Effects of Music and Dance Training on Executive Functions in Children

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Abstract

A body of evidence demonstrates superior executive functions in musicians, although most previous studies are cross-sectional. Dance, being similar to music, also offers potential for transfer to cognitive performance. A controlled experiment was used to isolate the causal influence of music and dance training on the executive functions of working memory, interference control, and task switching.

Children between 6-9 years old were randomly assigned to music or dance groups, and tested on executive functions before and after training. Following training, significant decreases in global and local switch cost were observed, but no change on measures of working memory or interference control. Results show 15 days of training transferred to improved task switching, with no difference between groups. The current study provides early evidence on the influence of dance training on task switching in children, and the similarity between music and dance on executive functions.

Dedication

To my parents, the wisest of them all

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Table of Contents

List of Figures

List of Tables

1. Introduction

The current study investigated the transfer from arts training in music and dance to cognitive ability. We investigated working memory, inhibition, and task switching, a triad of separable executive function skills (Miyake et al., 2000). These constructs were measured in elementary school children prior to and following a training program in one of the two arts domains.

Transfer refers to the process whereby learning in one situation influences performance in another situation (Royer, 2005; Singley & Anderson, 1989). As demonstrated in Figure 1, research on the transfer of cognitive ability has supported a similarity gradient. Transfer is more probable for near transfer, where effects are seen in a domain comparable to the trained domain, than for far transfer, where there is little resemblance between domains (Barnett & Ceci, 2002). For example, exercise produces near transfer, with improvements on physical health, as well as far transfer to cognitive and brain health (Voss, Nagamata, Liu-Ambrose, & Kramer, 2011).

Research findings have demonstrated transfer from experiential activities to executive function (Diamond & Lee, 2011). In particular, a body of evidence reveals that musical training impacts various cognitive abilities (Schellenberg, & Weiss, 2013; Wan & Schlaug, 2010), including executive functions (Degé et al., 2011). However, since previous studies have been mostly correlational or quasi-experimental (Schellenberg, 2009), there is a need for controlled experimental designs with random allocation to clarify whether training exerts a causal influence. Further, the lack of a proposed mechanism for the observed effects of musical training leaves open the question of whether findings are specific to musical training or general. Far transfer has been observed for non-musical domains, suggesting that such mechanisms may be general (Hannon & Trainor, 2007). It is possible that other activities may also engage similar domain-general processes (Bialystok & Depape, 2009). The current study explores dance training as one such activity.

A Content: What transferred			
Learned skill	Procedure	Representation	Principle or heuristic
Performance change	Speed	Accuracy	Approach
Memory demands	Execute only	Recognize and execute	Recall, recognize, and execute

B Context: When and where transferred from and to					
	Near ←				→ **Far**
Knowledge domain	Mouse vs. rat	Biology vs. botany	Biology vs. economics	Science vs. history	Science vs. art
Physical context	Same room at school	Different room at school	School vs. research lab	School vs. home	School vs. the beach
Temporal context	Same session	Next day	Weeks later	Months later	Years later
Functional context	Both clearly academic	Both academic but one nonevaluative	Academic vs. filling in tax forms	Academic vs. informal questionnaire	Academic vs. at play
Social context	Both individual	Individual vs. pair	Individual vs. small group	Individual vs. large group	Individual vs. society
Modality	Both written, same format	Both written, multiple choice vs. essay	Book learning vs. oral exam	Lecture vs. wine tasting	Lecture vs. wood carving

Figure 1. Taxonomy of Transfer (Barnett & Ceci, 2002).

Note. As stated in the original paper, the taxonomy is for practical and illustrative purposes only, and contains no mathematical meaning.

1.1 Executive Functions

Executive functions are supervisory control processes involved in goal-directed behavior (Anderson, 2002; Diamond, 2013). While executive functions are used as an umbrella term for a range of functions (e.g., planning, mental flexibility, response inhibition, interference control, multi-tasking, working memory), three core processes of working memory, inhibition and interference control, and cognitive flexibility have been identified through the literature (Diamond, 2013). Factor analysis has supported the existence of these three separable but related functions (Miyake et al., 2000), and inter-correlations among the three functions have been replicated across the lifespan (Diamond, 2002; Miyake et al., 2000).

Working memory is the system or mechanism for the temporary storage, activation, and monitoring of information (Baddeley & Hitch, 1974). Updating involves actively maintaining and manipulating information in working memory (Miyake et al., 2000). In comparison with long-term memory, working memory has a smaller capacity and temporal duration. Working memory includes the capacity of short-term memory, in addition to other processing mechanisms (Cowan, 2008).

Many theories exist on the nature and components of working memory, and how it relates to long-term memory and attention (Miyake & Shah, 1999). An early influential theory on working memory proposes a three-component model (Baddeley, 2003; Baddeley & Hitch, 1974), with a supervisory system (central executive) and two storage systems. Other theoretical perspectives have differed on whether working memory is separated by content (phonological and visuospatial subsystems) or is alike across modalities (e.g., Cowan, 1999). Perspectives have also differed on the link between working memory and long-term memory, with some theorists advocating that long-term information and skills account for individual differences in working memory (Ericsson & Kintsch, 1999).

Inhibition refers to the active suppression of a dominant, automatic, or 'prepotent' response. The current study focuses on one type of inhibition: interference control, which is the ability to avoid competing events and responses (Barkley, 1997). It can be further divided into 1) selective attention, focusing on relevant stimuli, and 2) cognitive inhibition, suppressing prepotent mental representations such as information obtained previously or from long-term memory (Diamond, 2013). Interference control is closely related to working memory and involves regulation of distracting information in working memory (Unsworth, 2010).

The final executive function construct is task switching, also known as set-shifting. Task switching involves shifting between mental sets, operations or tasks, with different rules for each set (Kiesel et al., 2010; Monsell, 2003). Shifting is considerably challenging (Diamond, 2013) as it involves both working memory (remembering the task rules) and inhibition (suppressing an irrelevant rule). It can be assessed through task switching or attention shifting paradigms (Cepeda, Cepeda, & Kramer, 2000; Kray & Lindenberger, 2000; Rogers & Monsell, 1995). In a non-switch condition participants are presented with one of two task sets (e.g., AAAA or BBBB), whereas in a switch condition participants switch between task sets (e.g., AABABA). Typically, activating a relevant task set and inhibiting an irrelevant one causes a decrease in accuracy or increase in response time, termed a switch cost. The expense of switching can be measured in two ways - the difference between the non-switch and switch conditions (global switch cost), or performance within the switch condition (local switch cost). Global switch costs require a higher working memory load as it involves maintaining set rules in working memory (Kray & Lindenberger, 2000).

Executive functions have been linked to activity of the prefrontal cortex (Best, Miller, & Jones, 2009; cf. Alvarez & Emory, 2006). The prefrontal cortex is one of the last brain regions to mature, with a slow progression of development from early childhood until around 25. The fine-tuning of neural networks takes place during development by neuron proliferation, myelination, cell death and pruning (Best et al., 2009), and occurs partly as a result of one's experiences. Therefore, investigating executive functions in a young population is particularly interesting because it offers a window of opportunity to examine how environmental stimulation can impact cognitive processes as they develop.

Individual executive functions develop at varying time courses. Inhibitory control is the first function to emerge (Jurado & Rosselli, 2007). It displays a large, qualitative improvement in children aged 4 and 5, followed by quantitative refinements until adulthood (Best et al., 2009). Performance on working memory tasks improves linearly from preschool until late adolescence (Davidson, Amso, Anderson, & Diamond, 2006). Task switching is the last executive function to develop. Children up to 11 years have difficulty with switching between task sets (Davidson et al., 2006), although studies using child-appropriate paradigms have demonstrated early switching abilities in children below six years (Dibbetts & Jolles, 2006). Switch costs decrease gradually through childhood (Cepeda, Kramer, & Gonzalez de Sather, 2001). Younger children show longer reaction times for global switch costs than local switch costs (Dibbetts & Joles, 2006; Kray et al., 2004), indicating greater difficulty with maintaining task sets in working memory compared with shifting itself (Kray & Lindenberger, 2000).

When investigating executive functions, attention should be paid to task selection. Several popular neuropsychological measures of executive function have poor reliability. Measures such as the Wisconsin Card Sorting Task or the Tower of London task are complex and can involve more than one executive function, as well as non-executive variance such as motor processes (Miyake et al., 2000). The issue of measurement is particularly salient for inhibition, which shows poor convergent validity across tasks (Friedman & Miyake, 2004). As a result, tasks measure inhibition of something, such as a response or event, and will inevitably involve variance from other processes. In light of task impurity, the current study used simple measures of executive function, with multiple tasks for each construct.

1.2 Executive Function Training and Transfer

Executive functions play a key role in a wide range of behaviours and have been associated with intelligence, academic achievement, and later life outcomes (Alloway, Gathercole, Kirkwood, & Elliott, 2009; Diamond, 2013). Research shows that executive functions influence, and are influenced by, one's experiences (Diamond, 2012). Given that executive functions are predictive of cognitive performance, it is desirable to investigate how they can be improved. Consequently, training of executive function has gained considerable attention and given rise to commercial training software aimed at improving cognitive performance. The literature on improving executive functions can be divided into two main training modes: computerized training and real-life interventions.

A pioneering study (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008) demonstrated transfer from a working memory computerized training program to fluid intelligence, although later studies have failed to find transfer (Redick et al., in press; Shipstead, Redick, & Engle, 2012). Additionally, working memory training shows transfer to executive functions such as cognitive control (Chein & Morrinson, 2010), although this also lacks replication (Dahlin, Nyberg, Backman, & Neely, 2008; Thorell, Lindqvist, Bergman, Bohlin, & Klingberg, 2009). Not all executive functions benefit from training. For example, preschoolers improved on working memory but not inhibition after computerized training programs (Thorell et al., 2009). Likewise, findings have been mixed transfer from task switching training to other abilities (Karbach & Kray, 2009; Minear & Shah, 2008).

Given the inconsistency of findings surrounding computerized training programs, and the artificial environment they create, it is useful to look to real-life activities as training interventions. Early evidence suggests that everyday activities (such as martial arts, fitness, and school programs) can also lead to transfer, although there is a need for further investigation using randomized longitudinal trials (Diamond, 2012). A review of executive function training interventions (Diamond & Lee, 2011) found a narrow transfer window, suggesting that interventions need to globally address executive functions for effects to occur. They also address other domains such as various sensory modalities and self-efficacy (Bugos, 2010). In comparison, computerized training programs often involve a single cognitive training task and may fail to capture the complexity of tasks in real life. It is possible that the combination of processes in everyday activities leads to stronger benefits - indeed research indicates that addressing a range of social, affective, and cognitive domains is more effective than targeting cognitive domains alone (Diamond & Lee, 2011).

Training interventions that challenge participants with novel and increasingly difficult material display the largest cognitive transfer effects (Bugos, 2010; Diamond, 2012). One question that will be addressed in the following sections is whether general structural components can lead to benefits regardless of the type of training paradigm, or whether transfer effects are more specific to the type of training received.

1.3 Transfer from Musical Training

Learning music is a complex, specialized activity that involves integrating multiple processes such as melody, rhythm, and motor activity. As a result, music training has repeatedly been presented as a model for the effects of skill acquisition on brain and behaviour (Jäncke, 2009; Rodrigues, Loureiro, & Caramelli, 2010). A body of evidence suggests that individuals with musical training outperform non-musicians on a range of abilities (Schellenberg & Weiss, 2013; Wan & Schlaug, 2010). Near transfer has been observed for abilities that resemble those trained in music, including auditory domains (such as pitch and rhythm discrimination, Fujioka, Ross, Kakigi, Pantev, & Trainor, 2006) and motor abilities (such as finger sequencing). Far transfer to non-musical domains has been observed in numerous behavioural investigations, including transfer to specific abilities, such as linguistic aptitude (Milovanov & Tervaniemi, 2011), mathematics (Vaughn, 2000), reading (Butzlaff, 2000; Standley, 2008), verbal memory (Franklin, Rattray, Moore, Moher, Yip, & Jonides, 2008), and visuospatial ability (Hetland, 2000), as well as general transfer to intelligence (Schellenberg, 2006).

It is known that the brain adapts in response to environmental variants, a phenomenon termed plasticity (Pascual-Leone et al., 2005). In line with behavioural evidence, neuroimaging research has revealed structural and functional plasticity in adult musicians (Jäncke, 2009; Wan & Schlaug, 2010), and in children after a period of musical training (Hyde et al., 2009). Musicians demonstrate neural reorganization in auditory, motor, and polymodal integrative networks, with improvements proportionate to the amount of training and practice, implying training-induced changes (Wan & Schlaug, 2010).

The simplest explanation for the various observed cognitive benefits is that learning music may improve general intelligence (Schellenberg, 2006). In an experimental study (Schellenberg, 2004), six-year old children who received musical training had improvements in full-scale IQ scores (FSIQ), as measured by the Weschler Intelligence Scale for Children (WISC-III; Weschler. 1991). No benefits were seen in a control group with either drama training or no training, indicating that improvements were not a result of general cognitive development alone. Similarly, a subsequent study (Schellenberg, 2006) with 6-11 year old children and university undergraduates found positive correlations between length of musical training and IQ after controlling for background variables such as parent's education and family income.

One hypothesized mechanism (Hannon & Trainor, 2007; Schellenberg, 2011; Schellenberg & Peretz, 2008) mediating the link between musical training and intelligence is executive function (Figure 2). Executive functions are associated with intelligence (Arffa, 2007; Obonsawin, Crawford, Page, Chalmers, Cochrane, & Low, 2002; Roca et al., 2010), as well as music. Learning music is a cognitively demanding activity (Hanna-Pladdy & MacKay, 2011), which places high demands on attention, memory, and planning (Jäncke, 2009). As a result, musical training may transfer to general improvements on executive skills (Hannon & Trainor, 2007).

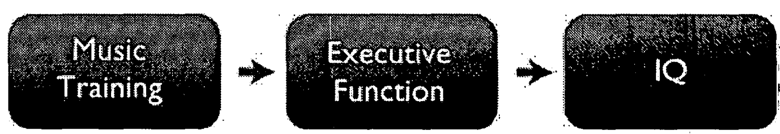

Figure 2. Executive functions as a mediator between music and intelligence (Schellenberg, 2011).

Musical training involves focusing attention to integrate multisensory processes (Bugos, Perlstein, McCrae, Brophy, & Bedenbaugh, 2007). The combination of bottom-up and top-down processing may underlie transfer in music (Trainor, Shahin, & Roberts, 2009). Higher-level cognitive mechanisms play a large role while learning music, and evidence suggests that enhanced cognitive performance accompanies improved auditory skills in musicians (Strait, Kraus, Parbery-Clark, & Ashley, 2010).

Numerous studies have shown that musicians perform differently to non-musicians on behavioural measures of executive function. Four to six year old children outperformed healthy controls on working memory, as measured by the digit span task, after a year of Suzuki musical training (Fujioka et al., 2006). Other researchers have found superior verbal memory in children with violin training, but no impact on visual memory (Ho, Cheung, & Chan, 2003). After four and eight months of classroom keyboard instruction, five and six year olds improved on spatial ability, although not memory for pictures (Rauscher & Zupan, 2000). Children with an average of six years of musical training outperformed a non-trained group on a range of working memory measures, including phonological storage, visuo-spatial memory, and executive working memory (Lee, Lu, and Ko, 2007). Conversely, children who received mental abacus training outperformed non-trained children on spatial working memory alone, indicating that working memory improvements may vary with training type.

Studies with adults also have provided support for the proposed link between music and executive function. In a retrospective study, musicians did better than non-musicians on the Simon task, indicating improved response inhibition (Bialystok & Depape, 2009). Older adults receiving 16 weeks of group piano instruction had improved performance on the cued colour word stroop task, but no change on a trial making task (Bugos, 2010), measures of interference control and set-shifting, respectively. Improved working memory performance occurred on the forward digit span task, but not the backward task, although the effect did not persist after instruction stopped (Bugos, 2010). Similarly, older adults who received six months of individualized piano instruction outperformed a group that did not receive the training on the digit symbol task, which the authors described as an index of working memory (Bugos et al., 2007). Improvement was seen also on the trial-making task, which contradicts the finding of Bugos (2010). The discrepancy between findings could be due to differences in the amount and type of training. In a cross-sectional study, older adults with musical training outperformed their non-trained counterparts on the trials task (Hanna-Pladdy & MacKay, 2011). Further, individuals with low musical activity (1-9 years, some formal training) had fewer benefits than those with high musical activity (over 10 years of formal training), highlighting that amount of training received should be considered when examining transfer. No differences between all three groups were found for the digit span task, letter number sequencing, and an auditory working memory task.

Adult musicians did better than non-musicians on phonological working memory, although not on visuospatial working memory or a measure of the central executive component (Lee et al., 2007). In a similar vein, Strait et al. (2010) found improvements on auditory tasks that are associated with cognitive abilities, which led the researchers to conclude that cognitive processes are central in musical training and drive perceptual improvements (Strait et al., 2010). No effects were observed for adult musicians on the digit backward task.

Working memory mechanisms were examined in a study using event-related potentials (ERP) (George & Coch, 2011). Musicians displayed shorter latency and larger amplitude on the P300, an index of working memory updating. Findings were strengthened by behavioural improvements on digit span forward and backward and letter span forward and backward. An EEG investigation (Trainor et al., 2009) demonstrated an impact of musical training on oscillatory networks associated with executive function - both in adult musicians and in four-year old children after one year of musical training.

A recent experimental investigation revealed that training as short as one month can impact verbal intelligence and attention (measured by behavioural and ERP performance on a go/no-go task; Moreno et al., 2011). Preschool children were randomly assigned to four weeks of computerized training in either music or visual arts. Importantly, the randomized design of the study deals with the issue of self-selection facing previous correlational research. A key finding was rapid transfer, highlighting that even short periods of learning music can have positive effects. Other studies have also shown that fewer than 12 months of training can induce near and far transfer on various abilities (Bugos et al., 2007; Corrigall & Trainor, 2009; Fujioka et al., 2006).

Although the current literature supports associations between musical training and overall executive function, findings are inconsistent on which executive functions can be improved. In light of this, a German study investigated an executive skills advantage in a sample of musically trained children between nine and twelve years of age (Degé, Kubicek, & Schwarzer, 2011). The researchers used a comprehensive neuropsychological assessment to measure executive function tasks, with subtests for set shifting, selective attention, planning, inhibition, and fluency. Analysis showed predictive effects for selective attention and inhibition, with a marginal effect of set shifting. Findings from previous studies on the effect of musical training on intelligence also were supported. Performance on the executive function tasks was significantly correlated with months of musical training and with fluid intelligence (ability to solve abstract problems; Cattell, 1963). In a hierarchical multiple regression analysis, demographic variables explained only 3.6% of the variance in intelligence, while executive functions accounted for 47.4% of the variance, signifying that executive functions may mediate the link between music and intelligence.

However, a study involving a Canadian sample of the same age range failed to find support for executive functions as a mediator (Schellenberg, 2011). Musical training was associated with higher IQs, but was independent of measures of executive functions (with the exception of a working memory task). Schellenberg's (2011) results contrast with Degé et al.'s (2011) findings, indicating that transfer from musical training to cognition may not always generalize to executive function measures. The inconsistency in findings could be due to differences between study design, type of training, or the tasks used (Schellenberg & Winner, 2011). Different indices of intelligence and executive function were employed by each study, and the reliability of the chosen tasks has been questioned (Bialystok, 2011). Given that the issue of measurement is particularly salient for executive function (Miyake et al., 2000), further investigation using reliable tasks and multiple measures for each construct is warranted.

A limitation of the executive function mediation hypothesis that has been overlooked is the second proposed link: between executive functions and intelligence.

While proponents of the hypothesis assume that the two constructs are linked, cognitive research has established a complex association whereby they overlap, but are not the same (e.g., Ardila, Pineda, & Rosselli, 2000). Factor analysis that accounts for the diversity of executive function shows large positive correlations between intelligence and working memory updating, but not shifting and inhibition (Friedman et al., 2006). To comprehensively advance current knowledge on music and executive function, it is essential to address each of the core executive constructs, including those that are not related to intelligence.

When examining the impact of musical training on executive function, several issues should be considered. First, despite the multiplicity of investigations, there is little examination of the mechanisms underlying transfer. One unanswered concern is whether observed executive function improvements are due to transfer from music to cognition, or a shared processing mechanism (Kraus & Chandrasekaran, 2010). On one hand, several researchers have advocated for general mechanisms, such as attention and executive function in music (Hannon & Trainor, 2007), which indicates that improvements may be due to the involvement of executive functions in training, rather than transfer. On the other hand, accumulating evidence from examination of the perceptual processes involved in music suggests that unique aspects of musical training boost performance, rather than cognitive effort alone. Studies using pre-attentive neural indices have related training effects to core theoretical components of music, such as pitch and auditory training rather than general attention or memory processes alone (Besson, Chobert, & Marie, 2011; Kraus & Chandrasekaran, 2010). Additionally, implicit (i.e., automatic or non-intentional) learning has been demonstrated in learning of many music-specific components (Rohrmeier & Rebuschat, 2012), suggesting that not all aspects of learning music require active focus.

A second issue is that a majority of studies employ a cross-sectional design by comparing groups of musicians to untrained groups. Although cross-sectional studies have provided substantial information on differences between groups, it is not possible to rule out confounding variables such as motivation or self-selection effects. It is possible that children with high IQs are more likely to take music lessons (Schellenberg, 2011). The need for prospective randomized controlled trials has been continually highlighted (Rodrigues et al., 2010; Schellenberg & Winner, 2011). Even the most established outcome of musical training, improved intelligence, has also been shown to be a predictor, thus raising serious questions about cause and effect. Only a few studies have included an active control group to dissociate the specific influence of musical training from other structured, intellectually challenging activities (Schellenberg, 2006).

Thirdly, the definition of musical training has been considerably open. Previous investigations into music encompass a broad range of training types, including different instruments (Degé et al., 2011), vocal training (Bialystok & Depape, 2009), formal lessons (Schellenberg, 2004), informal musical experience, music listening (Moreno et al., 2011), and individual versus group training (Bugos, 2010). Adequate reporting of core training content will enable studies to be compared and principal musical elements to be identified. Specific forms of musical training may produce findings that do not apply to musical training in general, such as the unique high attention levels noted in children who receive Suzuki training (Fujioka et al., 2006). Despite discrepancy among studies, the consistent reports of cognitive transfer suggest that there may be a general influence of musical training. Evidence for a general influence is seen in that effects were discovered for both instrumental players and vocalists (Bialystok & Depape, 2009), and on groups that received piano instruction or a musical listening course with no motor component (Bugos, 2010).

A fourth issue is that even for the same type of training, varying training parameters (frequency, intensity, etc.) in reported studies raise considerable within-group deviations in groups of musicians. Finally, the current evidence does not clearly dissociate how executive function is influenced by the age at which training is received. Studies indicate dissimilar effects across the lifespan, suggesting age groups should be investigated separately. For example, Lee et al. (2007) found that children with musical training were better on all forms of working memory, whereas adults were better only on auditory measures.

In summary, although there is considerable positive evidence suggesting music transfer (Table 1), more rigorously designed experiments are required to clarify the inconsistencies among findings. Systematic investigation of training, by delineating the duration, trained components, and mode of delivery, is needed for a cumulative research enterprise. Taken together, the literature suggests positive transfer of musical training to executive function across a range of musical training types (and even for music listening interventions). Observed patterns suggest that general effects may arise from musical training as a whole, even when specifics such as learning notation or instruments are not included.

Table 1.

Summary of studies that investigated the effects of musical training on executive function

Author(s)	n	Age (years)	Training type	Duration	Cognitive task	Results	Design (control Group, if applicable)
Bialystok & Depape (2009)	95	18-35	Classical instrumental or vocal	16-17 years (mean) 2 hrs daily practice	Simon task	effect	cross-sectional (untrained or bilingual)
					Auditory Stroop	effect	
					Forward and backward spatial span	no effect	
					Trail making task	no effect	
Bugos et al (2007)	31	60-85	Individualized piano instruction	6 months, 0.5 hr/week,	Forward digit span	effect (not persistent)	RCT (untrained)
				3 hrs daily practice	Backward digit span	no effect	
					Digit symbol	effect	
					Block design	no effect	
					Letter number sequencing	no effect	
Bugos (2010)	46	60-85	Group piano instruction	16 weeks, 0.75 hr/week	Cued colour word stroop	effect	RCT (Music Listening; also had effects)
					Trail making task	no effect	
					Verbal fluency	effect	
					Paced serial addition task	effect	
Dege et al (2011)	90	9-12	Instrumental training	1-4+ years	NEPSY II: Animal-sorting task of set-shifting	effect	correlational (no control)
					Auditory attention (selective attention)	effect	
					Clocks (planning)	effect	

Table 1
(continued)

Author(s)	n	Age (years)	Training type	Duration	Cognitive task	Results	Design (control group)
Dege et al (continued)					Inhibition test	effect	
					Design fluency	effect	
Fujioka et al. (2006)	12	4-6	Suzuki lessons (no notation)	1 year	Digit span	effect	cross-sectional
George & Coch (2011)	32	18-24	Instrumental, begun before age 9	over 9 years	Digit span forward and backward	effect	cross-sectional (untrained or <5 years)
					Letter span forward and backward	effect	
					Abstract visual memory	effect	
					Memory for location	effect	
Hanna-Pladdy & MacKay (2011)	70	60-83	Formal training with instruments	low (1-9 years) or high (>9 years)	Visual attention	no effect	cross-sectional (untrained)
					Digit span	no effect	
					Trail-making test	effect	
					Letter number sequencing	no effect	
Ho, Cheung, & Chan (2003) - Part 1	95	6-15	Band/orchestra program and classical lessons	1-5 years, 1hr/week	Hong Kong List Learning Test (HKLLT; verbal)	effect	cross-sectional (untrained)
					Brief Visuospatial Memory Test—Revised (BVMT–R; visual)	no effect	
Part 2			Band/orchestra	1 year	HKLLT	effect	longitudinal (discontinued or intent to learn)
					BVMT–R	no effect	

Table 1
(continued)

Author(s)	n	Age (years)	Training type	Duration	Cognitive task	Results	Design (control group)
Lee, Lu, & Ko (2007) - Part 1	40	12 (mean)	Musical training (passed tone recognition test)	6 years (mean)	Digit span forward and backward	effect	cross-sectional (untrained)
					Non-word span	effect	
					Operation span	effect	
					Simple spatial span	effect	
Part 2		22 (mean)		14 years (mean)	Digit span forward	effect	cross-sectional (untrained)
					Digit span backward	no effect	
					Non-word span	effect	
					Operation span	no effect	
					Simple spatial span	no effect	
Moreno et al (2011)	48	4-6	Computerized listening program	4 weeks, 10 hrs/week	Go/no-go paradigm	effect	RCT (visual arts)
Schellenberg (2011)	109	9-12	Musical training (various pedagogies)	>2 years (9-10 year olds) >3 years (10-12 year olds)	Digit span forward and backward	effect	cross-sectional (untrained)
					Phonological fluency	no effect	
					Sun-moon stroop	no effect	
					Tower of hanoi	no effect	
					WISC	no effect	
Strait et al (2010)	33	18-40	Musical training (started <9 years)	>10 years, 3 hrs/week practice	Auditory working memory (similar to backward digit span)	no effect	cross-sectional (untrained or <4 years)

1.4 Transfer of Dance Training

Dance is a complex, demanding skill that, like music, provides a unique combination of action experiences with perceptual and cognitive processes. Learning dance involves the acquisition of several building blocks (Schack, 2010), including coordination of movement processes with timing, orientation in space, and body representations (Bläsing et al., 2012). Over time, learning dance leads to 'an optimized cooperation of cognitive control and sensorimotor processing' (Bläsing & Schack, 2012). Simultaneously attending to the various building blocks produces and exercises highly specialized systems, making dance a potential domain for transfer to other cognitive abilities.

In comparison with music, considerably less inquiry exists into dance training. Cross-sectional studies involving older adults have shown near transfer to abilities such as gait, balance, motor ability, and posture (Kattenstroth, Kolankowska, Kalisch, & Dinse, 2010; Verghese, 2006). Imaging studies have revealed neural plasticity in dancers after as little as six weeks of training (Cross & Ticini, 2012). Changes were observed in parallel with learning of complex action sequences, implying dose-dependent effects.

Far transfer improvements are less consistent. In a large-scale study conducted over five years (Verghese et al., 2003), older adults who participated in certain leisure activities such as dancing or musical activity, were less likely to develop dementia, measured with several neuropsychological tests of intelligence and memory. No executive function improvements were observed for social dancers on several tasks, including the digit span, digit symbol, verbal fluency, and trail making tests (Kattenstroth et al., 2010). A general cognitive score, obtained by collapsing across various measures, showed better performance in dancers (Verghese, 2006). However, when looking at individual tasks there was no significant change on the one executive task used (a non-verbal geriatric concentration test, which measures selective attention). Additionally, drawing conclusions is limited by the wide range of expertise, type, and duration of training reported in dancers.

Pre to post studies of dance exercise have provided a clearer picture of the causal impact of training. Aerobic dance for 20 minutes produced immediate improvements on creativity (including flexible thinking) in women aged 19-35 (Gondola, 1987). Dance exercise in a population of elderly adults with metabolic syndrome (Kim et al., 2011), improved cognition on some measures, such as verbal fluency and word list recall, but not others, such as the trails test.

Currently, the specificity of cognitive transfer from dance training is unclear. Given the current exploratory state of dance research, most investigations tend to involve a broad range of measures (including cognitive, affective, social, and physical). With cognitive transfer, composite measures of attention, memory, intelligence and other constructs have been used to demonstrate significant effects. However, combined measures do not provide conclusive evidence on executive functioning specifically. Individual measures are not always reported, and only a few of those that are reported show significant changes. Most studies have been conducted from a physiological, sport science or geriatric standpoint, which limits conclusions on specific cognitive abilities.

Investigations using specific measures of executive function has indicated that while cognitive improvements do exist, they vary across constructs (Coubard, Duretz, Lefebvre, Lapalus, & Ferrufino, 2011). After less than six months of training in creative dance, a group of older adults outperformed control motor training groups (fall prevention and a Chinese martial arts group) on task switching, although not on the Stroop test of interference control. A randomized controlled trial with elderly participants found task switching benefits on a dance exercise program with movements arranged in choreographic sequences (Kimura & Hozumi, 2012). No changes were observed for a dance exercise program that was matched on all features (intensity, beat, and movements) except that the movements were not arranged. After two 40-minute sessions, participants in the organized program exhibited smaller switch costs on a computerized task switching measure, indicating that sequencing of movements may underlie improvements. Further evidence for domain-specific effects was displayed for implicit learning from exposure to structured sequences of movement in dance (Opacic, Stevens, & Tillman, 2009). A notable finding was that implicit learning was demonstrated even for long sequences, which are above the parameters of working memory in active learning, suggesting that some effects of dance training may be automatic.

A core building block of dance is movement, which involves coordinating body parts, time, and space (Calvo-Merino et al., 2008; Cross & Ticini, 2012). In this regard, exercise is a domain comparable to dance as it also involves considerable motor activity. Several reviews (Chaddock, Pontifex, Hillman, & Kramer, 2011; Tomporowski, Davis, Miller, & Naglieri, 2008; Voss et al., 2011) have established that exercise and physical fitness have a beneficial effect on cognition, particularly executive function. Positive effects of exercise have been reliably demonstrated across the lifespan, including in children (Chaddock et al., 2011), and are linked to the influence of aerobic fitness on cerebrovascular sufficiency.

Application of findings from fitness studies to dance may be restricted in that aerobic activity is differentially involved in dance training types, and is not a necessary component of dance training. Dance reflects a principally artistic activity rather than a sporting one (Puttke, 2010, p.103). Recent geriatric dance interventions have indicated far transfer to cognitive performance even when cardio-respiratory ability was not affected or involved (Coubard et al., 2011; Kattenstroth, Kalisch, Holt, Tegenthoff, & Dinse, 2013), indicating that it may not be the aerobic element alone that drives dance effects. Similarly, findings on the preventative impact of dance training on dementia were not observed for nine other physical activities, including walking and group exercise (Verghese et al., 2003), indicating the uniqueness of dance in comparison with other physical activities. Nevertheless, the strongly supported conclusion from fitness research - that motor activity can lead to cognitive benefits - offers a basis for guiding investigations into dance transfer.

The coupling between action and cognition is a marked part of dance training. Dance experts such as Puttke (2010, p.101) have proposed that “learning to dance means learning to think.” Movement in dance goes beyond motor activity alone to include cognitive control, with expert dancers demonstrating “complete intellectual control and mastery of mechanical skills” (Puttke, 2010, p.108). Anticipating effects in dance leads to formation of representations that regulate movement, and results in the development of a specialized perceptual-control system (Schack, 2010).

In conclusion, although evidence is indicative of a link between dance and mental functioning, the literature currently indicates general cognitive transfer, rather than executive functioning in particular. The breadth of findings may be due in part to the broad aims of current studies, and highlights a need for more detailed investigation of executive function changes following dance training (Table 2). A few studies into the components of dance (such as organized movements and action-cognition couplings) have suggested that such specific effects may exist.

Table 2.

Summary of studies that investigated the effects of dance training on executive function

Author	n	Age	Training type	Duration	Cognitive task	Results	Design (control group)
Coubard (2011)	100	59-89	Creative dance	5.7 months, 1 hr/week	Rule shift cards (task-switching)	effect	cross-sectional (motor activity training)
					Stroop test	no effect	
Gondola (1987)	37	19-35	Dance exercise	2 classes, 20 mins each	Alternate uses (flexibility of thought)	effect	cross-sectional (dance exercise, 1 class)
Kattenstroth et al (2013)	35	60-94	Dance program for elderly	24 weeks, 1 hr/week	Non-verbal geriatric concentration test	no effect	RCT (non-trained)
					Frankfurt Attention	effect	
Kattenstroth et al (2010)	62	61-94	Amateur dancers	4-28 years, 1.5 hrs/week	Non-verbal concentration test	no effect	cross-sectional (untrained)
Kim et al (2011)	38	above 60	Dance exercise	6 months 2 hrs/week	Verbal fluency	effect	experimental (untrained)
					Word list recall	effect	
Kimura & Hozumi (2012)	34	65-75	Dance exercise (organized movements)	2 classes, 40 mins each	Task switching measure	effect	RCT (dance exercise, no organized movements)
Verghese (2006)	108	above 70	Social dancing	3-75 years, 1-12 days/month	Digit span	no effect	correlational (no control)
					Digit symbol	no effect	
					Block design	no effect	
					Verbal fluency	no effect	
					Trail-making test	no effect	

1.5 Arts Transfer

Research on arts training provides a unique vantage point into investigating how changes in behaviour are associated with the acquisition of highly complex and coordinated skills. As described in the previous two sections, music and dance are two arts domains that offer multi-dimensional, rich learning experiences. Individual streams of research have established networks for each of the two domains, with transfer separately observed for both. The next step is to investigate the extent to which the networks overlap (Gazzaniga, 2008).

Similarities occur at several levels for the arts domains. Music and dance consist of different building blocks (domain-specific), but are alike in that they both contain a multiplicity of cognitive, perceptual and motor elements (domain-general). Combining basic parts occurs for all arts domains, which may result in highly specialized control mechanisms. The current study investigated the degree of similarity between behavioural outcomes of music and dance training domains. The most parsimonious explanation for the independently observed training benefits in these domains is the existence of general improvements, regardless of domain.

A single general factor across arts training forms is attention (Posner, Rothbart, Sheese, & Kieras, 2008). Although art forms have been investigated individually, high levels of sustained attention occur across domains and may explain increases in cognition for the arts. Aesthetic interest leads to motivation, followed by attention, which in turn leads to improved cognition (Posner et al., 2008).

However, findings on certain training domains suggest that there may be differences among training forms that persist after controlling for factors like attention and motivation. For example, cognitive improvements following musical training were not found for active control groups that received training in other arts such as drama or visual arts (Schellenberg, 2004; Moreno et al., 2011). Even the original theorists of a general interest factor have acknowledged the existence of separate brain networks for each domain (Posner et al., 2008). Further, findings on implicit (or automatic) learning for music and dance (Opacic, Stevens, & Tillman, 2009; Rohrmeier & Rebuschat, 2012; Tillmann, 2005) challenge the adequacy of a central attentional network explanation. Mere exposure to structures in music (Tillmann, 2005; Tillmann & McAdams, 2004) or dance (Opacic et al., 2009) can produce learning without the need for conscious recruitment of attention.

While a single general attention factor is not supported, resemblances across training domains may offer a general explanation for observed improvements. Key features of cognitive interventions have been proposed in the earlier section on executive function training. Complex inter-relationships between perception, action, and cognition have been identified for both music (Bugos et al., 2007; Wan & Schlaug, 2010) and dance (Cross & Ticini, 2012). Concurrent bottom-up and top-down processing has been proposed as a reason for transfer in music (Trainor et al., 2009), and may also apply to domains such as dance. At any point in performance, the musician or dancer is synchronizing various individual processes, such as switching between movements and counting to a beat. Multimodal sensorimotor integration improves in both domains, although the relative influence of independent modalities may vary for training forms – for example, proprioception plays a large role in controlling integration for dance (Jola, Davis, & Haggard, 2011). Beyond individual coordination, the musician or dancer must also attend to other artists. Hence, regardless of the varying components within each domain, music and dance domains are alike in the way consecutive processing occurs.

The idea of arts transfer is not new. Educational theorists have indicated conceivable improvement on domains outside arts as a function of arts learning. The term 'mental stretching' (Gardiner, Fox, Knowles, & Jeffrey, 1996) has been used to describe observed non-arts enhancement, and fits the description of transfer as it involves carryover of skills from one domain to another. Two complementary models have been proposed for transfer through learning the arts: 'conversation', which refers to creative and expressive processes in dialogue (inner and interpersonal), and 'silence' which refers to subconscious mental restructuring and processing (Catterall, 2005). The notion of 'silent' transfer – the process when arts training reorganizes neural structure and function, which in turn impacts processing of other tasks - bears resemblance to previously proposed domain-general processes for music (Hannon & Trainor, 2007). Although not directly investigated, experimenting with numerous components in the arts has been proposed as an aid toward mental flexibility (Cornett, 1999). In a field investigation involving over 2000 children, teacher reports identified the effects of school arts programs on cognitive abilities including fluency, flexibility in perspective-taking, and focused perception (Burton, Horowitz, & Abeles, 2000). While experimental investigation using reliable measures is required, nonetheless early reports from educational researchers reflect parallel development regarding arts training and highlight the interdisciplinary nature of arts training research.

Finally, rigorous design must be employed for studies into the arts. Issues with correlational findings have been previously discussed. Although randomized studies add direction to the current correlational evidence, simply measuring groups on extant measures will provide weak causation only (Gazzaniga, 2008). It is much more fruitful for theory-driven questions based on predicted mechanisms to guide investigations into the arts. Hence, the next section addresses how the current study looked to investigate some of the mechanisms that have been proposed in the literature on music and dance transfer.

1.6 Investigating Arts Transfer

The current study aimed to link together the bodies of evidence on music and dance, and in doing so, to answer questions regarding the parameters of transfer to executive function as a result of arts training. Given the lack of convergent evidence on the link between music and dance training on executive functions, it remains an open question which individual functions and training types can produce transfer. The current study aimed to test the theoretical mechanisms underlying transfer by examining whether effects were due to commonalities across arts domains (such as general attention, memory or multimodal demands), or more domain-specific elements.

Figure 3 demonstrates the domain-specific elements that were trained in the current study for each art domain. Training in the current study taught elements together, and not in isolation. The curriculum design reflected previous suggestions that domains such as dance are greater than the sum of their parts, and it would be ineffective to train each element separately without relating it to the art as a whole (Puttke, 2010).

Training domains were matched on intensity, structure and delivery, with the only difference being the content itself. Similarity in organization of domains allows investigation of whether observed effects are a general result of learning the arts, or whether effects differ according to content. Three possibilities exist: different improvements on each domain (as a result of domain-specific elements), similar improvements on both domains (due to a resemblance in domain-general executive processes), or no observed improvements.

Fundamental Concepts	
Dance	*Elements:* body, space, time, energy, and relationship
Music	*Elements:* duration, pitch, dynamics and other expressive controls, timbre, texture/harmony, and form

Figure 3. Elements trained for each domain. Adapted from the Ontario Curriculum for the Arts (2009, p.18).

Note. The original document also contains concepts for drama and the visual arts, which have been removed here.

A question that has been proposed for musical training, but which is equally applicable to arts research, is whether cognitive improvements are a result of transfer or shared processing. Common processing is defined as long-term experience in one domain influencing another domain, while transfer refers to long-term experience in one domain influencing the creation of abstract and specific rules in another (Besson et al., 2011). Using the taxonomy set out by Barnett and Ceci (2002), the current study used dissimilar training and testing contexts (Figure 4). Therefore, any improvements on executive function abilities were likely to arise from transfer, as the training was designed to improve arts-specific abilities rather than to train executive functions directly.

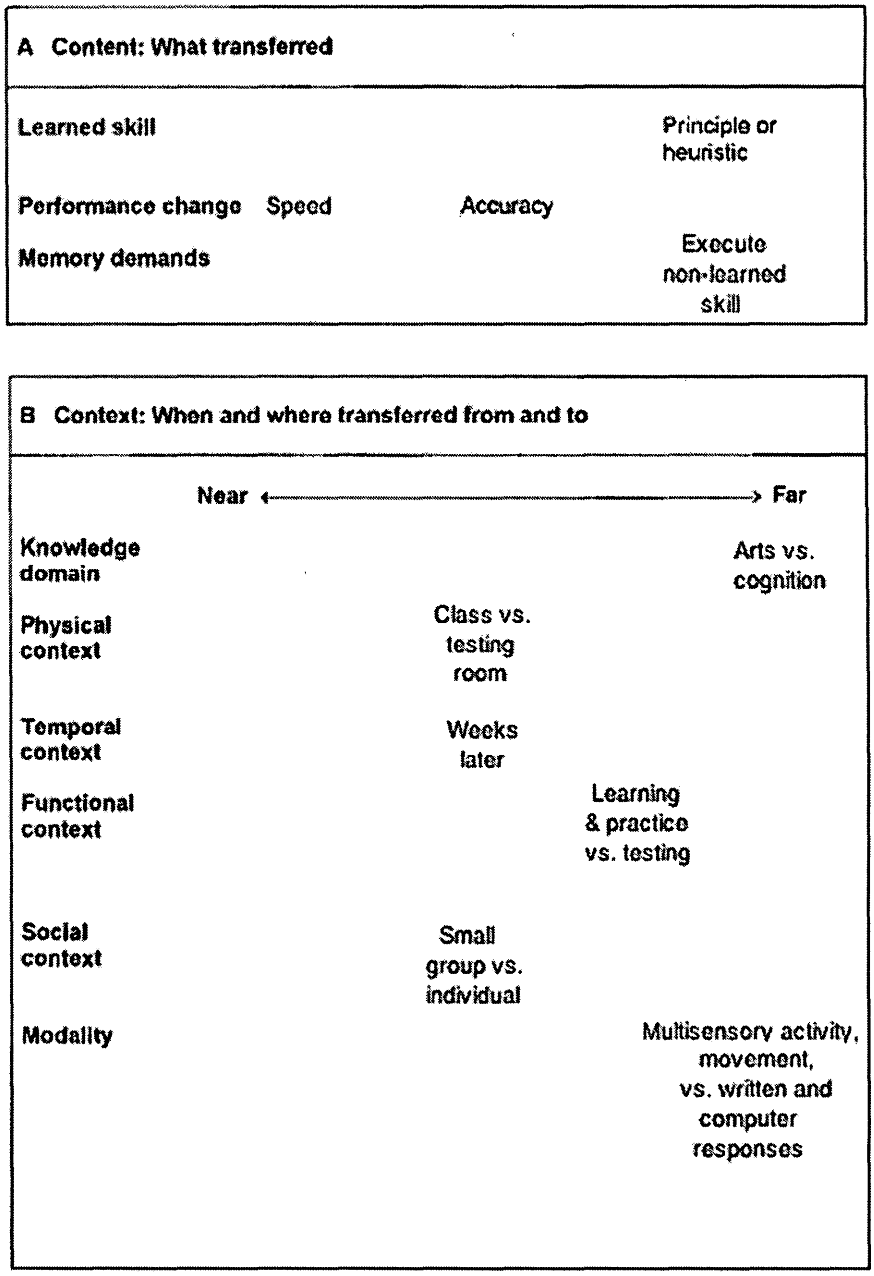

Figure 4. Comparison of training and testing domains based on Barnett and Ceci's (2002) framework.

As seen in Figure 4, any content that was transferred would involve general procedures, rather than specific skill sets or facts (the taxonomy describes specific skills as steps for a procedure, routines or algorithms, in comparison with general problem-solving heuristics, Barnett & Ceci, 2002). Similarly, the training context differed from the testing context to the extent that it qualifies as far transfer.

1.7 Hypotheses

The purpose of the study was to investigate the influence of arts training (music and dance) on children's cognitive ability. The transfer from arts training to executive function was a central enquiry. The following questions were investigated:

- Are executive functions influenced by short-term arts training (rapid transfer)?
- Is transfer specific to the type of training (music or dance)?

The main prediction was that both training groups would improve in performance on the executive function measures. In addition, there would be a differential effect for each training group:

- Working memory: Both groups would significantly increase in the number of items remembered after training.
- Interference Control: The music group would significantly improve on measures on interference control. The dance group would demonstrate no effect.
- Task switching: Both groups would significantly decrease in the time it takes to switch between task sets in a switch block (local switch cost) and between blocks (global switch cost).

In understanding these hypotheses on the effects of individual training domains, it is helpful to revisit the literature on training interventions. Studies of musicians and musical training (Table 1) have demonstrated benefits of learning music, although variables measured have been inconsistent. The most replicated effects have been for inhibition and task switching, hence an improvement was predicted on both these functions. Improvements in working memory have not always been replicated, and are more established for phonological measures than spatial – but since a few studies have demonstrated effects even with short-term training, an increase was predicted in the number of items that can be recalled in working memory (span).

Given that a few early studies have demonstrated effects of dance training on task-switching ability (Table 2), it was hypothesized that switch costs would decrease after the training. No direct effects of dance training have been previously observed for interference control, hence no changes were expected. Since learning movements has been linked to working memory, and movement is a key component of dance training, it was predicted that working memory span would increase.

2. Method

2.1 Design

The study was conducted as a randomized controlled design. Participants were randomly assigned to one of two training groups, music or dance. The study was divided into three phases: a testing phase, a training phase, and a second testing phase after training.

2.2 Participants

Sixty-five typically developing children (32 female) were recruited for the study. The mean age was 7.8 years (*SD* = 1.5, range = 6.0 to 9.8 years). Participants were recruited through posters in campus buildings, community recreation centers and schools; newspaper advertisements; distribution of flyers at family recreation events; online postings on family event websites; and messages to schools and community electronic mailing lists advertising a free arts summer program in either dance or music.

Since a consistent link between bilingualism and the executive function variables that were investigated has been found (Bialystok et al., 2009), recruitment was conducted in monolingual areas. The communities of Aurora and Halton Hills were selected for the study because about 90% of their populations (89% and 91% respectively) speak only English (Statistics Canada, 2007).

Parents responding to the advertisements and posters were screened via telephone. Children with developmental delays or learning disabilities, or who had previously received formal arts lessons were excluded from the study. To verify this information, guardians filled out detailed background questionnaires, which resulted in removal of six children who initially passed telephone screening but failed to meet the eligibility criteria after full disclosure. Exclusion was done before allocation to groups, as exclusions prior to randomization have no biasing influence on the results (Schulz & Grimes, 2002$_d$).

Following screening and an initial testing session, participants were assigned to one of two training groups: dance or music. Assignment was random (after stratifying for age, non-verbal IQ and gender). To control for baseline imbalance in randomized experiments, it is crucial to stratify groups based on current evidence of prognostic variables (Roberts & Togerson, 1999). Because IQ has been linked to music training previously (Schellenberg, 2004), adjusting for this factor helps avoid imbalance due to chance.

Participant characteristics are presented in Table 3. Nine participants were dropped from the analyses as a result of non-completion of the training, but the reasons for attrition (illness, behavioural disruptions and/or non-attendance) are unlikely to result in a selection bias. In the final sample training groups did not differ significantly on gender, age, years of mother's education, pre-intervention non-verbal IQ, or family income (all $p > 0.1$). We failed to detect any meaningful effects across sites, so this factor was collapsed.

Written consent was obtained from the parents or guardians, and verbal assent from the children, prior to participation. Parents were provided with an information booklet detailing the training and testing sessions and were directed to a website with further material. Consent rate after solicitation and child assent were both 100%. Correspondence with participating families was maintained via electronic mail and telephone. The study was approved by the Ethics Committee at York University.

Table 3.

Final sample of participants by age, pre-intervention IQ, years of mother's education and family net annual income (SD.)

	Dance training group	Music training group
n (start)	29	30
n (end)	26	24
Age (years)	8.1 (1.1)	7.6 (1.2)
IQ (K-Bit matrices[a])	112 (15)	107 (18)
Mother's education	4.0 (0.8)	3.9 (1.0)
Family Annual Income[b]	9.1 (4.1)	9.8 (3.4)

Note: Mother's education was measured on a scale of 1=No high school, 2=High school diploma, 3=Some college, 4=College diploma, 5=Graduate or Professional degree. Income was measured on a scale of 1=below $14999, 2=$15000-29999, 3=$30000-45999, etc.

[a]IQ scores were standardized using norms based on age

[b]Family Annual Income represents annual income of both guardians averaged over the past 5 years

2.3 Apparatus and Materials

2.3.1 Cognitive Measures. Five identical 15-inch screen laptops were used for the computer tasks. A gaming mouse (response time of 1 ms) was connected to the

equal to the number of pictures presented, and the spatial location of pictures was re-ordered after each selection.

Three conditions of increasing length (4, 6, and 8 pictures) were shown, with three trials for each condition (see Figure 5 for an example of the stimuli used). Stimulus presentation was self-paced, a participant's response led to the subsequent trial. A 2000 ms delay was set between trials. Performance was assessed in two ways: by number of errors (measured as pointing to a picture that was previously selected), and by span (measured as correct consecutive responses before the first error).

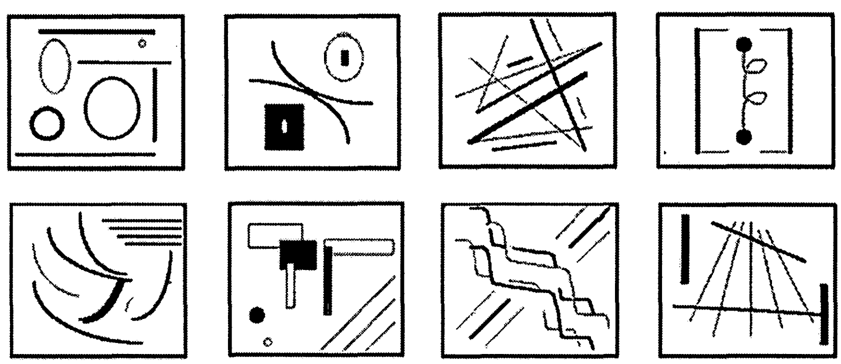

Figure 5. Stimuli for the 8-picture condition of the Self-Ordered Pointing Task.

What Number/How Many Switching Task (Cepeda, Cepeda, & Kramer, 2000). Four stimuli displays: 1, 111, 3 or 333, were randomly presented. A visual cue with the words 'What number?' or 'How many?' was displayed above the stimulus for each trial.

Trials were self-paced. A fixation cross appeared at the beginning of each trial. A random response-stimulus interval of 300-600 ms was used.

There were two non-switch blocks of 24 trials, and a switch block of 24 trials. Half the stimuli used were response compatible ('1' and '333'), in which the response was consistent for both identity and matching rules, and the other half were response incompatible ('111' and '3'). Each block was preceded by 8 practice trials with feedback. Experimenters read the cue aloud for the first four trials of each block.

In the first block, participants pressed the key '1' or '3' in response to what number was presented on the screen. In the second block, they pressed the same keys in response to how many items they counted on the screen. In the last two blocks, they switched between each of the task rules for every two trials. Task switches occurred predictably, every third trial. Cue-target interval was 0 ms. For this task and the next, local switch cost was calculated by comparing response times for trials in which the task repeated (non-switch trials) in the switch block with trials in which participants had to switch tasks (switch trials) in switch blocks. Global switch cost was calculated by comparing non-switch trials in non-switch blocks with non-switch trials in switch blocks.

Color-Shape Switching Task (Barac & Bialystok, 2012). A white screen constantly displayed a blue horse (top left) and a red cow (top right). For each trial, a target stimulus and cue were presented at the bottom of the screen until participants responded, followed by an inter-trial interval of 1000 ms. Stimuli consisted of a red horse and blue cow. Participants were required to match the stimulus presented to one of the two images at the top, by pressing the “F” keyboard button with their left index finger for the left image and the “J” button with their right index finger for the right image. Matching was done according to either shape or colour, with a cue (a black amorphous outline for shape and a colour wheel for colour) specifying which type was required. RT and accuracy were measured and used to calculate local and global switch costs in the same way as the previous task.

Participants received instructions at the beginning of each block. There were two non-switch blocks of 22 trials each. The first non-switch block involved matching by shape, and the second by colour. Next there were three switch blocks: a practice block and two experimental blocks. The switch block included switch trials (in which the rule changed between trials) and non-switch trials (in which the rule was the same for consecutive trials). The number of switch trials was fixed to 22 for the practice block and 25 for each of the experimental blocks, while the number of non-switch trials varied. For each trial, there was a 50% probability of a task change, producing a roughly equal number of switch and non-switch trials for each subject. This meant that the task changed immediately after a trial 50% of the time, two trials after 25% of the time, etc. The symbol cue indicated which rule should be followed.

Stroop Task (Stroop, 1935). Three sets of stimuli were used: neutral words printed in different inks, colour words, and a page of asterisks printed in different colours. Sixty items were in each set, divided into 10 lines with 6 items per line. Items were presented on a letter sized white page, and printed in the following colours: red, blue, green, purple, yellow and orange.

Participants were asked to name the ink colour for each item as quickly as possible. The second set introduced a conflict condition, for example the colour 'red' printed in blue ink. The completion time for each set was measured using a stopwatch. Prior to being shown the experimental stimuli, participants were given two practice tasks: colour naming of words printed in the corresponding ink colour, and colour naming of colour words printed in a different ink colour. Completion times for the neutral words condition were compared to the conflict words condition.

Flanker Task (Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999). Target stimuli were presented against a grey background. A fixation point was presented in the centre of the screen for 250 ms, followed by a target stimulus for 2000 ms, with an interstimulus interval of 2000 ms. Participants were introduced to the "Arrow Game". They were given one computer mouse for each hand, and responded to a left-facing arrow by pressing a computer mouse with their left index finger, and to a right-facing arrow by pressing a mouse button with their right index finger.

The task consisted of three blocks presented in the following order: target stimulus only, target stimulus surrounded by diamonds (neutral condition), target stimuli surrounded by black arrows as flankers (refer Figure 6 for images). Half the flanker trials included black arrows that were pointing in the same direction as the target (congruent condition), and half had arrows in the opposite direction (incongruent condition), with both types presented randomly. The first two blocks consisted of 24 trials, and were preceded by a practice block of 6 trials. Participants were provided with feedback on their performance in the practice blocks. The third block consisted of 12 practice trials and 48 experimental trials. After all three blocks were presented, the second block was repeated, followed by the first. Response times and accuracy were recorded, and used to calculate interference control by comparing congruent with incongruent trials.

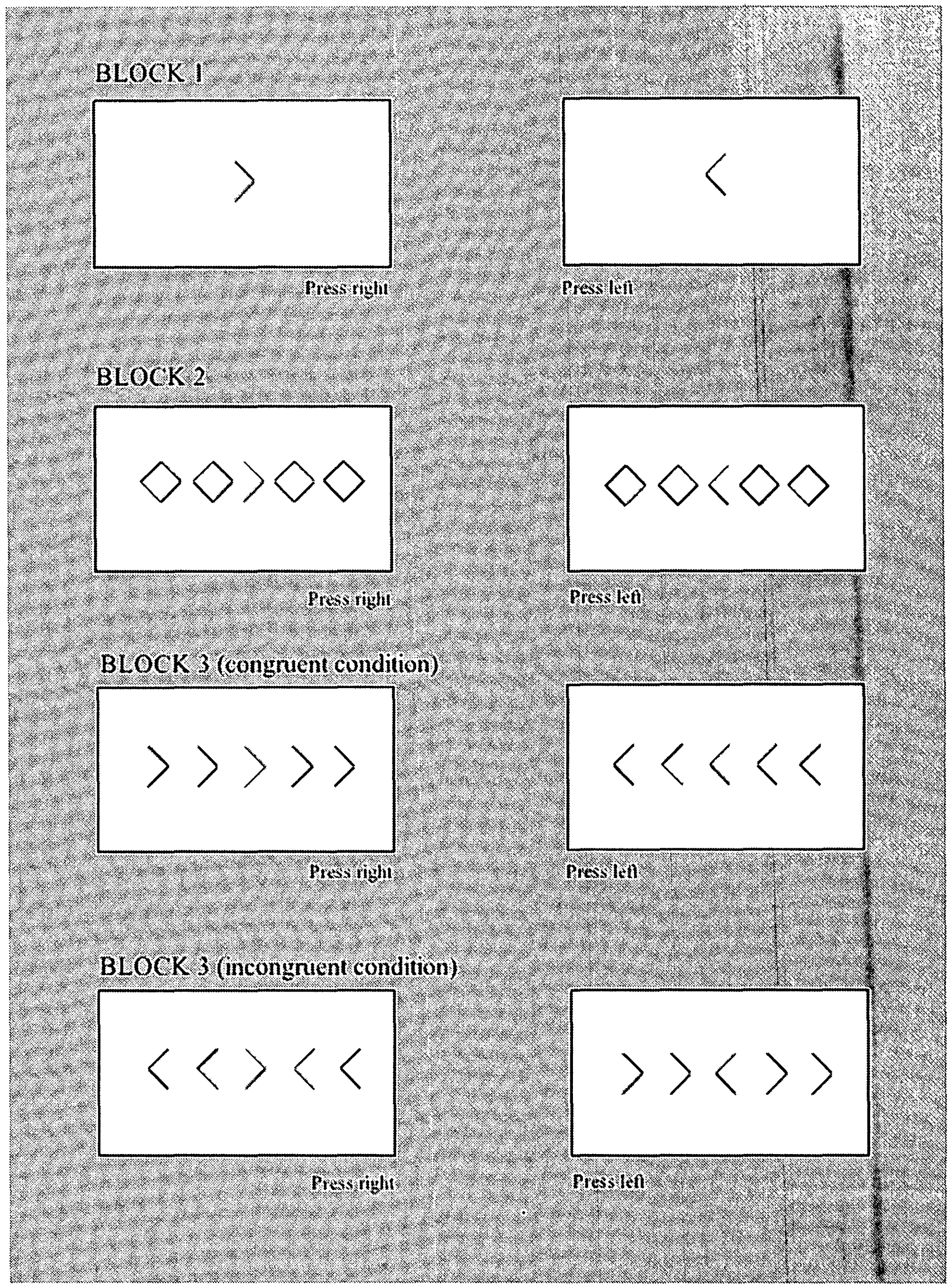

Figure 6. Stimuli used in the Flanker Task. In the Congruent Condition, flanker arrows are pointing in the same direction as the target stimulus. In the Incongruent Condition, flanker arrows are pointing in the opposite direction to the target.

2.3.2 Training Curricula.

Training programs were based on the curriculum guidelines set by the Ontario Ministry of Education (The Ontario Curriculum, Grades 1-8, The Arts, 2009) for teaching dance and music to grades 1 to 3, allowing delivery of an age-appropriate and standardized program. Each training domain was delineated into fundamental concepts for each art: dance as body, space, time, energy and relationship; and music as duration, pitch, dynamics and other expressive controls, timbre, texture/harmony, and form (p. 18, The Ontario Curriculum). Each element was introduced and developed through the training program, by means of direct instruction and class activities. Following the curriculum guidelines, the elements were taught together, and not as isolated components.

The music curriculum taught the elements through four basic ensembles. Each ensemble arrangement included instruments (ukuleles, steel drums and a xylophone) and a vocal section. The program rotated participants so that each child learnt each of the instruments and the vocal section for at least one ensemble.

Teaching plans were developed by faculty from York University's Faculty of Fine Arts and Faculty of Education. Teachers were involved throughout the curriculum development process, ensuring their familiarity and capability in delivering the program.

2.4 Procedure

2.4.1 Testing Phase. Testing was done in two sessions, one before and one after the training. These sessions were done in the three weeks prior to and following the training, so that the measures were taken as close to the training as possible. Each session lasted approximately two hours, with the cognitive tasks followed by a battery of academic measures (not reported here). Participants received stickers after completing tasks, and a small prize at the end of the session (worth approximately $15) to thank them for their participation. To minimize fatigue, participants were given a break halfway through the testing and were provided with snacks and a drink. Testing took place in participants' residences, in a quiet room with no distractions.

Testers were five graduate students and research assistants, four of who were blind to the participants' training groups. All testers received training and practice in task administration by a research assistant.

2.4.2 Training Phase. The programs were administered as a three-week summer day camp, with five days of training per week. Classes were conducted in dance studios, large school classrooms, and gymnasiums. Children received group lessons for two hours a day, with a 15-min break halfway. Attendance was recorded with daily sign-in sheets for parents, which were checked so that no participant missed more than 3 days of training.

Teachers had a doctoral degree and professional experience with children in their respective arts domain. Volunteers assisted with teaching and supervision. Volunteers had previous experience in the arts and in working with children and were trained in program protocols by a researcher. To engage all participants in the training, a 5:1 child to staff ratio was maintained.

Concurrent camps were run at Aurora and Halton Hills. Each site had one training group for each art form, with no differences between the duration and delivery of the program across sites and training forms. Discrepancy between sites was minimized as teachers worked together in the curriculum design, used the same day plans, and liaised throughout the training program. Video filming and supervision by researchers at each site was done to monitor the intensity of the training and ensure similarity across sites.

2.5 Analysis

Results for each task were analyzed using a two-way mixed analysis of variance (ANOVA): 2 (training type: dance or music) x 2 (testing session: pre/post training). For the two task-switching analyses, a third factor of switch was included, and separate ANOVAs were run to measure global and local switch costs. The second task switching analysis (what number/how many task) included a fourth factor of congruency.

3. Results

3.1 Working Memory

3.1.1 Digit Span Forward and Backward. The maximum number of correctly recalled numbers was recorded for each of the two tasks. No outliers were detected, so all

50 participants were used in the analysis. A mixed design ANOVA revealed a main effect of time for the digit span forward task, $F\,(1, 46) = 9.26$, $p = .004$, $\eta_p^2 = 0.17$, such that there was a significant increase in the number of digits that were recalled after training compared with before (Table 1). There was no statistically significant main effect of training group, and no statistically significant interaction, *p*s > 0.8. Analysis of the digit span backward task yielded no significant main effects or interaction, *p*s > 0.1.

Table 4.

Number of consecutive items correctly recalled on the Digit Span Task

	Before Training		After Training	
Measure	*M (SEM)*	95% CI	*M (SEM)*	95% CI
Digit Span Forward[a]	9.2 (0.2)	[8.8, 9.7]	10.0 (0.3)	[9.4, 10.5]
Digit Span Backward[a]	6.3 (0.2)	[5.8, 6.7]	6.4 (0.3)	[5.9, 6.9]

[a] Since no significant differences were found between dance and music groups, the data shown have been combined across training groups for this and all other tables (unless otherwise specified)

3.1.2 (SOPT) Self-Ordered Pointing Task. Participants were assessed on number of errors and their span, using the methods outlined by Cragg and Nation (2007). Number of errors was measured as the number of times a picture was selected that had been previously selected. Span was measured as the number of novel picture selections before the first error. For each set of pictures, the average number of errors and span was calculated across the trials. Five participants failed to follow instructions and were dropped from analysis, leaving a total of 45 participants for analysis. Data were analysed using mixed-design ANOVAs with factors of set size (4, 6, and 8 pictures), time (before and after training), and training group (dance and music).

For span analyses, Mauchly's test indicated the assumption of sphericity was violated for the factor of set size, ($\chi 2$ (2) = 15.1, p < .001), therefore degrees of freedom were corrected using the Greenhouse-Geisser estimates of sphericity (ε = 0.77). A main effect of set size was found, F (1.54, 66.02) = 31.68, $p < .001$, $\eta_p^2 = 0.42$. No other main effects or interactions were significant, $ps > 0.1$.

Pairwise comparisons for span indicated that the mean number of correct selections for the four-picture set was significantly lower than for the six and eight-picture sets, *MD* = 0.4, *SEM* = 0.1, 95% CI [0.2, 0.6], $p = .001$, $d = 0.4$ and *MD* = 1.0, *SEM* = 0.2, 95% CI [0.7, 1.3], $p < .001$, $d = 0.7$, respectively. The six-picture set was significantly different from the eight-picture set, *MD* = 0.6, *SEM* = 0.1, 95% CI [0.4, 0.9], $p < .001$, $d = 0.5$.

For error analyses, sphericity was violated for set size, ($\chi 2$ (2) = 10.5, p = .005), so the Greenhouse-Geisser correction was used (ε = 0.82). Similar to the span analysis, a main effect of set size was found, F (1.64, 27.56) = 186.50, $p < .001$, $\eta_p^2 = 0.49$, and no other significant main effects or interactions, $ps > 0.1$ (Table 2).

Table 5.

Performance on the Self-Ordered Pointing Task.

	Span		Error	
Set Size	*M (SEM)*	95% CI	*M (SEM)*	95% CI
4-picture	3.8 (2.8)	[3.8, 3.9]	0.1 (0.02)	[0.06, 0.2]
6-picture	4.3 (0.1)	[4.0, 4.5]	1.0 (0.07)	[0.9, 1.1]
8-picture	4.9 (0.2)	[4.6, 5.2]	1.7 (0.1)	[1.2, 1.9]

Pairwise comparisons for errors indicated that the mean number of correct selections for the six and eight-picture sets were significantly greater than the four-picture set, $MD = 0.9$, $SEM = 0.1$, 95% CI [0.8, 1.0], $p < .001$, $d = 1.58$ and $MD = 1.6$, $SEM = 0.1$, 95% CI [1.4, 1.8], $p < .001$, $d = 1.9$, respectively. The six-picture set was significantly different from the eight-picture set, $MD = 0.7$, $SEM = 0.1$, 95% CI [0.6, 0.9], $p < .001$, $d = 1.0$. These results indicate that as number of items in a set increased, participants had significantly larger spans and made significantly more errors, all *ps* < 0.001.

3.2 Task Switching

3.2.1 What Number/How Many Switching Task. RT and accuracy were measured. A cutoff was used for accuracy rates below 65%, or RTs larger or smaller than three SD from the mean, resulting in 20 participants removed from the analyses (1 outlier on RT, and 19 on accuracy). Local switch cost was analyzed by comparing mean responses of non-switch trials in the switch block with switch trials in the switch block. Global switch cost was analyzed by comparing mean responses of non-switch block trials with non-switch trials in switch blocks. RTs and accuracy scores were subject to four-way ANOVAs, with factors of time (before and after training), response compatibility (compatible and incompatible), switch, and training group (dance and music). Separate analyses were conducted for local and global switch cost.

Global switch cost analyses for RT revealed significant main effects of switch and response compatibility, $F\ (1, 28) = 103.812, p < 0.001, \eta_p^2 = 0.788$, and $F\ (1, 28) = 5.574, p = 0.025, \eta_p^2 = 0.166$, respectively. Participants had faster RTs for non-switch blocks and for response compatible trials. As predicted, a significant main effect of time was found, $F\ (1, 28) = 9.432, p = .005, \eta_p^2 = 0.252$, with faster RTs after training compared to before.

A significant interaction was found between time and switch, $F\ (1, 28) = 14.953, p = .001, \eta_p^2 = 0.348$. To further investigate this interaction, pairwise comparisons on non-switch trials were conducted. For non-switch trials in non-switch blocks, mean RTs before and after training were not significantly different. For non-switch trials in switch blocks, mean RTs after training were significantly faster than mean RTs before training, $MD = 289.3$, $SEM = 61.1$, 95% CI [167.0, 411.5], $p < .001$, $d = 0.61$ (Figure 7). No other significant main effects or interactions were found, all ps > 0.3.

Local switch cost analysis revealed significant main effects of switch, $F\,(1, 28) =$ 35.849, $p < .001$, $\eta_p^2 = 0.561$, and response compatibility, $F\,(1, 28) = 15.132$, $p = .001$, $\eta_p^2 = 0.351$. There was also a significant main effect of time, $F\,(1, 28) = 15.797$, $p < .001$, $\eta_p^2 = 0.361$, with faster RTs at post-testing as with global switch cost. No significant interaction was found between time and switch, $F\,(1, 28) = 0.944$, $p = 0.34$, $\eta_p^2 =$ 0.03,indicating, no change in local switch cost. No other significant interactions were found, all *ps* > 0.1 (Figure 8).

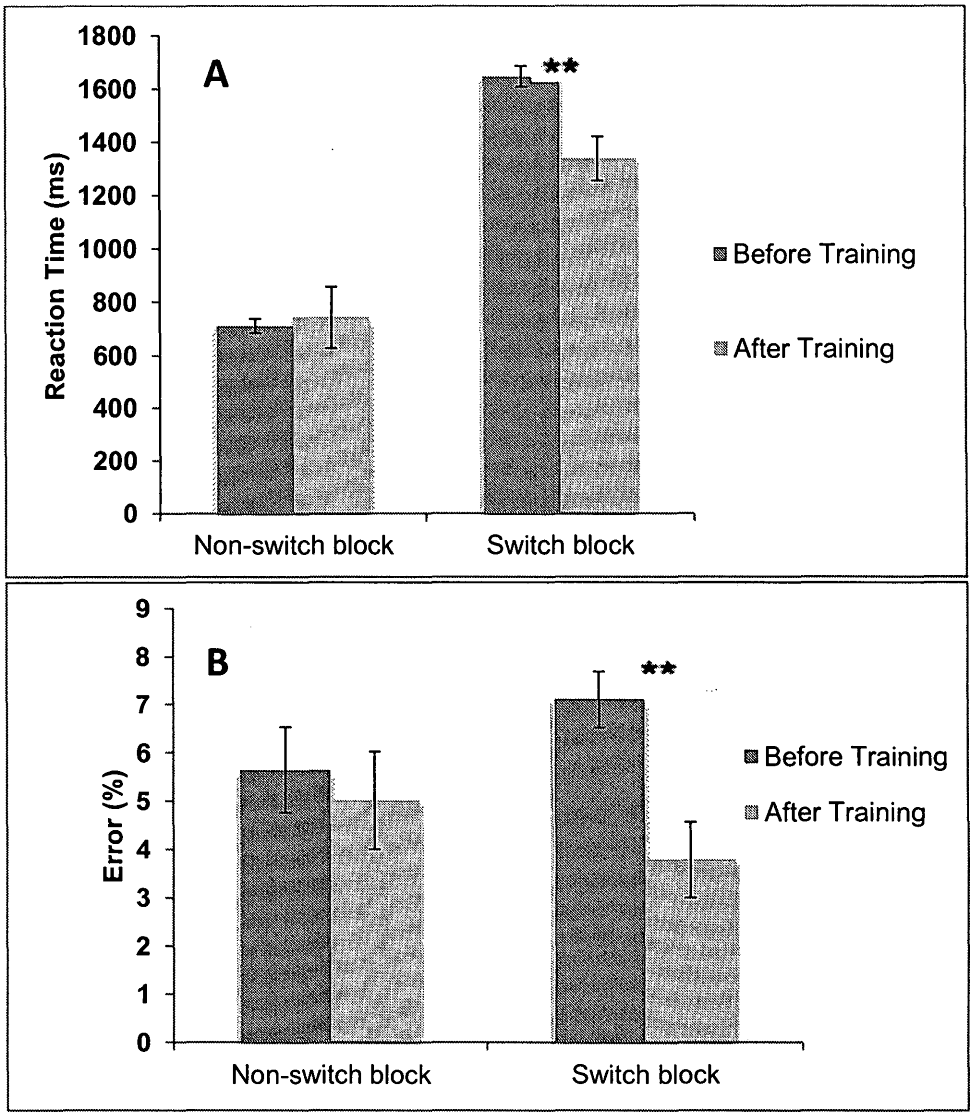

Figure 7. Global Switch Cost (± *SEM*) on the What Number/How Many task for reaction time (A) and errors (B)

** $p < 0.01$

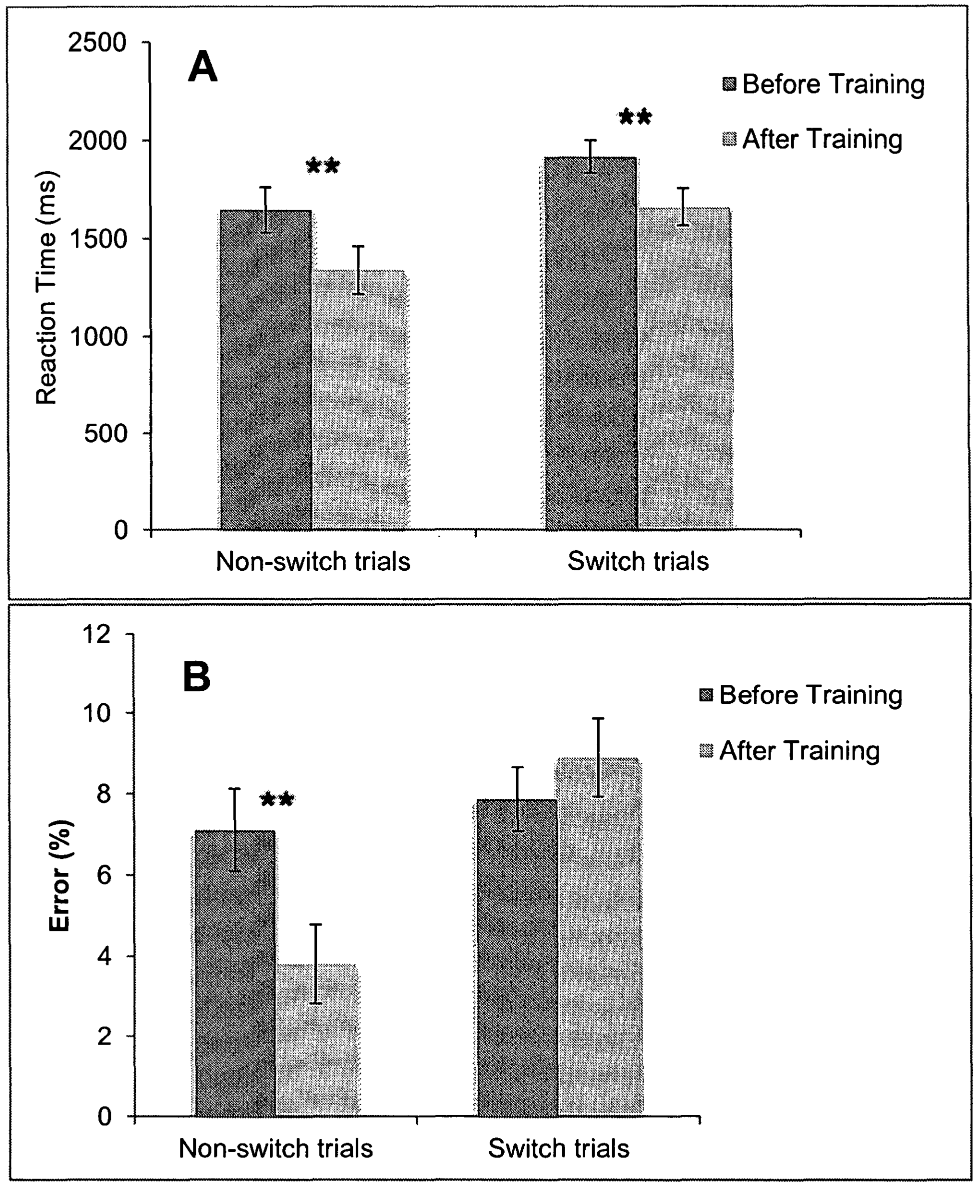

Figure 8. Local switch cost (± SEM) on the What Number/How Many task for reaction time (A) and errors (B).

** $p < 0.01$

Secondary analyses were conducted on the percentage of errors for both global and local switch cost. Global switch cost analysis found a significant main effect of time,

$F(1, 28) = 6.692$, $p = .015$, $\eta_p^2 = 0.193$, with fewer errors at post-testing, and a significant main effect of response compatibility, $F(1, 28) = 60.195$, $p < 0.001$, $\eta_p^2 = 0.683$, with fewer errors on response compatible trails. Significant two-way interactions for response compatibility and switch, time and switch, and time and response compatibility were qualified by a significant three-way interaction between time, switch, and response compatibility, $F(1, 28) = 11.382$, $p = .002$, $\eta_p^2 = 0.289$. The interaction was further investigated with pairwise comparisons on performance before and after training. For response-compatible stimuli, there were no significant differences for any of the trial types. For response-incompatible stimuli, pairwise comparisons showed no significant difference in errors before and after training for non-switch trails in non-switch blocks. There was a significant decrease in errors for non-switch trials in switch blocks, $MD = 6.6$, $SEM = 1.7$, 95% CI [3.1, 10.0], $p = .001$, $d = 0.7$, indicating improved accuracy on response incompatible non-switch switch block trials following training. All other main effects and interactions were not significant, $ps > 0.3$.

Local switch cost analysis of error percentages revealed significant main effect of switch and response compatibility, $F(1, 28) = 11.474$, $p = .002$, $\eta_p^2 = 0.291$, and $F(1, 28) = 123.036$, $p < .001$, $\eta_p^2 = 0.815$, respectively. There were significant two-way interactions between time and switch, and response compatibility and switch, $F(1, 28) = 8.422$, $p = .007$, $\eta_p^2 = 0.231$, respectively. A marginal interaction was found between time, switch and congruency, $F(1, 28) = 3.83$, $p = 0.06$, $\eta_p^2 = 0.120$. For response compatible stimuli, pairwise comparisons showed no difference in errors before and after training for any of the trial types. For response incompatible stimuli, there was a significant decrease in error rates on non-switch trials in the switch block after training (as reported above), and no change on errors for switch trials in switch blocks before and after training. All other main effects and interactions were not significant, *p*s > 0.1.

3.2.2 Colour-Shape Switching Task. RT and accuracy were recorded. Participants with RTs more than three SD from the mean or accuracy below 65% were excluded from analysis. Nineteen participants did not meet this cutoff and were removed (2 outliers on RT, 17 on accuracy). ANOVAs were conducted using switch as a factor for global switch cost and local switch cost, using the same trial types as in the previous task. For the global switch cost analysis of RTs, significant main effects of time and switch were qualified by a significant interaction between time and switch, $F(1, 29) = 12.104, p = .002, \eta_\rho^2 = 0.294$, $F(1, 29) = 78.802, p < .001, \eta_\rho^2 = 0.731$, and $F(1, 29) = 7.444, p = .011, \eta_\rho^2 = 0.204$, respectively. Similarly, for the local switch cost analysis, there were significant main effects of time and switch, and a significant interaction between time and switch, $F(1, 29) = 22.927, p < 0.001, \eta_\rho^2 = 0.442$, $F(1, 29) = 17.544, p < .001, \eta\rho^2 = 0.377$, and $F(1, 29) = 4.733, p = .038, \eta_\rho^2 = 0.140$, respectively.

Pairwise comparisons of RTs before and after training showed no significant difference in RTs for non-switch trials in non-switch blocks. There was a significant decrease in RTs before and after training for non-switch trials in switch blocks, $MD = 256.6$, $SEM = 68.4$, 95% CI [117.0, 396.2], $p = .001$, $d = 0.7$. RTs for switch trials in switch blocks also decreased significantly following training, $MD = 462.7$, $SEM = 113.8$, 95% CI [230.3, 695.1], $p < .001$, $d = 0.7$. Figures 9 and 10 demonstrate the faster RTs following training for global and local switch costs. All other main effects and interactions for RTs were insignificant for global switch cost and local switch cost, $ps > 0.2$, and $ps > 0.1$, respectively.

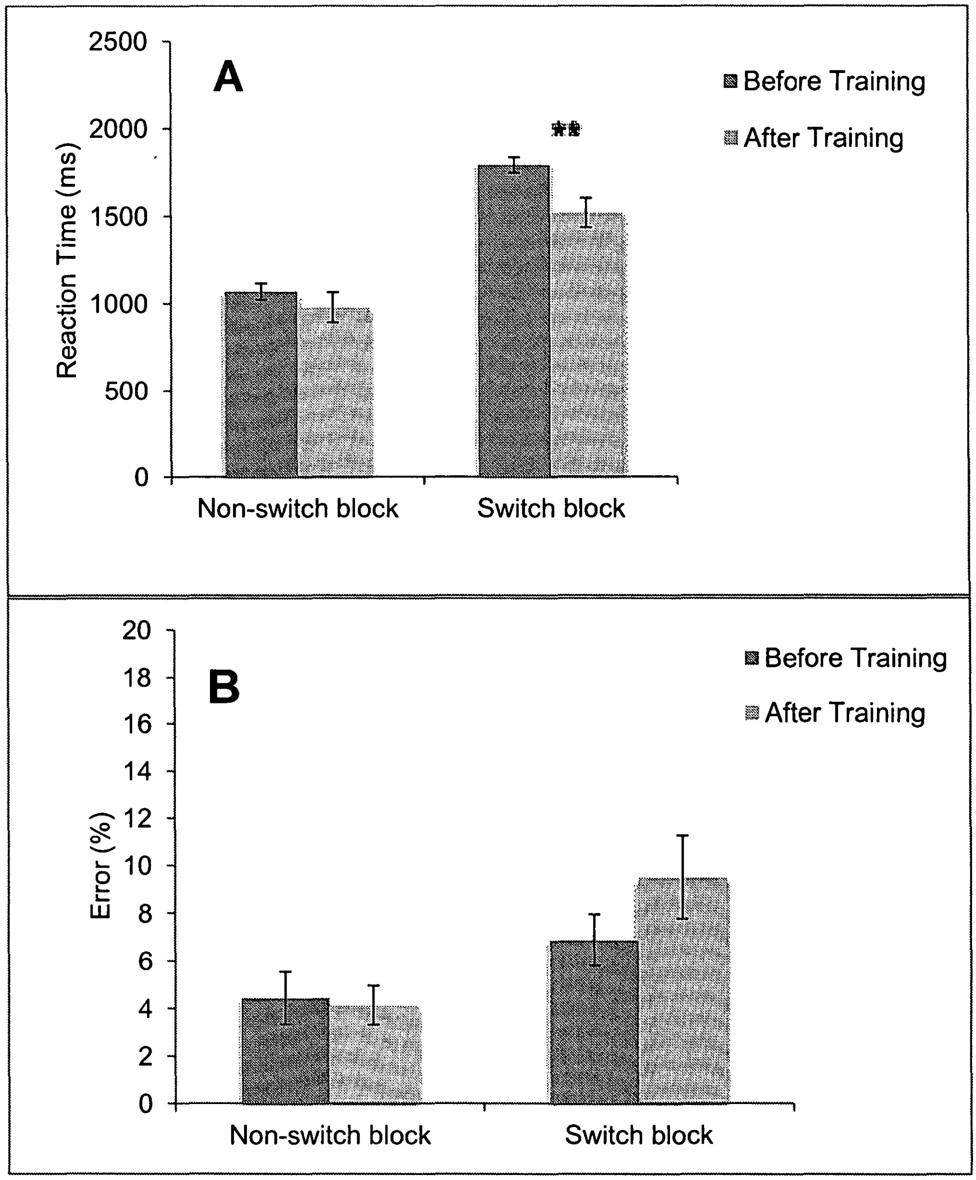

Figure 9. Global switch cost (± SEM) on the Colour-Shape task for reaction time (A) and errors (B).

** $p < 0.001$

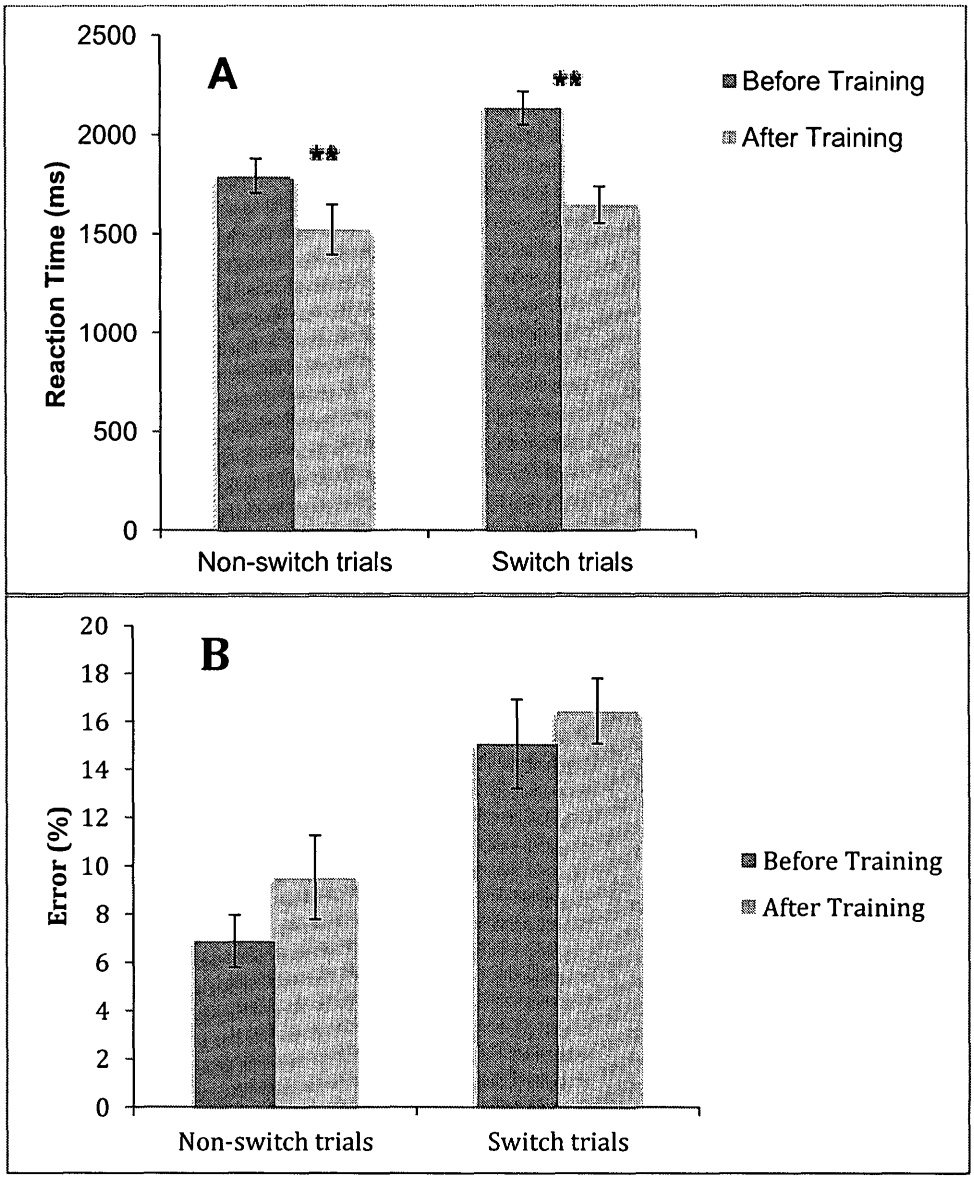

Figure 10. Local switch cost (± SEM) on the Colour-Shape task for reaction time (A) and errors (B).

** $p < 0.01$

Secondary analyses of the percentage of errors for global switch cost showed a significant main effect of switch, F (1, 29) = 13.479, p = .001, $\eta_p^2 = 0.317$. Accuracy was higher on non-switch trials in non-switch blocks than on non-switch trials in switch blocks. A local switch cost ANOVA showed a main effect of switch, $F(1, 29) = 42.405$, $p < 0.001$, $\eta_p^2 = 0.594$, with accuracy higher on non-switch trials in switch blocks than on switch trials in switch blocks. There was a significant interaction between the factors of switch, time, and training group, $F(1, 29) = 4.260$, $p = .048$, $\eta_p^2 = 0.128$.

Pairwise comparisons on non-switch trials in switch blocks, and switch trials in switch blocks indicated no significant changes for the music group from before training to after training. For the dance group, no significant effects were found on non-switch trials in switch blocks before and after training. A significant increase was found on error percentages for the dance group on non-switch trials in switch blocks before and after training, $MD = 6.6$, $SEM = 2.5$, 95% CI = 1.4, 11.9, $d = 0.6$ (Table 5). All other main effects and interactions for accuracy were insignificant for global switch cost and local switch cost, $ps > 0.1$, and $ps > 0.2$, respectively.

Table 5.

Percentage of errors on the Color-Shape task for local switch cost.

	Before Training		After Training	
Trial Type	*M (SEM)*	95% CI	*M (SEM)*	95% CI
Dance Group				
Non-switch	6.6 (1.4)	[3.7, 9.4]	12.5 (2.3)	[7.9, 17.2]
Switch	15.7 (2.4)	[10.8, 20.6]	17.2 (1.8)	[13.6, 20.7]
Music Group				
Non-switch	7.2 (1.6)	[3.8, 10.5]	6.5 (2.7)	[1.0, 11.9]
Switch	14.4 (2.8)	[8.7, 20.2]	15.7 (2.1)	[11.5, 19.9]

3.3 Interference Control

3.3.1 Stroop Task. Five participants were excluded from analysis: one who was colourblind, and four who had completion times of greater than three standard deviations above the mean. Time taken to complete the task was subject to a three-way ANOVA, with two levels of time (before and after training), two levels of condition (neutral and incongruent), and two levels of training group (dance and music). A significant main effect of condition was observed, $F\ (1, 43) = 78.76, p < .001, \eta_p^2 = 0.65$, with shorter completion times for neutral compared to incongruent conditions (Table 4). There was no significant main effect of time or training group, and no significant interactions, *p*s > 0.1.

Table 6.

Time (s) taken to complete Stroop task

Condition	*M (SEM)*	95 % CI
Neutral	94.0 (4.3)	[85.3, 102.6]
Incongruent	115.3 (4.7)	[105.8, 124.8]

3.3.2 Flanker Task. Means were calculated for the RTs of each trial type (congruent and incongruent). For each participant, RTs were examined and responses greater than 2.5 SD from the mean of each trial type were removed. Means for each participant were calculated using the remaining trials and used in the analyses. Participants with a mean accuracy level below 60% were removed from analysis, resulting in exclusion of eight participants.

A three-way ANOVA yielded a main effect of condition, $F\ (1,40) = 58.215, p < 0.001$, $\eta_p^2 = 0.593$, such that RTs for congruent stimuli were significantly faster than those for incongruent stimuli. A main effect of time was found, $F\ (1, 40) = 20.653, p < .001$, $\eta_p^2 = 0.341$, such that RTs were faster after than before training. A main effect of training group, $F\ (1, 40) = 5.487, p = .024$, $\eta_p^2 = 0.121$ was found, with RTs faster for the dance than the music training group at both time points (Figure 11). All other main effects and the interaction were not significant, all ps > 0.1.

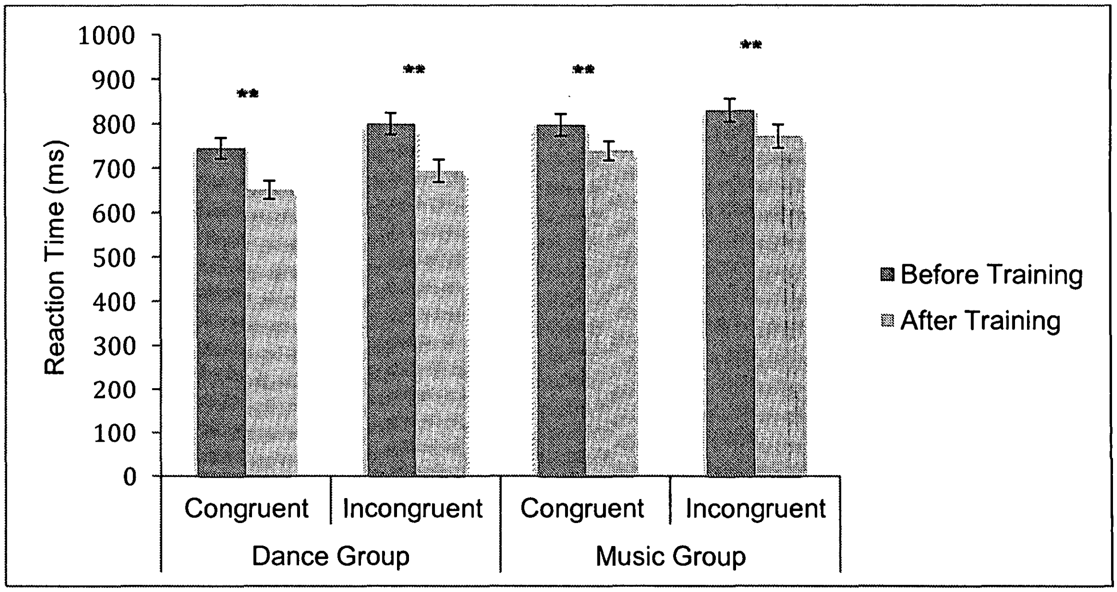

Figure 11. Reaction times (± *SEM*) by trial type for the Flanker task.

** $p < 0.01$

An ANOVA for accuracy of responses produced no significant effect of training group. Main effects of time and condition, $F\,(1{,}40) = 5.825$, $p = 0.020$, $\eta_p^2 = 0.127$, and $F\,(1{,}40) = 15.256$, $p < 0.001$, $\eta p^2 = 0.276$, respectively, were qualified by a significant interaction of the factors of time with condition, $F\,(1{,}40) = 14.832$, $p < 0.001$, $\eta_p^2 = 0.270$. Pairwise comparisons indicated a significant decrease in accuracy after training for incongruent trials, *MD* = 0.06, *SEM* = 0.02, 95% CI = 0.03, 0.09, d=0.6 (Figure 12). However, since accuracy rates were above 85% across trials, this decrease in accuracy is not considerable. No significant differences were found on accuracy for congruent trials before and after training. All other main effects and the interaction were not significant, *ps* > 0.3.

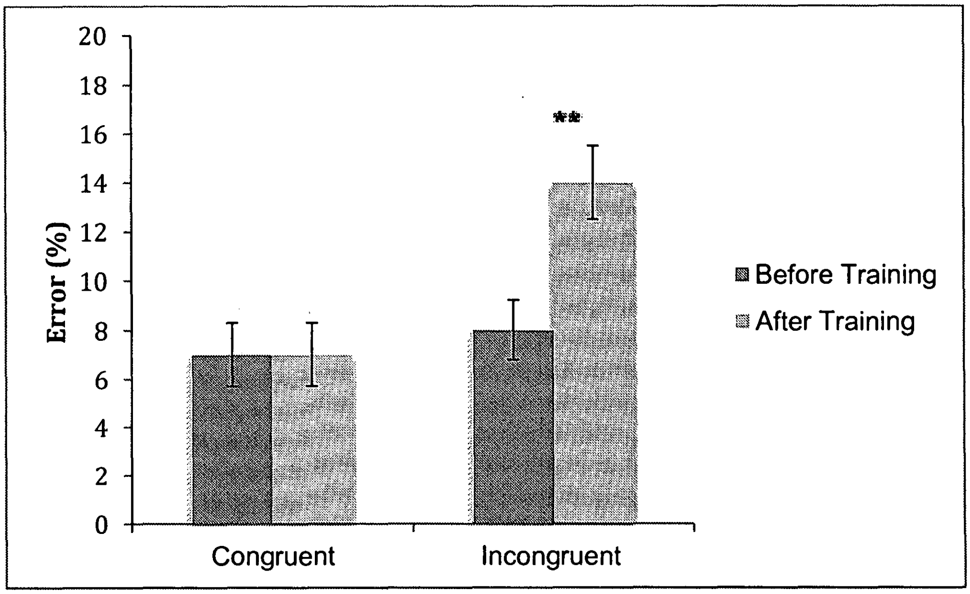

Figure 12. Error rate (± *SEM*) by trial type for the Flanker task.

** $p < 0.01$

4. Discussion

The present study investigated performance on executive function measures before and after a training program in either music or dance. As hypothesized, results showed that short-term arts training transferred to overall benefits in executive function. Specifically, training groups demonstrated improved performance on both measures of task switching performance, with decreases in both global and local switch cost. No changes were observed on the Stroop test, or on both measures of working memory, although an improvement was seen on short-term memory span. Shorter reaction times were also seen on the Flanker test of interference control, although it is difficult to qualify whether such effects are due to a shift in the speed-accuracy tradeoff. An unexpected finding was that no significant difference was found between the different training groups, thus suggesting a similarity at the level of executive functions for both the investigated training domains. The current data are consistent with past findings of superior task switching in musicians and dancers, and extend past evidence to a child population. Additionally, the current results add a causal influence of training to the previously observed differences between groups of experts and non-experts. Data are also consistent with the lack of a dance training advantage on the constructs of working memory and interference control, although they do not replicate the musician advantage for these constructs that has been found in some studies.

The observed results support previous findings on the short-term influence on musical and dance training on executive function. In this study, fifteen days of music or dance training produced changes in executive function performance. The finding of rapid transfer converges with existing evidence (Bugos et al., 2007; Corrigall & Trainor, 2009; Moreno et al., 2011) that even just one month of training can produce transfer to untrained domains. The persistence of the observed changes is open to future investigation, although studies have suggested that neural changes are maintained in adulthood after even three years of musical training in childhood (Skoe & Kraus, 2012). The optimal duration and amount of training is often poorly reported (Moreau & Conway, 2013), and the current findings help understand the parameters for transfer of training.

The current results provide detail on each of the individual constructs that can be improved by training. Participants demonstrated smaller local and global switch costs on measures of task switching, which matches previous findings of superior performance for musicians and dancers on task switching (Coubard et al., 2011; Degé et al., 2011; Hanna-Pladdy & MacKay, 2011; Kimura & Hozumi, 2012). Task switching appears to be the most constant executive function construct in the music and dance training literature. Although a few studies have not demonstrate a task switching benefit, researchers in such studies did not use pure measures, so it is not possible to separate out a task switching effect from other influences (Bialystok & Depape, 2009; Bugos, 2010; Kim et al., 2011; ; Schellenberg, 2011; Verghese, 2006).

The influence of training on inhibition or interference control has also been relatively constant in the musical training literature (Bugos, 2010; Bialystok & Depape, 2009; Degé et al., 2011; Moreno et al., 2011; cf. Schellenberg, 2011), although not for dance training (Coubard et al., 2011; Kattenstroth et al., 2010, 2013). Conversely, the current study did not find an influence on interference control, which suggests that effects may vary according to the type of musical or dance training received. It is possible that a lack of observed changes in the Stroop task may be due to the complexity of the task or the inappropriate nature of the language demands of the task for the sample age range (Jurado & Rosselli, 2007).

Previous training studies on the third investigated construct, working memory, have been less conclusive. No working memory advantage has been found in dancers (Verghese, 2006), which is consistent with the current findings. However, findings on musicians have differed on tasks that measure the capacity of working memory (short-term memory) and tasks that measure working memory updating. Studies with child populations have demonstrated positive effects of musical training on both measures (Fujioka et al., 2006; Ho et al., 2003; Lee et al., 2007; Schellenberg, 2011). In adults and older adults, effects have been observed for both (George & Coch, 2011), none (Hanna-Pladdy & MacKay, 2011), or on capacity but not updating (Bugos et al., 2007; Lee et al., 2007). Since working memory performance is also linked to a host of other activities (Lee et al., 2007), and past studies have been cross-sectional, it is unknown whether the working memory differences seen in different groups were a result of training. The current study demonstrated that neither music nor dance training caused a change in working memory after 15 days of lessons. The failure to find an impact on working memory performance in the current study could be due to the brief training period, since all of the previous studies involved training of at least six months. Another difference could be the training program - the training curricula in our study did not involve learning abstract representations such as notation for music, or symbols for dance. Further studies should investigate transfer to working memory by varying length and type of training.

To our knowledge, this is the first study to investigate the influence of dance training on executive function in children. Thus it provides detail on the age at which dance training effects can be observed. Music training has been previously investigated in children, with the current results on task switching also found by Degé et al. (2011). However, other studies on music training in a child population have found an effect on working memory span (Fujioka et al., 2006; Ho et al., 2003; Lee et al., 2007; Schellenberg, 2011). One possible explanation for the differences in performance on each of the executive function constucts after training is that the age at which training is received may impact transfer. The improvement on task switching observed in the current study may be since it is the most difficult executive function for children, and develops considerably until age 11 (Davidson et al., 2006), possibly offering more room for influence by training. Conversely, working memory and inhibition develop earlier (Davidson et al., 2006), hence there may be less opportunity for improvement than on task switching.

A sensitive period for musical training is thought to occur (Trainor, 2005), with the greatest effects seen in musicians who begin training before the age of seven (Penhune, 2011). The current findings question the parameters of the sensitive period, as effects of musical and dance training were observed in children up to the age of nine. Studies of older adults have indicated the potential of musical and dance training (e.g. Bugos et al., 2007; Coubard et al., 2011). Future studies should continue to investigate the proposed sensitive period, and the potential of arts training as a cognitive intervention across different age groups.

A notable finding in the current study is the resemblance of effects for both training domains. Although previous studies have demonstrated the effect of individual components of musical training (e.g. pitch, melody), the current study demonstrated that effects of music training are more general than was previously assumed in the literature. Our results support theory on domain-general influences of musical training (Hannon & Trainor, 2007), and extend it to dance training. Matching both training groups on the duration, intensity, and delivery of the program removed between-group differences other than training content itself, and suggests that domain-general effects exist beyond the domain-specific differences in arts content.

Importantly, the current findings of a general influence allow connectivity with the literature on executive function training interventions. Several domain-general features that existed for the investigated training interventions have also been identified in previous studies: 1) a fast-paced training program, 2) increasing difficulty through the program, and 3) high attention demands (Bugos et al., 2007; Diamond & Lee, 2011). The three features may explain why even programs as general as as music listening have led to improvements on executive function. The finding of similarity in training domains has implications for future studies because it suggests that there may be broad and identifiable features across training interventions. Although some interventions such as drama and visual arts may have failed to demonstrate any influence on executive function performance (Moreno et al., 2011; Schellenberg, 2004), this could be a result of their failure to address the proposed features. Further investigation should systematically measure whether transfer from musical and dance training is a result of similarities between components of those training forms (e.g., beat, movement), organization of those training forms (e.g., simultaneous top-down and bottom-up processing), or general components of training (e.g., learning novel material).

For transfer to occur, there must be a similarity between training and transfer domains (Barnett & Ceci, 2002). The recruitment of executive function in music and dance training (Hannon & Trainor, 2007; Jäncke, 2009) may underlie observed cognitive advantages in these trained groups. A limitation of this explanation is that the involvement of executive functions in arts training is not enough to drive improvements in performance. Conversely, it may be that since learning music (or other arts forms) is cognitively demanding, individuals with stronger executive function ability are more likely to begin and continue with learning (Neville et al., 2008). The randomized design of the current study controlled for such self-selection effects, and provides evidence supporting the executive function hypothesis for training.

Using a randomized trial addressed a need to delineate the existing correlations on arts training and cognition (Rodrigues et al., 2010; Schellenberg & Winner, 2011). The current results demonstrated that learning the arts could have a causal role on behavioural changes in executive function performance across individuals, and supplement past evidence on training-induced neural plasticity (Jäncke, 2009; Wan & Schlaug, 2010). Random assignment of participants to training groups controlled for third factors such as motivation (Posner et al., 2008), socioeconomic status, or initial differences in intelligence or cognitive ability (Schellenberg, 2006). The current findings on the causal effect of music training on cognition are in contrast with propositions that individuals with strong cognitive abilities are more likely to take musical training (Schellenberg, 2011). Taken together, the differing viewpoints suggest that the link between music and cognition is complex and may be bi-directional.

Randomized studies are helpful in understanding directionality of effects, although it is important that randomization be done properly with random sequence generation and allocation of concealment (Schulz & Grimes, 2002_a; Schulz & Grimes, 2002_b). Participants in the current study were randomly allocated after controlling for a few baseline variables. To control for expectation and selection effects, participants were not made aware of the initial hypotheses for each training type. Further, four out of five testers were blinded to the group assignment when testing, and data coders were also blinded.

4.1 Generalizability of Results

When measuring executive function, the discrepancy among task types and demands can limit the generalizability of results (Jurado & Rosselli, 2007). In addressing task impurity, the current study used simple measures for each construct (with the exception of the Stroop task). Using more than one task for each construct reduced measurement variance (Moreau & Conway, 2013). Consistent results across both measures of task switching and working memory strengthens the findings for these two constructs. In comparison, the differential results for interference control tasks mean that effects of training on interference control remain an open question.

Few eligibility criteria were used in the current study, which increases the generalizability of results (Schulz & Grimes, 2002_d). No significant differences were found across training sites, supporting the reliability of the observed effects. Further investigation is required to examine whether the current findings apply to similar demographics in other areas.

Currently, there has been a large variation in the types of programs that constitute musical training and dance training, with little report on details of what was trained. Using the Ministry of Education curriculum guidelines provided operational definitions of the arts forms that account for the essential components of each training form. In advancing training research, it is important to break down and define arts, so we can then compare studies and obtain cumulative evidence on the 'active' elements. Moreover, the use of real-world training measures means that the findings will have useful implications on education policy and practice. Since the two arts programs are set as equivalent teaching modules in the curriculum, the training programs were standardized across the groups.

The short training period of the current study means that effect sizes may be small in comparison with studies on musicians who have been learning for longer periods of time. Alternatively, it is possible that effect sizes are exaggerated, due to greater difficulty and novelty of material when one begins training. However, non-linear changes are unlikely since previous studies have indicated a dose-dependent effect of musical training (Schellenberg, 2006; Wan & Schlaug, 2010). Hanna-Pladdy and MacKay (2011) found significant differences between groups who had no training and low amounts of training, as well as low and high amounts, indicating that the effects of musical training are similar at the beginning and intermediate stages. Thus previous evidence suggests that it is likely that the observed effects are comparable to longer periods of musical training, rather than just reflecting 'beginner' effects.

4.2 Limitations

A possible limitation of the current study is the loss of sample, with 10 participants failing to complete the study. However, the observed dropout rate of 17% is a medium attrition ratio, with losses above 20% considered to compromise validity (Schulz & Grimes, 2002_d). Attrition is a considerable issue facing randomized trials, and the observed ratio is smaller than some studies (21% in Bugos et al., 2006; 32% in Moreno et al., 2011), although others have considerably lower ratios (14% in Kim et al., 2011; 0.1% in Schellenberg, 2004).

An imbalance was observed between the training groups on baseline interference control performance, and could have resulted from attrition or an existing imbalance. Stratifying groups on predictive factors of age, gender, and intelligence was done to control for baseline variance (Roberts & Togerson, 1999). It would have been possible to stratify participants on more factors, which may have avoided the existing baseline imbalance. However, it has been recommended that statistical comparisons of groups at baseline are "unsound" (Roberts & Togerson, 1999). Therefore, choice of baseline factors should be limited to available evidence of prognostic variables, rather than observed imbalance between groups. In the current study, intelligence was selected as a prognostic variable due to its association with executive function as well as musical training.

Although the sample size is not large, a power analysis was conducted prior to participant recruitment to determine an ideal number of participants. Sample sizes for intervention studies are expected to be smaller than cross-sectional designs (Coubard et al., 2011), because the reduced variance of a within-subjects design allows for a smaller number of participants. The current sample size of approximately 25 participants in each training group resembles other training studies (*N* ~ 20 in Bugos et al., 2006; *N*=16 in Coubard et al., 2011; *N*=23 in Kim et al., 2011; *N*=27 in Kimura & Hozumi, 2012; *N*=24 in Moreno et al., 2011; *N*=36 in Schellenberg, 2004). Although the obtained sample size was ideal for testing within-group differences from before to after training, a larger sample would be necessary for between-group differences. It is possible that a difference may exist between musical and dance training, but that the current study lacked the power to detect it.

Researchers have advocated for the importance of a control group in training studies, particularly active control groups who receive programs that are equally engaging as the training program (Moreau & Conway, 2013). The current study used two matched training programs with different benefits predicted for each program, allowing training forms to serve as active control groups. However, since identical results were observed for both training groups, a passive control would have been ideal to identify whether changes are a result of the specific training interventions or due to general attention or motivational influences of training. Another issue is that executive function tasks rely considerably on task novelty, and repeating tasks may lead to better performance (Friedman & Miyake, 2004). Data are currently being collected on a control group that does not receive any training, which will rule out general motivation influences, or practice effects that may arise from task repetition.

Another limitation is that differential findings were obtained on the two interference control tasks. The inconsistency of interference control results may arise from the Stroop test being a complex task. Past investigations are unclear on what the Stroop test measures, with the task previously described as prepotent response inhibition (Friedman & Miyake, 2004) or as interference control (Van Mourik, Oosterlaan, & Sergeant, 2005). Moreover the task involves language abilities (Jurado & Rosselli, 2007), which may have been especially demanding for the age range in our sample. Unusually long task completion times and reports from testers support the idea of the task stimuli being particularly difficult for participants.

A further issue linked to executive function is in definition. The current study employs the three core processes that have been most commonly proposed in the literature and supported by factor analysis (Miyake & Shah, 2000). However, debate over what constitutes executive functions still exists (Jurado & Rosselli, 2008). For example, recent theorists have suggested the existence of two functions only (Munakata et al., 2011). Definition of executive function is far from conclusive, but until further investigation determines otherwise, the triad of functions used in the current study has strong empirical support and has been followed by other researchers (Diamond, 2013).

A task-specific limitation is that there was a decrease in accuracy scores on the Color-Shape task switching measure. Both groups had a higher percentage of errors from before training to after, with the dance group displaying a significant increase. The fall in accuracy means that it is unclear whether the accompanying fall in reaction times was due to decreased switch costs or a change in speed-accuracy thresholds. However, the other task switching measure (the What Number-How Many switching task) displayed an increase in accuracy as well as a decrease in reaction times, which shows that training did produce smaller switch costs on that task.

In addition, both task-switching measures had a large number of outliers on accuracy, resulting in a removal of a large number of participants. The high error rates could be due to the particular age range investigated, as task switching is considerably difficult for young children (Davidson et al., 2006). However, other studies using a similar demographic and child-appropriate tasks have reported high accuracy scores (Cepeda et al., 2001; Dibbetts & Jolles, 2006), with no report of outlier removal rates. Future investigation with careful task selection is needed into transfer to task switching.

4.3 Conclusion

The results showed that three weeks of music or dance training produced far transfer benefits on task switching, but not working memory. Improvement on interference control on one measure was also found, but was difficult to interpret due to an accompanying decrease in accuracy. The controlled design of the current study establishes the causal influence of arts training on the observed effects. The obtained results enable comparisons to be drawn between independent streams of research on musical training, dance training, and executive function training interventions. Findings demonstrate that task switching can be improved after arts training, with music and dance demonstrating similarity at the level of executive functions.

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***Note**: At the time of sampling, this was the latest census profile available. A more recent census profile has been loaded since (see below). However, the targeted percentages of the English-speaking populations are the same (with any changes being less than 1%).

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