Psychomusicology: Music, Mind, and Brain
2017, Vol. 27, No. 1, 75–80
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0275-3987/17/$12.00 http://dx.doi.org/10.1037/pmu0000174

Early Musical Training Contributes to Decision-Making Ability

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This study examined whether musical training was associated with decision-making ability. Three groups of Chinese participants (with early, late, and no musical training) were compared in terms of their performance on the Iowa Gambling Task (IGT). Results showed that the participants with early musical training had significantly better performance in both decision under ambiguity and decision under risk than those with late and no musical training. These results were independent of participants' years of musical training, IQ, working memory, and emotion perceptions. This study suggests a positive benefit of early musical training on decision-making ability.

Keywords: early musical training, decision making, Iowa Gambling Task

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Decision making is a complex process that involves weighing the probabilities of alternative options that can be desirable, undesirable, or neutral. Such a process necessarily involves both emotional responses and cognitive processes (Damasio, Everitt, & Bishop, 1996; Li, Lu, D'Argembeau, Ng, & Bechara, 2010). Indeed, previous studies have found that decision-making performance is associated with both emotion (Bajaj, Lamichhane, Adhikari, & Dhamala, 2013; Choi, de Melo, Woo, & Gratch, 2012; Furl, Gallagher, & Averbeck, 2012; Mussel, Goritz, & Hewig, 2013) and cognition (e.g., working memory [WM]; Dretsch & Tipples, 2008; Kerr & Zelazo, 2004; Remijnse, Nielen, Uylings, & Veltman, 2005). Previous research has further distinguished two types of decision making based on the degree of uncertainty about the outcome: decisions under *ambiguity* are those without knowing the precise probability distribution of the possible outcomes, and decisions under *risk* are those with known outcome probabilities (Bechara, Damasio, Damasio, & Anderson, 1994, Bechara, Damasio, & Damasio, 2000; He et al., 2010; Stoltenberg & Vandever, 2010). The Iowa Gambling Task (IGT) has been widely used to assess decision making under both ambiguity and risk (Bechara et al., 1994, 2000; He et al., 2010). At the early stage of the IGT, players have little explicit knowledge about IGT alternatives, so they are making decisions under ambiguity. As the task progresses, players develop explicit knowledge of the risk profile across IGT alternatives, so they make decision knowing the risks (Brand, Recknor, Grabenhorst, & Bechara, 2007; Upton, Bishara, Ahn, & Stout, 2011).

Musical training has been found to improve emotional processes such as emotion perception (Alluri et al., 2015) and understanding (Schellenberg & Mankarious, 2012), as well as cognitive processes such as WM (George & Coch, 2011; Hou et al., 2014). However, no study to date has examined whether musical training can influence decision-making ability. Given the positive effects of musical training on emotional and cognitive processes, the current study tested the hypothesis that musical training (especially early training) would be associated with better performance on the IGT. In addition, this study examined whether such effects were inde-

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The original data on IGT and other cognitive measures have been published in previous papers (e.g., He et al., 2010; Hou et al., 2014; Li et al., 2011; Zhu et al., 2010), but the ideas about the effect of musical training on decision making and related analyses have not appeared at any public forums (dissertations, meetings, conferences, workshops, websites, etc.). This study was supported by the 111 Project from the Ministry of Education of China (Grant B07008). We thank all graduate research assistants who helped us with data collection.

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pendent of training-related improvement in WM and/or emotion perception.

Method and Materials

Participants

Data for this study came from a larger project (e.g., Chen et al., 2013; Hou et al., 2014). Five hundred sixty-seven undergraduates at Beijing Normal University took the IGT test as well as other cognitive tests (see below for details). Based on their self-report (see below), 42 participants had early musical training (e.g., piano, keyboard, violin, and accordion) starting before the age of 7 years (11 males and 31 females; Table 1); 52 participants had late musical training (e.g., piano, keyboard, clarinet, and saxophone) starting after the age of 8 years (13 males and 39 females; see Table 1). From 473 participants who had no musical training, we selected 60 participants (12 males and 48 females; see Table 1) to match, roughly, the early and late musical training participants, in terms of age, gender, and IQ.

Measures

Musical training history. Participants were asked the age at which they started formal musical training, the types of musical instruments they used, and the number of years they had such formal training.

The IGT. A computerized version of the IGT (Bechara et al., 2000; He et al., 2010) was used in the current study to assess decision making under ambiguity and risk (a screen shot is displayed in Figure 1). To motivate subjects, they were informed that the amount of their winning would be converted into real money. Participants were asked to select one card at a time (100 trials in total) from one of the four decks (labeled A, B, C, and D). As described in previous studies and the IGT manual (PAR, Inc, Lutz, FL), two of the decks were disadvantageous because they yielded high immediate gain but a greater loss in the long run (i.e., net loss of 250 yuan on average over 10 cards), and two decks were advantageous because they yielded lower immediate gain but a greater gain in the long run (i.e., net gain of 250 yuan on average over 10 cards; see He et al., 2010).

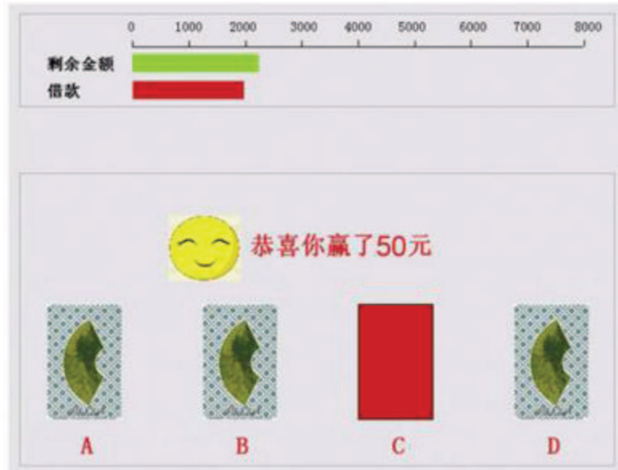

Figure 1. Illustration of the Iowa Gambling Task. Participants were instructed to choose one card at a time from four decks of cards (labeled A, B, C, and D). The green bar on the top represents money in his or her wallet ("Account balance"). The red bar represents his or her loan ("Loan amount"; adapted from He et al., 2010). The text next to the smiling face is "Congratulations, you have just won 50 yuan!" after the subject chose deck C. From "Serotonin Transporter Gene-Linked Polymorphic Region (5-HTTLPR) Influences Decision Making Under Ambiguity and Risk in a Large Chinese Sample," by Q. He, G. Xue, C. Chen, Z. Lu, Q. Dong, X. Lei, . . . A. Bechara, 2010, *Neuropharmacology, 59,* pp. 518–526. Copyright 2010 by Elsevier. Adapted with permission. See the online article for the color version of this figure.

Wechsler Adult Intelligence Scale. The Wechsler Adult Intelligence Scale (WAIS-III) Chinese Version was used to measure intelligence to be used as a potential confounding/control variable. From the total 11 WAIS subtests, we adopted three verbal IQ subtests (General Information, Digit Span, and Similarity) and three performance IQ subtests (Digit Symbols, Block Design, and

Table 1
Characteristics and Test Performance of the Participants

Characteristics	Musical training group			*F*	*p*	η^2	*MSE*
	Early	Late	None				
Age in years	20.45 (1.10)[a]	20.21 (1.32)	20.37 (1.25)	.88	.30	.01	5.93
Gender (male/female)[b]	42 (11/31)	52 (13/39)	60 (12/48)				
Handedness	All right-handed	All right-handed	All right-handed				
Age of starting musical training in years	5.52 (.63)	11.63 (1.31)		64.38	.001	.45	549.59
Years of training	5.33 (3.82)	2.93 (2.40)		13.50	.001	.13	131.90
Test performances[c]							
IGT_1	3.14 (17.11)	−2.35 (11.44)	−3.60 (11.41)	3.26	.04	.04	571.28
IGT_2	23.71 (21.20)	12.27 (25.42)	7.63 (28.36)	3.31	.02	.06	2,177.54
IQ	128.48 (5.97)	128.04 (7.45)	127.05 (8.25)	1.06	.35	.02	57.88
WM	.90 (.05)	.88 (.07)	.86 (.08)	3.89	.01	.08	.02
FERT_Chinese faces	29.11 (2.74)	28.82 (2.21)	28.47 (3.05)	.49	.69	.01	3.62
FERT_Western faces	30.79 (2.36)	30.90 (2.91)	30.02 (3.24)	1.96	.12	.04	16.46

Note. WM = working memory; FERT = Facial Expression Recognition Test.
[a] Shown in parentheses are *SD* (except for gender distribution). [b] Gender distribution did not differ by group, $\chi^2 = 3.25$, $p = .20$. [c] IGT = Iowa Gambling Task.

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Picture Completion). The General Information, Digit Span, Similarity, and Picture Completion subtests were verbally administered, whereas the Digit Symbols subtest was administered with paper and pencil, and the Block Design was administered with blocks. All tests were individually administered. The raw scores produced by each participant were converted to a standardized IQ score (also see He et al., 2010 and Hou et al., 2014).

WM Task. We used the classic two-back paradigm to measure WM. Three tasks were used. In the phonological judgment condition, Chinese words were visually presented and participants were asked to judge whether the current word rhymes with the word presented two trials earlier. In the semantic judgment condition, participants judged whether the words were semantically related. In the morphological judgment condition, Tibetan scripts were used. Participants had no prior knowledge of Tibetan letters, and were asked to judge whether the currently presented Tibetan word was the same as the word presented two trials earlier. Each condition included four blocks and each block had 10 trials. Participants pressed the keys on a reaction time box to respond. The whole task took about 15 min to complete and the mean accuracy rates of the three WM tests were averaged to yield the final score (see Hou et al., 2014 and Li et al., 2011).

Facial Expression Recognition Test (FERT). We used the FERT to measure emotional response. The FERT was adapted from the Chinese facial expression of emotion test (Wang & Markham, 1999) and a Western facial expression of emotion test (Matsumoto & Ekman, 1988). It assessed the ability of Chinese participants to judge facial expressions represented on Asian and Caucasian faces. Six basic emotions were included: happiness, surprise, anger, sadness, fear, and disgust. For each emotion there were six pictures from Wang and Markham (1999) and six pictures from Matsumoto and Ekman (1988). Participants selected from the six basic emotions to match it to each face. The total number of correct responses was used. Cronbach's alpha in this study was .83 (Zhu et al., 2010).

Data Analysis

The 100 trials of IGT were divided into 5 blocks of 20 trials. A net score was calculated by subtracting the total number of selections of the disadvantageous decks (A and B) from the total number of selections of the advantageous decks (C and D), separately for each block. Higher scores indicated superior performance. The net score for the first 40 trials (the first 2 blocks) was calculated to represent performance in decision under ambiguity (IGT_1), and the net score for the last 60 trials (the last 3 blocks) represented decision under risk (IGT_2; Bechara et al., 2000; Brand, Labudda, & Markowitsch, 2006, Brand et al., 2007; He et al., 2010; Homberg, van den Bos, den Heijer, Suer, & Cuppen, 2008; van den Bos, Homberg, Gijsbers, den Heijer, & Cuppen, 2009).

Results

Table 1 shows the descriptive statistics about the characteristics of participants and their performances on IGT, IQ, WM, and FERT. The three subgroups did not differ in age, gender, and IQ, indicating successful matching of the participants. As would be expected, the early training group had significantly more training years than the late training group. Table 2 shows the intercorrelations among the major variables. Age of starting training was significantly correlated with years of training, IGT_2, and WM. Years of training was significantly correlated with IGT_2 and WM. There were also significant correlations between related constructs: specifically between the two scores of IGT, between IQ and WM, and between the two tests of facial emotion recognition.

One-way analysis of variance also showed that the three subgroups significantly differed in IGT_1 and IGT_2 (see Table 1). Post hoc analysis showed that the participants with early musical training performed significantly better than those with late and no musical training on both IGT_1 (early vs. late: $p = .04$; early vs. no: $p = .01$) and IGT_2 (early vs. late: $p = .03$; early vs. no: $p = .001$; Figure 2). Participants with late and no musical training showed no significant differences in their performance on IGT_1 ($p = .62$) and IGT_2 ($p = .34$; see Figure 2).

The three subgroups also differed significantly in WM (see Table 1). Post hoc contrasts showed that those with early training had significantly better WM than those with no training ($p = .001$). Those with late training differed marginally from those without training ($p = .06$). The two groups with musical training did not differ from each other ($p = .14$). The three subgroups also did not differ in the Chinese FERT or Western FERT (see Table 1).

We also examined whether subgroup differences in WM would account for the effect of musical training on IGT. With WM as a covariate, the subgroup differences in IGT remained significant (IGT_1: $F_{(2,154)} = 2.41$, $p = .04$, $\eta^2 = .08$, $MSE = 404.20$;

Table 2
Intercorrelations (Pearson's R) Among Major Study Variables

Variables	Years of training	IGT_1	IGT_2	IQ	WM	FERT_Chinese	FERT_English
Onset age of training	−.62**	−.13	−.19*	.01	−.26**	−.11	−.16
Years of training		−.08	.16*	−.10	.18*	.06	−.02
IGT_1			.25**	.11	.06	.09	.06
IGT_2				−.15	−.06	.08	−.09
IQ					.18*	.12	.18
WM						.06	.05
FERT_Chinese							.46**

Note. $N = 154$. For the purpose of correlational analyses, *years of training* was assigned 0 for the participants who had no musical training, and correspondingly *onset age of training* was assigned the average age of 20 years. IGT = Iowa Gambling Task; WM = working memory; FERT = Facial Expression Recognition Test.
* $p < .05$. ** $p < .01$.

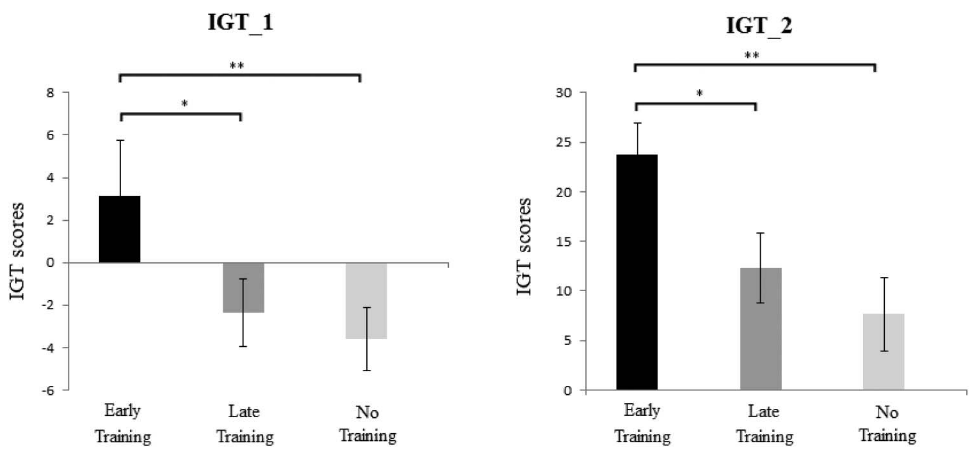

Figure 2. Iowa Gambling Task scores of the three groups. Error bars indicate standard errors. $^{*}p < .05$. $^{**}p < .01$.

IGT_2: $F_{(2,154)} = 3.83$, $p = .001$, $\eta^2 = .12$, $MSE = 2{,}480.26$). The covariate was not significant.

Because years of training was significantly correlated with onset age of training as well as IGT_2 and WM, analysis of covariance was conducted to investigate whether group differences remained after controlling for years of training. Results showed that the inclusion of years of training did not affect the group differences (IGT_1: $F_{(2,154)} = 3.45$, $p = .03$, $\eta^2 = .04$, $MSE = 601.57$; IGT_2: $F_{(2,154)} = 4.98$, $p = .01$, $\eta^2 = .06$, $MSE = 3{,}262.33$). The covariate was not significant.

Discussion

Musical training, especially early musical training, has been found to affect many mental processes such as emotion perception (Alluri et al., 2015), emotion understanding (Schellenberg & Mankarious, 2012), and WM (George & Coch, 2011; Hou et al., 2014). It has been speculated that such effects may have been mediated by training-induced enhancement in a widespread brain network including the temporal, parietal, and frontal cortices, as well as the thalamus, basal ganglia, and cerebellum (Nakahara, Furuya, Masuko, Francis, & Kinoshita, 2011; Parsons, Sergent, Hodges, & Fox, 2005). These brain regions are also involved in decision making (Cardoso et al., 2014; Li et al., 2010). The current study aimed to examine whether musical training was related to decision making.

We found that early (before 7 years of age) but not late musical training was associated with better performance on IGT (even after statistically controlling for years of training). Perhaps early musical training may have greater effects on brain structure and function than late training (Hensch, 2005; Steele, Bailey, Zatorre, & Penhune, 2013). For example, a diffusion tensor imaging study found that, compared with late and no musical training, musical training before the age of seven significantly enhanced the white matter in the corpus callosum and promoted the maturation of the sensorimotor region (Steele et al., 2013), both of which have been associated with the reward activity (Kraus & White-Schwoch, 2015; Marsh, Tarigoppula, Chen, & Francis, 2015; Steele et al., 2013). Biochemically, musical training, especially during early childhood (Miendlarzewska & Trost, 2014), can enhance the expression of dopamine D4 receptors (in the prefrontal cortex) (Cocker, Le Foll, Rogers, & Winstanley, 2014; Miendlarzewska & Trost, 2014; Nemirovsky, Avale, Brunner, & Rubinstein, 2009). Dopamine levels in the brain and associated genetic variants have been found to influence learning from feedback, in general (DeYoung et al., 2011; Miendlarzewska & Trost, 2014; Robbins, 2005), and decision making, in particular (He et al., 2010; Mapelli, Di Rosa, Cavalletti, Schiff, & Tamburin, 2014). Early musical training may also facilitate the interaction between sensory processes (auditory processing) and cognition (attention, language, and reward; Steele et al., 2013). In sum, early musical training's effect on decision making may be due to training-induced long-term changes in the brain.

We further found that the effect of early musical training on IGT was independent of musical training's effects on IQ, WM, and emotional processes (FERT). We successfully matched the three groups in IQ, so it would not have been a factor. As for WM, the two groups with musical training performed better than the no-training group as expected. The onset time of training (early vs. late) however did not seem to matter. This is consistent with previous findings that training onset (before vs. after age 7) was not associated with many cognitive abilities such as digit span, letter number sequences, vocabulary, and reasoning (Bailey & Penhune, 2010, 2012). More important, after controlling for WM, the effect of early training on IGT performance remained significant in this study. In terms of emotion recognition (FERT), the scores did not differ across the three groups and hence would not affect group differences in IGT performance. Our result on FERT was not consistent with the study of children (7 to 8 years of age) by Schellenberg and Mankarious (2012), which found that musical training improved the scores on the Test of Emotion Comprehension. However, our result based on young adults was similar to that of another study of adults (18 to 45 years of age) by Webb, DelDonno, and Killgore (2014) who did not find a correlation between IGT and emotional intelligence, including facial expression recognition (using the Bar-On Emotional Quotient Inventory and Self-Rated Emotional Intelligence Scale). They did find a

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significant correlation between the IGT and the Mayer–Salovey–Caruso Emotional Intelligence Test which included cognitive intelligence. Consequently, after controlling for IQ, that correlation was no longer significant (Webb et al., 2014). It appears that age may moderate the effect of musical training on emotional intelligence. Future research is needed to replicate this age effect and, if confirmed, to understand why the effect of musical training on emotional intelligence is limited to children.

Several limitations of the current study need to be noted. First, there were potential confounding variables that were not considered. The three groups differed not only in early versus late versus no musical training, but also in terms of musical instruments, style of music, and frequency (or intensity) of training. If some of these factors systematically covary with early versus late training (e.g., early onset of training usually involves piano whereas late onset of training may be more likely to involve wind instruments; or early training may be of higher frequency than late training), they may have acted as the mechanisms (or explanatory variables) of early versus late versus no training differences. In addition, although we statistically controlled for years of training in our analyses, future research should experimentally manipulate the two variables separately in order to ascertain their causal roles. Second, participants of this study were all nonmusician Chinese college students, so the results may not be generalizable to musicians or other cultural groups. Finally, cognitive, motivational, and affective factors beyond the few included in this study as well as other measures of the factors included in this study should be considered in order to find mediating processes (i.e., personality) between early musical training and decision making ability.

In summary, early musical training was found to be associated with better ability of decision making. Future research should replicate this result with other groups and investigate mediating cognitive, affective, motivational, and neural mechanisms involved in this effect.

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Received May 18, 2016
Revision received January 28, 2017
Accepted February 6, 2017 ■

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