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Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 38(0)

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Publication Date
2016

Peer reviewed

Can Musical Engagement Alleviate Age-Related Decline in Inhibitory Control?

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Abstract

The purpose of our study was to determine whether active musical engagement alleviates decline in inhibitory control due to cognitive aging. Given that musical training in young adults has been shown to improve attentional performance, we can expect this benefit to persist for older adults as well. With the help of the stop-signal procedure, we measured response inhibition of young and older adults who provided a self-reported assessment of their musical engagement, using the recently validated Goldsmiths Musical Sophistication Index. The Gold-MSI addresses a variety of musical activities and thus offers a more comprehensive measure than ability to play a musical instrument used in the past. Results of the experiment showed that older participants had longer stop-signal reaction times, independently of their musical training and engagement, but musical training and ensemble practice were negatively related to the proportion of missed responses suggesting a weak effect of certain types of musical activities on inhibitory control.

Keywords: inhibitory control; musical sophistication; attention; cognitive aging; stop-signal task.

Introduction

Inhibiting an action that has just been initiated, like crossing the street when the light suddenly turned red, requires high levels of cognitive control (Verbruggen & Logan, 2008a). Cognitive control refers to "purpose control mechanisms that modulate the operation of various cognitive subprocesses and thereby regulate the dynamics of human cognition" (Miyake et al., 2000:50); it is used as a cover term for high-level executive functions that coordinate the cognitive ability of selective attention and a range of other complex cognitive processes (e.g., Diamond, 2013; Miyake et al., 2000; Moreno & Bidelman, 2014). Metaphorically speaking, cognitive processes in the human mind are regulated by executive function in a way similar to how the conductor of a symphony orchestra coordinates the performance of individual instrumentalists (Brown, 2006).

Response inhibition is considered to be a key component of higher order executive functions (Miyake et al., 2000). This type of inhibition is often defined as the ability to stop actions or responses that are no longer required or appropriate, in order to support flexible and goal-directed behavior in dynamic environments (Verbruggen & Logan, 2009a). It is the ability of having control over one's attention, thoughts, emotions and behavior (Diamond, 2013). According to a recent study by Moreno & Farzan (2015), inhibitory control is also an important mediator in transferring skills between cognitive functions. Without response inhibition, human behavior would be dominated by impulsive reactions, habits and distracting factors in the environment.

Response inhibition also plays a central role in theorizing about human cognitive aging (e.g., Bedard et al., 2002; Hasher & Zacks, 1988; Williams et al., 1999). It has often been argued that, similar to other cognitive functions (i.e., working memory, auditory perception, or motor control), performance on response inhibition declines as we get older and considerable resources are being spent on training and improving it. Repeated practice throughout life appears to be key (e.g., Ericsson, Nandagopal, & Roring, 2009), as suggested by the *mental-exercise hypothesis* (Salthouse, 2006). However, existing programs mostly yield mixed results, particularly with respect to far-transfer to untrained tasks (Barnett & Ceci, 2002; Owen et al., 2010).

Contrary to the limited impact of specialized cognitive training tasks and (video-)games, musical training appears to result in robust domain-independent transfer effects (Schellenberg, 2004). Playing a musical instrument not only requires complex motor movements, but also demands high levels of executive control including selective attention, switching, inhibition, updating and monitoring (for a review, see Moreno & Bidelman, 2014). In fact, musicians' cognitive advantages have been found in a variety of domains including mathematics (Vaughn, 2000), verbal and non-verbal skills (Forgeard et al., 2008), and working memory in both the auditory (Chan, Ho, & Cheung, 1998; Pallesen et al., 2010) and visual domain (George & Coch, 2011; Weiss et al., 2014).

Existing studies focus on the comparison of musically trained and untrained individuals, thus disregarding the potentially advantageous effects of other types of musical engagement, such as DJ-ing, music engineering and even frequent passive exposure to music, particularly if accompanied by emotional response. In addition, the research of Corrigall, Schellenberg and Misura (2013) showed that the length of musical training during childhood and adolescence is strongly related to variables such as openness-to-experience, IQ and education of parents, suggesting that simple comparative studies of the relation between musical training and cognitive abilities in a single age group are likely to be dealing with several confounding socio-demographic and personality variables. Finally, from a cognitive psychological point of view, it is important to gain a better understanding of the mechanisms that underlie the relationship between musical performance and different levels of inhibitory control. There is a wealth of experimental evidence suggesting that musical experience enhances inhibitory control at the level of interference control (e.g., selective attention) in both the auditory (e.g., Bialystok & DePape, 2009; Parbery-Clark, Skoe, & Kraus, 2009; Strait & Kraus, 2011) and visual domain (Rodrigues, Loureiro, & Caramelli, 2013). However, little research has focused on the effect of musical experience on inhibitory control at the level of response inhibition (e.g., Moreno et al., 2014).

Present Study

The present study addresses the following research question: 'Can musical engagement alleviate the negative effect of aging on inhibitory control?' Based on earlier research regarding the developmental link between aging and inhibitory control, we expect that young adults would be faster in stopping prepotent responses than older adults. Second, in accordance with research on musical training and enhanced inhibitory control performance, we expect that musical engagement would improve inhibitory control in all ages. In order to test these hypotheses experimentally, we made use of the stop-signal procedure (e.g., Logan, Cowan, Davis, 1984; Verbruggen & Logan, 2008a, 2009a). In this task, the primary performance variable is the amount of time that is needed to withhold your response when a stop-signal is given. This variable is also known as the stop-signal reaction time (SSRT) and provides the latency of the stop process.

Method

Participants

In total, 120 participants, consisting of two music groups (musicians and non-musicians) and two age groups (young and older adults) voluntarily took part in the study. All participants were native speakers of Dutch. Fifty-eight of the participants were young adults (28 female; M_{age} = 22.9 (*SD* = 3.1), range: 18-29 years), and sixty-two were older adults (29 female, M_{age} = 65.5 (*SD* = 5.5), range: 57-83 years). In order to ensure that skilled musicians were included in the sample, as well as to address the potential effect of ensemble musical practice, about a half of the participants (*N*=62), both young and older, was recruited from three Dutch symphony orchestras (the Philips Symphony Orchestra of Eindhoven, the Wildacker Orchestra of Goirle and the South Netherlands Philharmonic), and from the conservatory of Tilburg.

Instrumentation and Material

Goldsmiths Musical Sophistication Index. In line with recent research on musical abilities (e.g., Carey et al., 2015), we used the Goldsmiths Musical Sophistication Index (Müllensiefen, Gingras, Stewart, & Musil, 2014) to assess participants' musical experience. The Gold-MSI is a comprehensive instrument that was developed to account for individual differences in active musical engagement beyond the traditional focus on the ability to play an instrument. It is based on the assumption that other forms of engagement such as DJ-ing, music production and music engineering can have an effect on the cognitive system that is comparable to the impact of instrumental practice. The Gold-MSI consists of five sub-scales: *active engagement* (9 items addressing resources spent on music, e.g., 'I am intrigued by musical styles I am not familiar with and want to find out more'), *perceptual abilities* (9 items on accuracy of musical listening skills, e.g. 'When I sing, I have no idea whether I am in tune or not'), *musical training* (7 items regarding one's life history of formal musical training, e.g., 'I would not consider myself a musician'), *singing abilities* (7 items on singing performance, e.g., 'I am able to hit the right notes when I sing along with a recording'), and *emotions* (6 items on the ability to discuss emotional musical expressions, e.g. 'I am able to talk about the emotions that a piece of music evokes for me'). Next to the five scales, a *general* measure of musical *sophistication* is derived from a subset of items associated with the five subscales. Table 1 provides an overview of the dimensions measured by the Gold-MSI including Cronbach's alpha.

Table 1: Overview of the Gold-MSI subscales

Subscale	Cronbach's α	Nr. of Items	Score Range
Active Engagement	.838	9	9-63
Perceptual Abilities	.869	9	9-63
Musical Training	.950	7	7-49
Singing Abilities	.879	7	7-49
Emotion	.750	6	6-36
General Sophistication	.951	18	18-126

Stop-Signal Task. The inhibition task was based on the stop-signal paradigm developed by Logan et al. (1984), which is considered to be a sophisticated measure of response inhibition (Diamond, 2013; Verbruggen & Logan, 2008a). In the STOP-IT task (Verbruggen, Logan, & Stevens, 2008), the presentation of the stop-signal is adaptive in that it is presented with a variable delay. Participants are assigned a primary shape judgment task, discriminating between a square and a circle. A stop-signal (a 750 Hz tone, 75 ms long) is occasionally presented to inhibit the judgment reaction (on 25% of the trials). If inhibition is successful, the stop-signal delay (the interval between the presentation of the stimulus and the stop-signal, SSD) will increase in intervals of 50 ms from the default delay of 250 ms. In case of unsuccessful inhibition, SSD will decrease with the same interval length (the lowest SSD being 50 ms).

The task consisted of two phases: a practice block of 32 trials, designed to accustom the participants to the task, and an experimental phase of three blocks of 64 trials, each followed by performance feedback presented for 10 seconds. Subsequently, two variables were used as performance measures on the task: the stop-signal reaction time (SSRT) and the proportion of missed responses on no-signal trials (MISS). SSRT is considered to serve as a reliable indication of overall performance, while MISS provides a useful indication as to which response strategy had been used during the stop-signal task (Verbruggen et al., 2008; Verbruggen & Logan, 2009b).

The stimuli for the STOP-IT task were displayed on two Dell Laptops running on Windows 7 Professional with a 15.6" display, or on an ASUS N56VZ-RH71 running on Windows 8 with a 15.6" display. For all three laptops, the response keys "Z" and "/" were covered with a sticker displaying a square and a circle, respectively. The auditory stop-signal was presented via a Sennheiser PC 320 headset.

Results

In order to obtain a comprehensive view of the relation between musical engagement and inhibitory performance, we made use of all the five sub-scales obtained with the Gold-MSI (*active engagement, perceptual abilities, musical training, singing abilities, and emotions).* In an additional analysis, we also tested separately the so-called *general sophistication* (calculated with a subset of the items included in the sub-scales). Finally, we tested the relation with participants' experience with ensemble musical performance encoded as a binary variable. Table 2 presents a correlation matrix for the outcome variables of the stop-signal task (SSRT and MISS), the five Gold-MSI sub-scales and the *general sophistication* score of the Gold-MSI, as well as participants' age. As can be seen from the table, age related positively with SSRT and MISS. Furthermore, a negative correlation was found between the proportion of missed responses on no-signal trials (MISS) and musical training. Finally, all Gold-MSI measures were strongly related to each other.

Table 2: Correlations between the sub-scales of the Gold-MSI, outcome variables of the stop-signal task and age.

Variable	1	2	3	4	5	6	7	8	9
1. Age	-								
2. SSRT	$.24^{*}$	-							
3. MISS	$.32^{*}$	.06	-						
4. AE	-.15	.06	-.11	-					
5. PA	-.06	-.01	-.11	$.74^{*}$	-				
6. MT	-.05	-.01	$-.20^{*}$	$.69^{*}$	$.74^{*}$	-			
7. SA	.01	.08	-.01	$.66^{*}$	$.77^{*}$	$.79^{*}$	-		
8. EMO	-.03	.04	-.05	$.69^{*}$	$.75^{*}$	$.59^{*}$	$.62^{*}$	-	
9. GS	-.02	-.09	-.13	$.82^{*}$	$.86^{*}$	$.93^{*}$	$.91^{*}$	$.72^{*}$	-

Note. SSRT = stop-signal reaction time; MISS = missed responses on no-signal trials; AE = active engagement; PA = perception abilities; MT = musical training; SA = singing abilities; EMO = emotions; GS = general sophistication; $*p < .01$.

Musical Ensemble Practice. Since experience in performing with a musical ensemble could lead to a significant improvement in inhibitory control, we first examined the effect of the binary variable musical ensemble practice in combination with a participant's age as possible predictors of SSRT and MISS. A regression analysis revealed a significant effect of age for both stop-signal performance outcomes, with an additional effect of musical ensemble practice on the proportion of missed responses on no-signal trials, see Table 3.

Table 3: Summary of regression analyses for Age and Musical Ensemble Practice (MEP) as predictors of stop-signal reaction time (SSRT) and the proportion of missed responses on no-signal trials (MISS).

	SSRT			MISS		
Variable	*B*	*SE B*	*t*	*B*	*SE B*	*t*
Age	0.844	0.313	2.698^{**}	0.129	0.035	3.644^{**}
MEP	3.539	13.625	0.260	-3.341	1.536	-2.174^{*}
R^2		0.06			0.13	
F		3.67^{*}			9.1^{**}	

Note. MEP = Musical Ensemble Practice; SSRT = stop-signal reaction time; MISS = missed responses on no-signal trials; $^{*}p < .05$, $^{**}p < .01$.

As can be seen from the box plots in Figure 1, there was no effect of musical ensemble experience on the stop-signal reaction time. However, the proportion of missed responses was effected by participants' musical ensemble experience; non-musicians with no experience had a significant higher percentages than orchestra musicians.

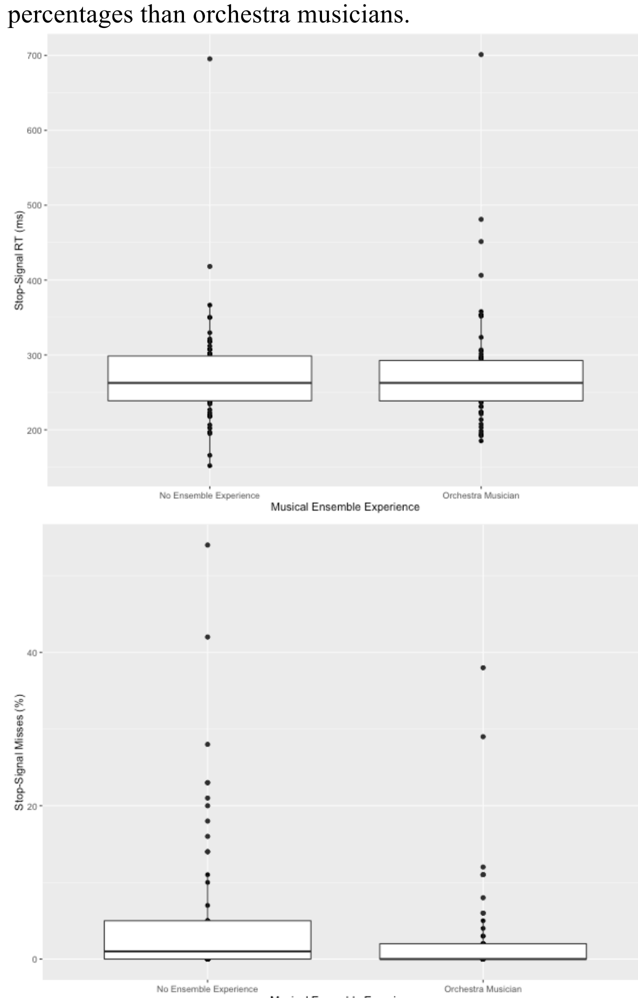

Figure 1: Box plots illustrating the stop-signal reaction times (top) and proportion of missed responses (bottom) for both participants with and without musical ensemble experience.

Five Gold-MSI Sub-scales. To capture the relation between inhibitory control, age and other forms of musical experience, we subsequently performed a regression analysis with the five Gold-MSI Sub-scales (active engagement, perceptual abilities, musical training, singing abilities, emotions) and age as predictors of SSRT and MISS. This regression showed a significant effect of age for both stop-signal performance outcomes, with an additional effect of the scale 'musical training' on the proportion of missed trials (see Table 4). The same effects were found in additional two regression analyses in which four SSRT-outliers (with SSRT around 700ms) were discarded (results not reported due to space limit).

Table 4: Summary of regression analyses for Age and the five Gold-MSI Subscales as predictors of stop-signal reaction time (SSRT) and the proportion of missed responses on no-signal trials (MISS).

		SSRT			MISS	
Variable	*B*	*SE B*	*t*	*B*	*SE B*	*t*
Age	0.862	0.317	2.717**	0.124	0.036	3.431**
AE	1.171	0.994	1.178	0.059	0.113	0.516
PA	-2.157	1.307	-1.650	-0.087	0.149	-0.582
MT	-0.860	0.817	-1.052	-0.231	0.093	-2.475*
SA	1.689	1.208	1.398	0.204	0.138	1.478
EMO	1.774	1.667	1.064	0.093	0.190	0.490
R^2		0.11			0.16	
F		2.24*			3.53**	

Note. AE = active engagement; PA = perception abilities; MT = musical training; SA = singing abilities; EMO = emotions; SSRT = stop-signal reaction time; MISS = missed responses on no-signal trials; $^*p < .05$, $^{**}p < .01$.

General Musical Sophistication. Finally, to assess the relation between inhibitory control, age, and general musical sophistication we carried out a regression analysis with general musical sophistication and age as predictors of SSRT and MISS. This regression analysis only revealed a significant effect of age for both stop-signal performance outcomes, as listed in Table 5.

Table 5: Summary of regression analyses for Age and General Sophistication (GS) as predictors of stop-signal reaction time (SSRT) and the proportion of missed responses on no-signal trials (MISS).

		SSRT			MISS	
Variable	*B*	*SE B*	*t*	*B*	*SE B*	*t*
Age	0.847	0.313	2.709**	0.128	0.036	3.588**
GS	0.120	0.251	0.479	-0.038	0.029	-1.337
R^2		0.06			0.11	
F		3.75*			7.47**	

Note. GS = general sophistication; SSRT = stop-signal reaction time; MISS = missed responses on no-signal trials; $^*p < .05$, $^{**}p < .01$.

Figure 2 illustrates the association between the six sub-scales of the Gold-MSI and the stop-signal reaction times.

Furthermore, the relation between the six sub-scales of the Gold-MSI and the proportion of missed responses on no-signal trials is shown in Figure 3.

Conclusion

Taken together, these results of the stop-signal task suggest that there is an association between inhibitory control and aging; as we grow older, our ability to stop responses that have already been initiated decreases, regardless of musical engagement and ensemble experience. However, musical training and ensemble practice were negatively related with the proportion of missed responses. Therefore, on the question whether musical engagement alleviates age-related decline in inhibitory control, we suggest a weak effect of certain types of musical activities on inhibitory control.

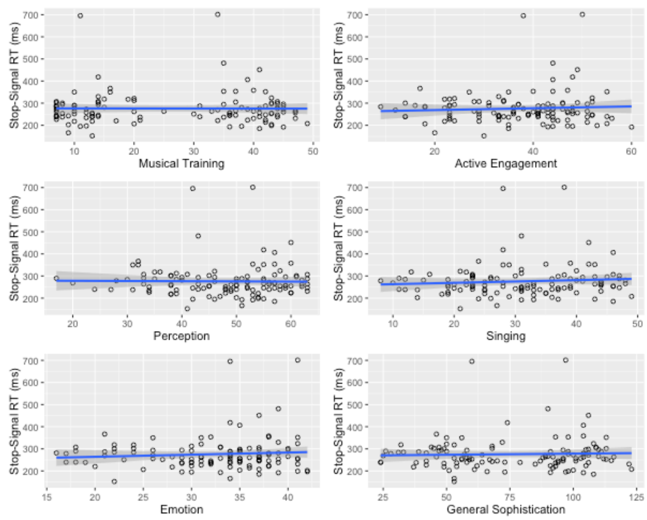

Figure 2: Plots of Gold-MSI scale in relation to stop-signal reaction times.

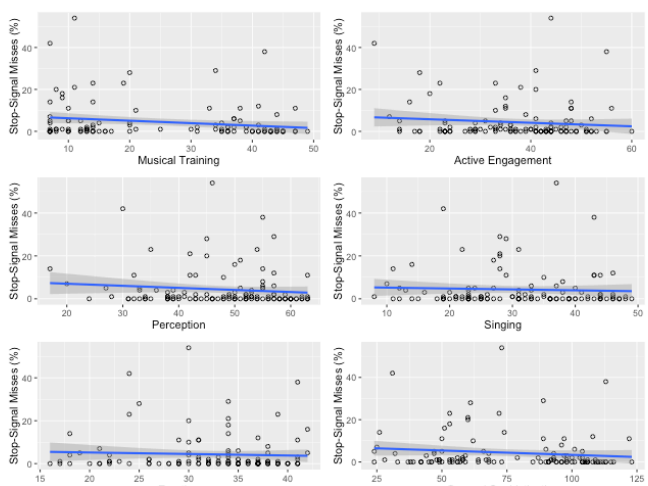

Figure 3: Plots of Gold-MSI scale in relation to stop-signal misses.

Discussion

The purpose of the current study was to determine whether different forms of musical engagement decrease age-related decline in inhibitory control. Musical engagement was assessed with the Goldsmiths Musical Sophistication Index (Gold-MSI, Müllensiefen et al., 2014). In addition, we tested the effect of musical ensemble practice on the behavioral aspect of inhibitory control, that is, response inhibition, using the stop-signal procedure (Logan et al., 1984; Verbruggen & Logan, 2008a).

The SSRT, which is the primary performance variable and indicates the speed of process of inhibitory control (Verbruggen et al., 2008), increased with age. This is in line with previous findings (Bedard et al., 2002; Kramer et al., 1994), though see Williams et al. (1999) for an opposing view. A possible explanation is that during stop-signal trials, participants are confronted with constant cognitive demand on task goals (i.e., stopping and going), and on set shifting modalities (i.e., auditory and visual stimuli). Therefore, the observed age-related losses in inhibitory control might be caused by increased cognitive demand (Bedard et al., 2002; Verbruggen & Logan, 2009b for similar reasoning).

Next, we found that various kinds of musical engagement did not improve inhibitory control performance, contrary to the *mental exercise hypothesis* (Salthouse, 2006), which assumes that continued practice helps slow down age-related losses in cognition. Possibly, the ability to inhibit a planned action is not only one of the earliest emerging executive functions but is also maintained the longest (Barkley, 1997), given the importance of inhibitory control for survival (e.g., Bedard et al., 2002).

The results obtained in this study are inconsistent with research of Moreno and colleagues (2014). Arguably, this might also be due to the use of different paradigms (i.e., the Go/No-Go paradigm and the stop-signal paradigm). Both paradigms test different kinds of response inhibition and require different demands of cognitive control (Verbruggen & Logan, 2008b).

Finally, we noted that the proportion of missed trials (MISS) increased with age; however, older adults with usical ensemble experience and/or musical training had fewer missed responses than their peers. These outcomes suggest that older adults use a different response strategy during the stop-signal task that is aimed at waiting for a stop-signal to occur. By doing so, they reduce the risk of pressing on stop-signal trials. This observed waiting strategy could be attributed to the proactive-adjustment hypothesis (Verbruggen & Logan, 2009b), which means that during the stop-signal task, participants proactively change their response threshold when they expect a stop-signal to occur on the next few trials. Older adults with musical training apply the waiting strategy and are better in timing their response. Perhaps musicians benefit from their extensive rhythmic experiences and enhanced timing skills, and auditory-motor expectancies (Brown, Zatorre, & Penhune, 2015), which may help them anticipate thoughts or actions for unexpected events related to music, such as the stop-signal in the present study (Furuya & Soechting, 2010).

A key contribution of the present study was that we treated musical expertise as a multifaceted concept. Classically, the distinction between musicians and non-musicians was primarily based on participant's musical training background. However, the degree of musical engagement in our study was established by the recently validated Gold-MSI (Müllensiefen et al., 2014), which provided a more comprehensive measure than a simple focus on the ability to play a musical instrument. By gathering data from young and older adults, we ensured that the association between personality and early musical training played a limited role as confounding variable (Corrigall et al., 2013).

Notwithstanding, some important issues with regard to musical expertise should be mentioned. Future studies should examine the exact contribution of ensemble practice compared to solo practice. In ensemble settings, musicians are required to listen carefully to different aspects of sounds produced by other musicians (e.g., intonation, timing, and dynamics), as well as to observe the visual input provided by the conductor in order to time their reaction. This, howeverm is not need in private musical training (Habibi et al., 2014). Also, different instruments might impact inhibitory control in various ways. Past research that compared two specific instrumental groups (violinists versus pianists) (Carey et al., 2015) found differences in terms of auditory skills (e.g., violinists showed a greater ability to detect small changes in pitch than both pianists and non-musicians), suggesting possible effects on general cognitive skills as well.

To conclude, the present findings strengthen the idea that response inhibition decreases during normal cognitive aging. Although we found no evidence that both musical training and general musical engagement alleviate the negative effect of aging on inhibitory control, other life-long activities, such as occupational complexity, can be explored in the future. However, musical training and ensemble practice relates negatively to the proportion of missed responses suggesting a weak effect of certain types of musical activities on inhibitory control. Arguably, response inhibition is an example of a complex executive function and more research should be undertaken in the future, in order to enhance our understanding of its components and how they can be trained effectively.

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