard notes.

1.1.2 Multitasking

Musicians integrate visual, tactile, and auditory information in real time (McPherson 2005; Moradzadeh et al. 2015; Wan and Schlaug 2010). This includes visual cues from sheet music and the physical keys (e.g., on a piano) or neck[2] of an instrument, tactile feedback from fingers, feet, and the respiratory system, and the sound of what is being produced by each musicians' actions. Music-making requires attention to one's part while simultaneously attending to the performance of other people in the ensemble to coordinate performance across the entire ensemble (Hasty 2004; Loehr and Palmer 2011; Loehr et al. 2013). Conducting requires the formation of a mental representation of the score[3] and guidance of decisions about performance in real time based on incoming auditory and visual information (Chaffin 2011). When errors occur, many conductors shift their attention to the error and generate a resolution, while simultaneously keeping track of where the score is going. At least while learning a piece, singing can be considered a dual task (Racette and Peretz 2007). Likewise, many dual-task paradigms require cross-sensory attention to simultaneously respond to multiple streams of information.

Over time, musicians develop increased sensitivity to details of musical structure (Palmer and Drake 1997), which could reflect improved multitasking skills. Production becomes more automatic, facilitated by performance cues (Chaffin and Logan 2006). Perception and action are more effectively coordinated (Pfordresher 2006). The combination of these skills could help musicians more effectively develop accurate, automatic responses in a dual-task paradigm.

1.1.3 Other Skills

Musicians practice general skills that might be helpful to laboratory task performance, such as error detection (Palmer and Drake 1997) and the ability to act flexibly in the face of unpredictable events (Geeves et al. 2014). Other practiced skills might be less relevant to multitasking, such as synchrony of movement (Repp 2006), efficient chunking skills to facilitate access of information from working memory (Geeves et al. 2014), control and precision of timing, consistency of performance, and planning (Janzen et al. 2014; Palmer 1997).

1.2 Methodologies

Two major methodologies have been used to investigate music and dance training effects on cognition. Most of the literature is experimental but correlational, comparing individuals with many years of music expertise, either instrumental or vocal,

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[2] The location on stringed instruments where fingers are placed in order to sound notes.

[3] A visual representation of a piece of music; also known as sheet music.

to controls who are not music experts. The largest advantage of these studies is the use of musicians and dancers with many years of expertise, which increases the likelihood of finding training effects. One downside is that it is difficult to find matched participants for the control group, who are identical to the experimental group on all factors except expertise. For the most part, researchers attempt to match samples on a range of background factors, such as age and socioeconomic status, but it is impossible to match all participant factors, such as level of interest in music.

A strong test of whether music-making produces changes in performance requires an experimental design in which there is random assignment into music training and control groups. The strength of this design is that potential confounding factors can be controlled; the downside is that experimental studies tend to be short, with at most months or a few years of music training. It is possible that many years of music training are needed before cognitive benefits can be detected.

While most studies compared groups with and without expertise, a few studies examined individuals with different degrees of expertise, such as those assigned to a music training group who have one, two, or three years of training, or individuals with varying hours of professional work experience. A couple of studies have examined correlations between objective measures of musical skill—such as pitch perception and rhythm discrimination—and cognitive skill.

1.3 Near and Far Transfer

While music training is obviously useful for the task of music-making, it is not a given that music training will improve other types of skills. If training works, it could improve skills that are quite similar (i.e., near transfer), such as memory training producing benefits on a different memory task. When tasks share common features between the source and target domain, as is likely to happen for similar tasks, the likelihood of transfer is increased (Thorndike and Woodworth 1901).

Alternatively, training could improve more distant skills, such as memory training improving general processing speed. This is called far transfer (Barnett and Ceci 2002). One theory of transfer divides tasks into a set of production rules, some of which are task specific, and others of which are general (Taatgen 2013). To the extent that these rules are involved in both tasks, even if the tasks appear to be dissimilar, transfer will occur. Theories of skill acquisition nearly always make predictions that far transfer can be achieved, despite the rarity of far transfer successfully occurring (Sala et al. 2019).

Unsurprisingly, near transfer is much easier to find than far transfer (Melby-Lervåg and Hulme 2013). In fact, there is debate in the training literature whether far transfer effects exist (De Simoni and von Bastian 2018; Guye and von Bastian 2017). Recent meta-analyses provide nuanced data on when and to what extent training programs show near and far transfer. Combining these meta-analyses, Sala et al. (2019) conducted a second-order meta-analysis of training programs. This analysis increases the accuracy of effect size estimates by reducing sampling error

(Schmidt and Oh 2013). After correcting for publication bias and the placebo effect, there was zero effect of training on far transfer across a wide range of domains, including music training.

Music production heavily relies on processing multiple streams of information and switching attention between incoming stimuli, which makes these skills obvious possibilities for far transfer. Even so, previous meta-analyses have not examined whether music training transfers to task-switching or dual-task performance.

2 Experts Compared to Imperfectly Matched Controls

Studies that involve music and dance experts, who have many years of training, provide the greatest opportunity to observe training benefits (Table 1). These studies account for the possibility that many years of training might be required before far transfer to cognitive benefits occurs. Typically, these studies sample individuals with existing expertise, along with a control group of individuals who have not trained in music or dance. The control group cannot be matched on every single background factor, making this a liberal test case for the possibility of training benefits but not definitive evidence that training alone is responsible for any observed benefits. These studies are quasi-experimental, not randomized controlled trials.

While many music expertise studies have shown training benefits, researchers have questioned the validity of the conclusion that music expertise causes cognitive benefits. Once background factors and music aptitude are statistically controlled, music expertise benefits often disappear (Schellenberg 2016; Swaminathan et al. 2017; Swaminathan and Schellenberg 2018, 2019). The question is whether task-switching and dual-task performance show robust benefits in music experts.

2.1 Task Switching

The most highly controlled task-switching paradigms investigate local and global switch costs, typically using tasks in which the participant must alternate between two task sets, such as parity (even or odd) and letter type (consonant or vowel). Local switch cost is the comparison of switch and nonswitch trials within blocks that involve task set alternation, while global switch cost is the comparison of nonswitch trials in blocks that have a single task set or in which alternation takes place (Kiesel et al. 2010; Koch et al. 2018).

Evidence fails to suggest that musicians benefit at task switching, namely, local or global switch costs. Moradzadeh et al. (2015) used one of the largest sample sizes in this review chapter and found inconclusive results due to a lack of baseline matching (despite the large sample size). Two other studies with large sample sizes failed to find improvements in local switch costs with increasing years of training (Okada and Slevc 2018; Slevc et al. 2016). The remaining studies measuring local and global switch costs contained confounds that limit the interpretation of results.

Table 1 Studies comparing a group with music or dance training to a nonmusically trained group

Paper	Age (years)	Sample size	Music training	Control group	Task(s)	Measure(s)	Results
Wang et al. (2019)	17	96	Dong ethnicity: Song is integral to culture	Han ethnicity: Song is not part of culture	Pitch detection (bass or treble); timbre detection (wind or string); predictable switching	Local switch cost	Smaller local switch cost in Dong ethnicity
Wang et al. (2019)	17	96	Dong ethnicity: Song is integral to culture	Han ethnicity: Song is not part of culture	Parity (even or odd); letter type (consonant or vowel); predictable switching	Local switch cost	Smaller local switch cost in Dong ethnicity
Moradzadeh et al. (2015)	18–31	153	6–22 years of formal training	Yes	Numerical quantity (one or three items); numerical identity (numeral 1 or 3); predictable switching	Local and global switch cost	Larger local and global switch costs in musicians; results difficult to interpret because groups were not baseline matched
Slevc et al. (2016)	18–32	96	Continuous range from nonmusician to 5+ years of training	Yes	Parity (even or odd); letter type (consonant or vowel); predictable switching	Local switch cost	No relationship between the level of music training and local switch cost
Slevc et al. (2016)	18–32	96	Continuous range from nonmusician to 5+ years of training	Yes	Pitch detection (bass or treble); timbre detection (wind or string); predictable switching	Local switch cost	No relationship between the level of music training and local switch cost
Okada and Slevc (2018)	17–22	150	Continuous measure of music training using general undergraduate sample	Yes	Parity (even or odd); letter type (consonant or vowel); predictable switching	Local switch cost	No relationship between the level of music training and local switch cost

Paper	Age (years)	Sample size	Music training	Control group	Task(s)	Measure(s)	Results
Hesterman et al. (2019)	18–30	32	~5 years of music lessons	Yes	Tapping consistency; switch vs. nonswitch blocks; predictable switching	Global switch cost	Musicians showed better performance during switch blocks; this could be due to better memory for longer musical phrases
Saarikivi et al. (2016)	9–15	90	Mean training start age of 7 years old	Yes	Trail making test B	Trails B performance	Nonsignificant group difference
Bialystok and DePape (2009)	18–35	71	Mean of 16 years experience (half instrumental; half vocal)	Yes	Trail making test B	Trails B performance	Nonsignificant group difference
Hou et al. (2014)	~20	88	Mean training start age of 5 years old	Yes	Trail making test B	Trails B performance	Nonsignificant group difference
Bugos and Mostafa (2011)	~19	30	~9.5 years of music lessons	Yes	Trail making test B	Trails B performance	Musicians showed better performance
Hanna-Pladdy and Gajewski (2011)	59–80	70	10+ years music experience	Yes	Delis–Kaplan executive function system	Trail making test	Nonsignificant group difference
Zuk et al. (2014)	18–35	45	Mean training start age of 6 years old	Yes	Delis–Kaplan executive function system	Trail making test	Nonsignificant group difference
Zuk et al. (2014)	9–12	39	Mean training start age of 6 years old	Yes	Delis–Kaplan executive function system	Trail making test	Musicians showed better trail making performance
Strong and Midden (2020)	65+	57	1–20 years of private music lessons	Yes	Delis–Kaplan executive function system	Color-word interference task 4	Active musicians showed better performance than former musicians or nonmusicians

(continued)

Table 1 (continued)

Paper	Age (years)	Sample size	Music training	Control group	Task(s)	Measure(s)	Results
Strong and Mast (2019)	~73	58	Varied, with most participants having some history of private lessons	Yes	Delis–Kaplan executive function system	Color-word interference task 4	Musicians showed better performance
Clayton et al. (2016)	20–29	34	10+ years of formal training	Yes	Delis–Kaplan executive function system	Color-word interference task 4	Nonsignificant group difference
Hanna-Pladdy and Gajewski (2011)	59–80	70	10+ years music experience	Yes	Delis–Kaplan executive function system	Category switching fluency	Nonsignificant group difference
Mannermaa (2017)	13–20	59	Began training 4–7 years old	Yes	NEPSY-II	Arrow task	Nonsignificant group difference
Saarikivi et al. (2016)	9–15	90	Mean training start age of 7 years old	Yes	NEPSY-II	Arrow task	Musicians showed better performance
Degé et al. (2011)	9–12	90	1+ years of music lessons	Yes	NEPSY-II	Set-shifting task	Correlation between months of music lessons and set shifting (but correlation may be uninterpretable because one-third of participants had no music lessons, violating the continuous data requirement of the statistical test)
Robertson (2019)	14–18	40	3+ years of music training	Yes	Wisconsin card sorting test	Perseveration score	Nonsignificant group difference
Schellenberg (2011)	9–12	106	2+ years of music lessons	Yes	Wisconsin card sorting test	Perseveration score	Nonsignificant group difference
Hanna-Pladdy and Gajewski (2011)	59–80	70	10+ years music experience	Yes	Wisconsin card sorting test	Perseveration score	Nonsignificant group difference

Paper	Age (years)	Sample size	Music training	Control group	Task(s)	Measure(s)	Results
Sirisumthum et al. (2015)	18–24	40	Studying in a music program	Studying in a nonmusic program	Wisconsin card sorting test	Perseveration score	Nonsignificant group difference
Cocchini et al. (2017)	19–38	40	4–20 years of private instrument lessons	Yes	Visual pattern test and music recognition task	Percent change from single to dual task	Nonsignificant group difference
Douglas and Bilkey (2007)	~22	34	5+ years of music training	Yes	Pitch discrimination and either mental rotation or animal matching	Dual task relative to a single task baseline	Means show no evidence of a group difference
Walker et al. (2014)	18–24	66	Self-reported as a musician	Yes	Are beat tracks on or off the beat of music tracks (primary); track a moving dot by moving a cursor (secondary) or determine if a dot changed color (secondary)	Beat judgment accuracy	Interaction between training and secondary task type, with musicians outperforming nonmusicians on the primary task only when the secondary task was motor; nonsignificant group difference on secondary tasks
Walker et al. (2014)	18–28	70	Self-reported as a musician	Yes	Determine if three notes are the same or different (primary); track a moving dot by moving a cursor (secondary) or determine if a dot changed color (secondary)	Pitch judgment accuracy	Musicians outperformed nonmusicians at the primary task; nonsignificant group difference on secondary tasks
Moradzadeh et al. (2015)	18–31	153	6–22 years of formal music training	Yes	Motor tracking and letter detection	Dual task relative to a single task baseline	Musicians were more accurate

(continued)

Table 1 (continued)

Paper	Age (years)	Sample size	Music training	Control group	Task(s)	Measure(s)	Results
Moradzadeh et al. (2015)	18–31	153	6–22 years of formal music training	Yes	Auditory and visual n-back	Dual task relative to a single task baseline	Musicians were more accurate
Lim et al. (2001)	19–62	78	7+ years of formal music training	Yes	Melody comparison simultaneous with finger tapping	Melody comparison accuracy	Musicians were more accurate
Patston and Tippett (2011)	~24	72	10+ years of formal music training	Yes	Grammar checking simultaneous with one of three conditions (music with errors, music without errors, or no music)	Grammar checking accuracy	Musicians outperformed nonmusicians in the correct music and no music conditions
Patston and Tippett (2011)	~24	72	10+ years of formal music training	Yes	Visual search simultaneous with one of three conditions (music with errors, music without errors, or no music)	Visual search accuracy	Musicians outperformed nonmusicians in all three conditions
Escobar et al. (2020)	18–28	49	10+ years of formal music training	Yes	Dual task (auditory sentence plus noise) and single task (visual sentence without noise)	Word recall accuracy difference between single- and dual-task conditions	Nonsignificant group difference

For example, Wang et al. (2019) conducted task-switching studies that examined the Dong ethnic group in China. This ethnicity has a great deal of music expertise, as song is an integral part of their life. Some people in this ethnic group have expertise in singing Dong songs, which provide a means of transmitting culture between generations, while others do not sing these songs. Dong songs are polyphonic and sung a capella; they have harmonic and tonal complexity. In contrast, individuals of Han ethnicity are not familiar with Dong songs, as they speak a different language, and music is not an integral part of Han culture. This study, while notable, confounded cultural differences with differing degrees of music expertise.

The Trail Making Test Part B (Trails B) requires participants to draw lines between numbers 1–13 and letters A to L in ascending sequence (Reitan 1958). The Delis–Kaplan Executive Function System (D-KEFS; Delis et al. 2004) includes a similar trail making task, and it was shown to be equivalent to Trails B in a factor analysis (Atkinson and Ryan 2008; Delis et al. 2004).

Of the seven studies that investigated trail making test performance, only two showed a musician benefit. These two studies used small sample sizes, and the evidence suggests that these two studies were outliers, as four studies with double or triple the sample size failed to find a musician benefit. Notably, trail making test studies used participants from across the lifespan, from childhood to older adulthood, suggesting that the presence or absence of a music training benefit is not related to age.

There are significant issues with the trail making test as a measure of task switching. The trail making test involves shifting attention between letters and numbers, maintaining a mental record of the last letter and number used, and a significant visual search component, as the participant must locate circles with the appropriate character. Maintaining the proper sequence of letters might be less challenging for musicians, who are used to naming the letters A to G as indicators of musical notes. As a result, the task might be easier for musicians due to a factor that has nothing to do with task switching. In general, it is difficult to know if any observed advantage at Trails B performance is due to task switching, or another component of task performance.

The trail making test does not measure baseline performance on all task components individually (i.e., both number and letter sequence-making). Thus, this task fails to measure baseline performance against which switch performance can be measured. Trails B is measured as a time-to-complete score. Incorrect performance results in a tester prompt to correct the error, which results in the time score also including error correction time.

The D-KEFS includes a task that combines Stroop and task switching, with task changes between naming ink color and color word. Thus, this measure combines inhibition and task switching (cf. MacLeod et al. 2003, who argue that Stroop might not, in fact, be an inhibition task; note that no single task is a pure measure of an entire construct). There was evidence for a musician benefit on the Color-Word Interference Task 4 in older adults (Strong and Mast 2019; Strong and Midden 2020). It is not possible to determine if the musician benefit was related to inhibition or task switching.

Three other set-shifting measures (D-KEFS category switching fluency, NEPSY-II set-shifting task, and Wisconsin Card Sorting Test) failed to show a musician benefit, across six studies, despite some studies using a reasonably large sample size. The category switching fluency task of the D-KEFS involves switching between naming exemplars of two different categories of objects. This task combines retrieval of semantic knowledge and set switching. The NEPSY-II set-shifting task involves sorting animal cards into as many categories as possible, with a maximum of 12 possible categories. This task requires category generation skills in addition to sorting ability. The Wisconsin Card Sorting Test (WCST) requires participants to sort card into piles based on the number, shape, and color of geometric objects printed on the cards (Berg 1948). The sorting rule is changed after 10 correct sorts. The WCST requires problem-solving to determine the next task rule, as well as efficient working memory to keep track of which task rules have and have not been tried. As a result, performance on this task involves factors that are not related to task switching, making the common interpretation of this task as a measure of set shifting incorrect (Cepeda et al. 2000). Like the trail making tests, the WCST does not provide baseline performance measures. The WCST is untimed, so only accuracy scores are available. Researchers use the perseveration score as a measure of task switching.

Two studies have used the NEPSY-II arrow task, which involves naming the direction of an arrow, or the opposite direction, depending on arrow color (Brooks et al. 2009). This task is not a controlled task-switching measure because one of the component tasks requires inhibition, and there is no correction for this additional task component. This task produced inconsistent results across studies. Overall, scant evidence exists that music expertise is related to task-switching performance.

2.2 Dual-Task Performance

In general, quasi-experimental studies showed a musician advantage at dual-task performance, with five studies showing a musician benefit and three studies failing to do so. In particular, the studies that showed a musician benefit used relatively large sample sizes, whereas those that failed to find a benefit used smaller sample sizes, raising the possibility that the lack of a significant difference was due to insufficient sample size.

3 Differing Degrees of Expertise or Training

Some studies had no control group and instead examined music or dance experts with greater or fewer years of training or higher or lower performance on objective measures of music expertise (Table 2). Potentially, these studies provide stronger evidence than studies of music experts in comparison to controls because all individuals chose to partake in music or dance training.

3.1 Task Switching

The size–shape–color variantof the Dimensional Change Card Sort test involves the placement of cards into bins as indicated by a cue (Cepeda and Munakata 2007; Deák and Wiseheart 2015). This task, which is appropriate for young children who might not be able to complete a complex computerized task-switching paradigm, only has switch trials.

Janurik et al. (2019) examined the Dimensional Change Card Sort test performance of first-grade students, all musically trained using the Kodály[4] method. There was no control group. Five objective music perception tests (melody, pitch perception, chord analysis, rhythm discrimination, and tempo discrimination) were moderately correlated with task-switching performance, using the moderately difficult version of the card sorting task (Józsa et al. 2017). This study was notable in its use of large sample size and that it measured correlations between task-switching and objective measures of music ability rather than music training. While the study fails to contribute to the knowledge of whether task-switching skill improves because of training, it is useful to know that individuals who are good at task switching are also better at music skills.

Wood (2016) conducted a study on clef switching in musicians without a control group. Participants switched between playing triads in the treble and bass clef, with a clef change every two trials. Key signature changed every two blocks of 40 trials. Clef-switch trials were slower than clef-repeat trials, and initial trials in key signature change blocks were slower than later trials. The level of music ability did not predict switch cost. Music performance itself appears to involve a local switch cost, based on these two indicators.

3.2 Dual-Task Performance

It seems clear that having a large sample size is not sufficient to produce conclusive results. Jones (2006) compared musicians majoring in music or another field. Despite a sample size of 192 participants, Jones found a complex set of dual-task results that cannot be interpreted. Future studies need to use an objective measure of music expertise, which is a more nuanced measure of one's degree of musicianship than the choice of major.

[4] A form of music training based on solfège, which is a movable pitch range with a name for each individual pitch. This form of music training emphasizes rhythm and movement in a social environment.

Table 2 Studies using individuals with differing levels of music expertise without a nonmusically trained control group

Paper	Age (years)	Sample size	Music training	Control group	Task(s)	Measure(s)	Results
Janurik et al. (2019)	7	131	8 months Kodály	No	Dimensional change card sort	Card sorting performance; five music perception tests (melody, pitch perception, chord analysis, rhythm discrimination, and tempo discrimination)	r = 0.26–0.45 between card sorting and music perception tests
Wood (2016)	18–74	22	Professional and hobbyist musicians	No	Clef switching; key signature switching	Local switch cost	Both groups showed a local switch cost for clef and key signature changes
Schneider (2018)	39–77	39	Current or former member of a professional orchestra	No	Trail making test B	Trails B performance; years of lessons, age began lessons, hours of practice, years worked for an orchestra, and type of instrument played	r = −0.09–0.19 between trails B and music experience measures
Jones (2006)	~21	192	Music majors and musicians not majoring in music	No	Visual image and auditory excerpt tasks (participants were asked if stimuli were novel)	Accuracy in dual- and single-task conditions	Complex interaction between major and condition (single vs. dual task), which is difficult to interpret
Wöllner and Halpern (2016)	18–73	30	Conductors and pianists who were professionals or students	No	Divided attention between two auditory streams	Detection of small timing or pitch variations	Experts and conductors were more accurate

Wöllner and Halpern (2016) compared more and less experienced conductors and pianists, all adults. The conductors also played piano, although they had fewer years of formal piano training than the pianists did. The paradigm involved dividing attention between two auditory streams and detecting small timing or pitch variations. Experts and conductors were more accurate at detecting target stimuli, which contained variations in timing or pitch. This study raises the possibility that different forms of music expertise could be related to the presence or absence of multitasking benefits. Replication of this study with a larger sample size would be useful, and it is not clear how much age-related factors played a role in producing observed conductor and expert benefits (since experts were older than students, and the age range included all of adulthood).

4 Experimental Training Studies

The strongest studies are randomized controlled trials, in which participants are randomly assigned into experimental or control groups (Table 3). If the sample size is reasonably large, any random differences between individuals will be equivalent for experimental and control groups so that more definitive statements about whether training benefits multitasking can be made. The major downside of these studies is that it can be challenging to collect a sample in which participants successfully complete a large amount of training, thereby maximizing opportunities to observe training benefits. Without lengthy training, it is not possible to rule out lack of sufficient training as an explanation for a lack of observed training benefit.

In contrast to most existing reviews, a meta-analysis by Meng et al. (2020) reported results of 13 dance training studies in relation to executive function, including a few that involved task switching. Similarly, Predovan et al. (2019) reported results for seven dance and cognition studies. Studies relevant to the current review are described, and specific task-switching effects are separated from effects of other executive functions.

4.1 Task Switching

Of the studies that used the best possible measures of task switching, either local and global switch cost or the trail making test, only one study found a musician benefit. Notably, the study that produced a training benefit (Bugos et al. 2007) was the only one to use individual rather than group training. It might be the case that individual instruction is more intense and thus more capable of producing a training benefit. However, this possibility seems unlikely. A case could be made that performing in a group more greatly taxes the executive function system and thus should be more likely to produce a benefit at multitasking. Also, other studies utilized intense training, in one case for several years, yet failed to show a training benefit.

Table 3 Randomized controlled trials of music or dance training

Paper	Age (years)	Sample size	Intervention	Training time	Control group	Task(s)	Measure(s)	Results
Alves (2013)	60–80	65	Group ballroom dance	Two 2-h sessions per week for 4 months	Walking or passive control	Quantity (larger or smaller than five)/ parity (even or odd); predictable switching	Local and global switch cost	No group x time interaction
D'Souza and Wiseheart (2018)	6–9	75	Group music or dance training	Five 2-hour sessions per week for 3 weeks	Passive control (not randomly assigned)	Color (red or blue)/shape (cow or horse); unpredictable switching	Local and global switch cost	Local switch cost: Support for null hypothesis for both music and dance training; global switch cost: Inconclusive evidence
D'Souza and Wiseheart (2018)	6–9	75	Group music or dance training	Five 2-hour sessions per week for 3 weeks	Passive control (not randomly assigned)	Numerical quantity (one or three items); numerical identity (numeral 1 or 3); predictable switching	Local and global switch cost	Local and global switch cost: Support for null hypothesis for both music and dance training
Alves (2013)	60–80	65	Group ballroom dance	Two 2-h sessions per week for 4 months	Walking or passive control	Trail making test B	Trails B performance	No group x time interaction
Bugos (2010)	60–85	46	Group piano training	Weekly 45-min sessions for 16 weeks, plus 30 min of daily independent practice	Music listening	Trail making test B	Trails B performance	No group x time interaction

Paper	Age (years)	Sample size	Intervention	Training time	Control group	Task(s)	Measure(s)	Results
Bugos (2019)	60–80	135	Group piano training or group percussion ensemble	Weekly 45-min sessions for 16 weeks	Music listening	Trail making test B	Trails B performance	No group x time interaction
Bugos et al. (2007)	60–85	31	Individual piano instruction	Weekly 30-min sessions for 6 months, plus 3 h of independent practice per week	Passive control	Trail making test B	Trails B performance	Improvement in experimental but not control group, with training
Doi et al. (2017)	~76	172	Group ballroom dance or percussion playing	Weekly 60-min sessions for 40 weeks	Health education	Trail making test B	Trails B performance	No group x time interaction
Hackney et al. (2015)	~83	52	Group tango classes	Twenty 90-min sessions over 3 months	Classes on well-being and general scientific advances	Trail making test B	Trails B performance	No group x time interaction
Holochwost et al. (2017)	6–13	265	Orchestral music education	Five 2-h sessions per week for 39 weeks, for 1–3 years	Passive control	Trail making test from Atkinson and Ryan (2008)	Trails performance	No effect of number of years of music training
Kim et al. (2011)	~68[a]	38	Group dance (cha-cha)	Twice weekly 60-min sessions for 6 months	Passive control (not randomly assigned)	Trail making test B	Trails B performance	No group x time interaction

(continued)

Table 3 (continued)

Paper	Age (years)	Sample size	Intervention	Training time	Control group	Task(s)	Measure(s)	Results
Lazarou et al. (2017)	55–75[b]	129	Group ballroom dance	Twice weekly 1-h sessions for 10 months	Passive control	Trail making test B	Trails B performance	Group comparison data and analyses were not reported
Merom et al. (2016a)	Older adults	79	Group ballroom dance	Twice weekly 1-h sessions for 8 months	Walking	Trail making test B	Trails B performance	No group x time interaction
Merom et al. (2016b)	Older adults	424	Group folk or ballroom dance	Twice weekly sessions for a total of 80 h in 1 year	Passive control	Trail making test B	Trails B performance	No group x time interaction
Seinfeld et al. (2013)	60–84	29	Group piano training	Weekly lessons plus 45 min of individual practice for 4 months	Leisure activities (not randomly assigned or matched in piano learning interest)	Trail making test B	Trails B performance	No group x time interaction
Bugos (2019)	60–80	135	Group piano training or group percussion ensemble	Weekly 45-min sessions for 16 weeks	Music listening	Delis–Kaplan executive function system	Category switching fluency	No group x time interaction
Sachs et al. (2017)	6	56	Orchestral music education or sports (community soccer or swimming)	Seven hours per week for 2 years	Passive control (not randomly assigned)	NEPSY-II	Arrow task, with alternate stimuli (hearts and flowers)	No group x time interaction

Paper	Age (years)	Sample size	Intervention	Training time	Control group	Task(s)	Measure(s)	Results
Holochwost et al. (2017)	6–13	265	Orchestral music education	Five 2-h sessions per week for 39 weeks, for 1–3 years	Passive control	Wisconsin card sorting test	Number of perseverative errors	Improved performance with more years of music training
Kosmat and Vranic (2017)	69–88	24	Group dance (waltz)	Weekly 45-min sessions for 10 weeks	Group discussion of various topics (e.g., needs and interests of older adults)	Wisconsin card sorting test	Number of perseverative errors	Improved performance at post-test for the dance group but not for controls
Norgaard et al. (2019)	13–14	155	Jazz band; concert band class plus improvisation	Two months (no details on frequency or length of training, or whether total training time was matched between groups, were provided)	Concert band	Wisconsin card sorting test	Number of perseverative errors	No group x time interaction
Coubard et al. (2011)	60–89	110	Group contemporary dance or tai chi	Weekly 1-h sessions for 6 months	Fall prevention (not randomly assigned)	Behavioural assessment of the Dysexecutive syndrome	Rule shift cards test	Groups were not matched at baseline, so data cannot be interpreted

(continued)

Paper	Age (years)	Sample size	Intervention	Training time	Control group	Task(s)	Measure(s)	Results
Chen and Pei (2018)	~77[c]	25	Individual musical dual-task training (music therapy)	Weekly 60-min sessions for 2 months	Reading newspapers, playing chess and/or walking	Forward and backward digit recall while walking	Percent change in gait speed under dual-task vs. single-task conditions; percent change in stride length under dual-task vs. single-task conditions	No group x time interaction
Esmail et al. (2020)	~67	41	Group dance and movement or aerobic exercise training	Thrice weekly 1-h sessions for 12 weeks	Passive control	Two visual discrimination tasks	Single- and dual-task RT	No group x time interaction
Hamacher et al. (2015)	~68	35	Group dance training	Twice weekly 90-min sessions for 6 months	Exercise (endurance, strength, and flexibility)	Reciting serial three subtractions while walking	Serial subtraction speed; stride time variability; stride length variability; toe clearance variability	Greater improvement over time in serial subtraction speed and toe clearance variability in dance group; no group x time interaction for stride time or stride length variability

Note: [a] with metabolic syndrome; [b] with amnestic mild cognitive impairment; [c] with mild to moderate dementia

The other exception is a study that utilized the Wisconsin Card Sorting Test. Holochwost et al. (2017) found a benefit to Wisconsin Card Sorting Test performance after years of group orchestral training. Interestingly, they did not find a benefit to trail making test performance in the same sample. These inconclusive findings highlight the importance of measure selection since measures that tap multiple executive functions (e.g., the Wisconsin Card Sorting Test) might be more likely to demonstrate a training benefit.

4.2 Dual-Task Performance

No experimental music training studies were located in the literature (although one music therapy study was found that used a dementia sample). Thus, the literature consists primarily of dance training studies. All the studies that measured dual-task performance used older adults.

In contrast to the positive findings of an expertise benefit compared to imperfectly matched controls, for dual-task performance, the literature failed to support a dance training benefit to dual-task performance for randomized controlled trials. Notably, the lack of observed dual-task benefit could be due to the relatively small sample size used by existing randomized controlled trials.

5 Do Training Programs Work?

Several meta-analyses exist, which examined music training in relation to control groups using randomized controlled trials. A meta-analysis by Kim and Yoo (2019) investigated music instrument training effects on a variety of aspects of cognition in older adults. They found 10 studies of music interventions. Effects of music training on cognition were minimal, at best. Sala and Gobet (2017a, b, 2019, 2020) examined music training effects on a wide range of cognitive tasks. Their conclusion was that music training has near-zero benefits across tasks, especially when music training and active control groups are compared. A second-order meta-analysis showed that studies using passive control produced a small music training benefit, while those using active controls had no music training benefit (Sala et al. 2019). Likewise, the current review found little evidence of a training benefit to task-switching or dual-task performance.

5.1 Issues with Training Studies

Unlike trials of pharmaceuticals, it is not possible to blind participants to their experimental condition, so expectation effects could be present (Green et al. 2014). It might be possible to choose an active control group that negates this concern, such as a comparison of music and dance training (D'Souza and Wiseheart 2018). With an appropriate control group, expectation effects might be made equivalent between experimental groups.

Ideally, a control group would account for improvement due to mechanisms of no interest (Green et al. 2014; Von Bastian and Oberauer 2014). Commonly, active control groups account for factors such as experimenter attention, motivation, and engagement. Conversely, passive control groups fail to account for expectation and experimenter effects, which could affect post-trial test performance differences between groups (Morrison and Chein 2011). Studies that have an active control group showed a smaller music training benefit than those with a passive control group (Cooper 2020).

A more general concern is that each study uses its own conceptualization of the intervention of interest (Green et al. 2014; Morrison and Chein 2011). Not all music training programs include the same training elements. Some are purely instrumental and others include vocals; some are long and others comparatively brief. Music is a multidimensional construct (Cogo-Moreira and Lamont 2018), making it critical to ensure that evaluated cognitive skills overlap with trained music skills.

Test–retest effects can be a concern (Green et al. 2014). We know that task switching shows steep practice effects (Cepeda et al. 2001), and there might be less room for improvement in task performance at post-test compared to pre-test. These practice effects might make it challenging to detect a benefit of training, masking the presence of a true music training effect.

Not always discussed is that all training programs used in randomized controlled trials are brief in comparison to the amount of training needed to move from novice to expert skill level. When meta-analyses find that the literature does not appear to support training benefits, they are working from a definition of training that is short-term. The training literature is underpowered in the sense that short-term interventions are not a strong test of long-term music training effects. True music training effects might exist but be missed because studies do not measure performance changes across many years.

Few studies formally assessed the amount of improvement that took place during training. Yet the degree of training improvement predicted cognitive task performance (Jaeggi et al. 2011; Von Bastian and Oberauer 2014). Perhaps music programs did not show a training effect because the intervention only produced a small improvement in music skills. Or, perhaps some individuals in the sample showed a large training improvement and others did not, due to differences in trainee characteristics, such as motivation and self-efficacy (Burke and Hutchins 2007; Grossman and Salas 2011). That would lead to a reduction in training effect size since individuals who failed to show an improvement with training would reduce the potential for performance benefits on cognitive measures.

Training studies tend to measure intervention effects soon after the end of the training program, sometimes with a follow-up a year later. It is important to know whether training effects are long-lasting or only short-term (Melby-Lervåg and Hulme 2013). Articles often imply that training produces long-term benefits, but there is usually insufficient data to make this claim. If short-term benefits of music training are not found, it is unlikely that long-term benefits would suddenly occur. There is no reason to expect incubation effects, in which there are changes in a skill—such as problem-solving—after a break (Browne and Cruse 1988; Sio and Ormerod 2009).

Ideally, studies would utilize latent variables or multiple tasks to measure constructs, such as dual-task performance, rather than a single task, such as a specific dual-task paradigm (Noack et al. 2014; Shipstead et al. 2012). Doing so would result in less biased and more parsimonious estimates of a construct, as well as reduced measurement error (Spirtes 2001). Many studies in this review only included a single measure per construct, and almost none included a formal latent variable.

Only one study (D'Souza and Wiseheart 2018) used Bayesian analyses, which are capable of distinguishing null from indeterminate results. It is critical that studies of music and dance training update their analysis methods. Currently, it is not certain whether the many failures to find a training benefit are due to a true null effect or an insufficient sample size. If the true effect size for a music or dance training benefit is small, this effect would be missed by most previous research. That said, the sheer number of studies that failed to find a training benefit using randomized controlled trials—including a study with a large sample size and years of intense, formal music training—suggests that any music or dance training benefit is in fact small in magnitude.

5.2 General Conclusion

Until recently, it appeared that music training might improve performance on unrelated tasks, including task-switching and dual-task performance (Moradzadeh et al. 2015). However, randomized controlled trials of music and dance training suggest that training might not have an effect, especially compared to an active control group (Alves 2013; D'Souza and Wiseheart 2018). More research is needed—especially studies that use a long intervention of at least 6 months—since it appears likely that benefits of music training are only observed after substantial training time (Bugos et al. 2007; Holochwost et al. 2017).

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