



**Musical expertise has minimal impact on dual task performance**

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## Musical expertise has minimal impact on dual task performance

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**ABSTRACT**

Studies investigating effect of practice on dual task performance have yielded conflicting findings, thus supporting different theoretical accounts about the organization of attentional resources when tasks are performed simultaneously. Because practice has been proven to reduce the demand of attention for the trained task, the impact of long-lasting training on one task is an ideal way to better understand the mechanisms underlying dual task decline in performance.

Our study compared performance during dual task execution in expert musicians compared to controls with little if any musical experience. Participants performed a music recognition task and a visuo-spatial task separately (single task) or simultaneously (dual task). Both groups showed a significant but similar performance decline during dual tasks. In addition, the two groups showed a similar decline of dual task performance during encoding and retrieval of the musical information, mainly attributed to a decline in sensitivity. Our results suggest that attention during dual tasks is similarly distributed by expert and non-experts. These findings are in line with previous studies showing a lack of sensitivity to difficulty and lack of practice effect during dual tasks, supporting the idea that different tasks may rely on different and not sharable attentional resources.

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3 When two tasks are executed at the same time, individuals tend to show poorer performance in one  
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5 or both tasks when compared to single task performance. Yet in many everyday and expert  
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7 situations, people do carry out multiple tasks successfully, such as driving while conversing, or  
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9 playing a piano piece accurately as well as expressively. According to recent studies (e.g. Logie,  
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11 2011), as long as two tasks do not compete for specific cognitive processes, the cost of concurrency  
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13 during dual tasks is relatively limited. This multiple resources approach originally suggested that  
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15 each task draws resources from different not-sharable attentional pools (Navon & Gopher, 1979).  
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17 The assumption is that each task can engage different specific attentional pools that can operate in  
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19 parallel (e.g., Logie, 2011). In line with this observation, recent neuroimaging and  
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21 electrophysiological studies have observed that different tasks are supported by distinctive brain  
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23 networks during dual tasks (Alavash, Thiel, & Gießing, 2016) and that, at least initially, brain  
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25 processes can operate in parallel during dual tasks (Marti, King, & Dehaene, 2015; Sigman &  
26  
27 Dehaene, 2008). It follows that the decline in performance observed during dual tasking is relatively  
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29 small, as it does not represent the impact of time-sharing of a single resource, but rather a cost of  
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31 co-ordination of two parallel processes. The process of co-ordination would itself require some  
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33 resources (e.g., Navon & Gopher, 1979) and the cost of concurrency would reflect the demand of an  
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35 executive mechanism responsible for co-ordinating responses and for deciding how to allocate  
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37 resources (e.g., Logie, Cocchini, Della Sala, & Baddeley, 2004).  
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47 Studies with healthy and clinical populations have proposed that the central executive of  
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49 working memory could offer the appropriate mechanism to interpret co-ordination of concurrent  
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51 tasks (e.g. Baddeley, 1996; Baddeley & Della Sala, 1996; Della Sala, Baddeley, Papagno, &  
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53 Spinnler, 1995; Logie, 2011; Logie et al., 2004). Within this framework, the effect of training of  
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55 one task would lead to a better performance of a single task but the co-ordination of two tasks  
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57 would be relatively unaffected by practice. Hence, the study of practice effects in dual task  
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3 situations can offer the ideal means to provide further understanding of underlying attention  
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5 mechanisms when two tasks are performed simultaneously.  
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9 Recent studies have provided contrasting results on the effect of practice during dual tasks,  
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11 which could be due, at least in part, to the different paradigms used. On the one hand, some studies  
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13 reported improved performance or increased speed following practice (e.g. Goh, Sullivan, Gordon,  
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15 Wulf & Winstein, 2012; Strobach, Gerstorf, Maquestiaux, & Schubert, 2015a; Strobach, Liepelt,  
16  
17 Pashler, Frensch, & Schubert, 2013) contributing, according to Strobach et al. (2013), to faster time-  
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19 sharing of the resources. On the other hand, other studies have reported a practice benefit during  
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21 dual tasking only for some individuals (Schumacher et al., 2001), while still other authors, testing  
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23 adults of different ages and neurological patients, have reported effects of practice limited to single  
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25 task performance (Della Sala, Foley, Beschin, Allerhand, & Logie, 2010b; Foley, Cocchini, Logie,  
26  
27 & Della Sala, 2015). For example, in Foley et al.'s (2015) study, the participants were asked to  
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29 simultaneously perform a verbal memory task and a visuo-motor task six times. No significant  
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31 change in the dual task decrement was observed over practice sessions, despite performance on the  
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33 visuo-motor single task improving after the six-trial practice phase.  
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40 The relatively modest, though inconsistent, practice effect in dual task efficiency suggests a  
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42 modularity process in dual tasking: That is, despite the practised task requiring fewer resources, this  
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44 efficiency gain is not shared with the secondary task. However, in Foley et al.'s study, the  
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46 participants practiced during the dual task situation rather than during single tasks, thus the practice  
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48 may have had a limited impact on the resources required for each single task. Indeed, the practice  
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50 effect was modest also in the single task and only appeared in the visuo-motor task. In addition, the  
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52 practice phase was limited to six repetitions of the dual task; longer periods of training, over  
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54 months, have been associated with some improvement during dual tasking (e.g. Pliske,  
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56 Emmermacher, Weinbeer, & Witte, 2015; Strobach, Frensch, & Schubert, 2012).  
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3 Therefore different results might be observed with more intense practice. It is possible that  
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5 long and persistent training of one task, enabling individuals to reach high levels of expertise on at  
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7 least one task, may lead to a profound change in how the overlearned task is addressed and how  
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9 attention is organised during the dual task. Recent studies have reported that people with high  
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11 expertise on a task, such as musicians (Schroeder et al., 2016; Schellenberg, 2006; Bialystok &  
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13 DePape, 2009, Ho et al., 2003; Lee et al., 2007; Trainor et al., 2009), simultaneous interpreters  
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15 (Strobach et al., 2015b), and bilinguals (Bialystok & Depape, 2009; Schroeder et al., 2016), tend to  
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17 perform better than nonexperts on several cognitive single tasks. It seems therefore that the crucial  
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19 aspect in these expert groups is the extensive training on a cognitive domain (likely combined with  
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21 some predispositions) rather than the specific type of training.  
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27 Interestingly, two studies have also observed that these experts perform better than controls in  
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29 dual task situations (e.g., Strobach et al., 2015b; Moradzadeh et al., 2015). In Strobach and  
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31 colleagues' (2015b) study, the tasks were presented sequentially, with limited temporal overlap  
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33 between the tasks; whereas in Moradzadeh and colleagues' (2015) study, the tasks required similar  
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35 types of responses (pressing a key and following a moving target with a mouse) that were likely to  
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37 overload similar output resources (Logie, 2016). In addition, the task used in these studies were  
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39 unrelated to the skilled domain. This makes it difficult to assess whether the specific domain  
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41 resources 'freed' by the intensive practice can be 'transferred' to the executive component to co-  
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43 ordinate the simultaneous execution of the two tasks or, as mentioned above, whether the experts'  
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45 dual task performance is facilitated by a general cognitive superiority observed in various single  
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47 tasks (e.g., Bialystok & DePape, 2009; Strobach et al., 2015; Schroeder et al., 2016).  
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53 Inevitably, comparing individuals with very different levels of expertise on a task involves a  
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55 methodological limitation, if initial task difficulty is not equated during single task between the  
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57 groups. As pointed out by Perry and Hodges (1999; see also Salthouse, Rogan, & Prill, 1984),  
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3 groups of participants with initial different abilities may show different dual task decrements due to  
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5 the unequal attentional load required by each individual task even in single task condition. Previous  
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8 studies suggest that high expertise on one task may lead to a widespread advantage on various  
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11 cognitive tasks (e.g., Schroeder et al., 2016; Strobach et al., 2015b; Bialystok & Depape, 2009).  
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13 Hence, the single task load of each group should be adjusted in both musical and non-musical tasks  
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15 in order to obtain a similar level of performance in single tasks, which is then compared with dual  
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17 task performance, to allow estimation of the cost of concurrency. Some previous studies (e.g. Logie,  
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19 et al., 2004) have therefore titrated each single task load around each individual's ability, an  
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21 approach we follow here.  
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26 Musical experts are an ideal group engaged in long-life intense training to compare with naïve  
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28 (to musical skills) group. Our study investigates whether prolonged and intense training in music,  
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30 combined with a likely predisposition to learn and practice music, may affect specific task resources  
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32 and the organisation of the co-ordination process during dual tasking when tasks are entirely  
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34 simultaneous, share minimal (if any) overlapping resources, and when single task performance is  
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36 titrated, i.e., equated between the expert and novice group. If dual task performance reflects the  
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38 time-sharing of a single resource, we should observe a high cost of concurrency, although expert  
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40 individuals should be significantly less susceptible to this cost than non-expert individuals. In  
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42 contrast, if dual task cost reflects the cost of an executive mechanism responsible for co-ordinating  
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44 responses, which is also relatively impermeable to practice, experts and non-experts should show i)  
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46 a significant but relatively small decline in performance during dual tasks, reflecting a cost of  
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48 concurrency rather than sharing of a general resource, ii) a similar degree of dual task decrement  
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50 regardless on the degree of expertise and iii) a similar qualitative impact of concurrency (i.e. similar  
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52 pattern of dual task performance in different phases of tasks, here the encoding and discrimination  
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3 phases of a short-term comparison task) across the two groups, reflecting a co-ordination  
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5 component independent from individual task expertise.  
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## 10 11 12 **METHODS**

### 13 14 15 16 **Participants**

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18 Musical expertise of 40 university students and professionals was classified according to Halpern,  
19 Bartlett and Dowling's (1995) criteria for musical expertise, and participants were assigned into two  
20 different groups. Twenty participants, attending a postgraduate course on music and neuroscience,  
21 were considered as expert musicians having on average 11.39 years (sd= 5.45; range= 4-20) of  
22 private instrument lessons; 6.00 years (sd= 4.13; range= 0-15) of amateur music experience (e.g.,  
23 playing in peers or school bands); and 4.32 years (sd= 4.93; range= 0-15 ) of professional  
24 experience. The other 20 participants, attending a different course of study, were considered  
25 nonmusicians, having no more than 2 years of music training (average= 0.18; sd= 0.53; range= 0-2)  
26 or amateur experience (average = 0.47; sd= 1.07; range=0-3) and none of them had professional  
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43 In the Musician group (16 females; 18 right-handed, 2 left-handed and 1 ambidextrous) the  
44 average age was 25.75 (SD= 3.8; range= 19-34). In the Nonmusician group (12 females; 17 right-  
45 handed and 3 ambidextrous) the average age was 24.8 (SD= 4.42; range= 20-38).  
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### 51 52 **Tests**

#### 53 54 55 *Visual Pattern Test – Individual titration*

56 An E-prime version of the original test (Della Sala, Gray, Baddeley, Allamano, & Wilson, 1999)  
57 was devised. A white and black checkerboard pattern on the centre of a PC screen was displayed for  
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3 3 s, followed by a mask. The matrix varied in complexity from 2 to 11 black squares. Participants  
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5 were first presented with a 2x2 pattern with two black squares (span 2) for 3 s and then were given a  
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7 blank 2x2 grid in which they had to indicate the previously filled squares with no time limits for a  
8  
9 response. Responses were recorded on a printed template using a pen. Following correct recall of  
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11 one out of three patterns at any given span, complexity was increased by presenting a new series of  
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13 three random patterns where the matrix was enlarged by two (one black) squares (e.g. for span 3 a  
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15 matrix with a total of six squares, for span 4 a matrix with a total of eight squares, etc...) until a  
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17 maximum span of 11. This procedure continued until the participant failed to recall the filled  
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19 squares on all three trials at a given level. The level of complexity of a pattern was defined as the  
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21 number of filled squares in a grid. Following Della Sala et al. (1999), the individual visual pattern  
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23 span was taken as the mean of the last three patterns for which filled squares were correctly  
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25 recalled.  
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#### 34 *Visual Pattern Test -Single task*

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36 The single task consisted of 30 trials with the complexity of the checkerboard pattern set for each  
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38 individual's span and was constant for the entire single task. The novel checkerboards (same stimuli  
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40 used in Cocchini, Logie, Della Sala, MacPherson, & Baddeley, 2002) were generated by randomly  
41  
42 filling (in black) half of the squares forming each matrix. Patterns that obviously formed canonical  
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44 shapes such as letters or numbers were excluded.  
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48 In order to allow time-matching with the musical task during dual task conditions, each pair  
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50 of VPT trials lasted 30 s: The first stimulus was displayed for 3 s followed by a 3-s mask, then 8 s  
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52 response window, followed by 2 s of pause before starting the second trial of the pair (See Figure  
53  
54 1). The entire VPT single task (i.e. 15 pair of trials) lasted 7 min and 30 s. Accuracy was measured  
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56 as percentage of matrices correctly recorded.  
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### *Music recognition single task*

The other task was same-different recognition of melodies ( Halpern et al. 1995). Each target melody consisted of four repetitions of a novel 7-note tonal sequence played in the original key, transposed to two musically close keys, then again in the original key. The comparison melody (see example in Figure 2) was either identical to the target melody (ID) (although transposed to yet another key), or it was transposed and also differed by one note in the second measure, but maintained a similar pitch contour (Same Contour, SC = difficult discrimination) or was transposed and the note change resulted in a different contour (Different Contour, DC = easy discrimination) from the target melody. All melodies were unfamiliar, tonal melodies with isochronous rhythm, omitting large interval leaps. Type of trials (i.e., ID, SC and DC) were presented randomly. Each Music trial lasted 30 s: the target melody was presented for 14 s, followed by a pause of 2 s, then the 7-note comparison melody was played and participants had 11 s to respond before a new trial began (see Figure 1). The entire Music Single task lasted 7 min and 30 s. To ensure that participants clearly understood instructions and to familiarise them with the procedure, each participant performed a practice trial with the well-known melody of ‘Frère Jacques’. This was then followed by 15 consecutive experimental trials.

A series of pilot studies investigated the best combination of novel stimuli to titrate the musical task difficulty across the two groups. None of the participants taking part in this phase were recruited for the experimental task. Pilot data indicated that the single task difficulty was roughly equated for Musicians and Nonmusicians by considering performance on ID & SC trials for the Musician group and ID & DC trials for the Nonmusician group. Therefore, though all participants were presented with all the same combination of stimuli, we considered single and dual task performance for ID & SC trials for Musicians and ID & DC trials for Nonmusicians (Perry & Hodges, 1999).

### *Dual tasks: Visual Pattern Test and Music Recognition task*

Following the two single tasks, participants were asked to complete both tasks at the same time (dual task condition), giving them equal weight. The same procedures adopted for the single task were applied for the dual task and Figure 1 illustrates how the two tasks were combined. To explore possible different effects of dual tasking during encoding and retrieval of musical information, respectively, half of the VPT trials were presented during the encoding phase of the target melody and half during the musical discrimination phase, which consisted of the comparison melody and response. VPT performance during dual task was then considered separately according to whether the simultaneous musical task was in a 'encoding' (VPT-Enc) or 'discrimination' (VPT-Dis) phase. There were 30 trials for the Visual Pattern Test and 15 trials for the Music Recognition test. The entire dual task lasted 7 min and 30 s.

### **General procedure**

Following dual task methodology used in previous studies (e.g. Logie et al., 2004), single tests were always performed before dual tasks, and participants were randomly assigned to run one of the two single tests first. Dependent variables were assessed in terms of percentage of correct responses, sensitivity ( $d'$ ), and criterion ( $\beta$ ).

---Insert Figures 1 & 2 about there ---

## **RESULTS**

Age and years of formal education did not differ between the two groups. The two groups significantly differed according to years of private lessons ( $p < .001$ ); years of amateur musical experience ( $p < .001$ ) and years of professional experience ( $p < .001$ ). Following previous studies (e.g.

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3 Logie et al., 2004) individuals showing ceiling or floor effects during single task were excluded:  
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5 performance on either the Visual Pattern single task (2 Nonmusicians) or the Music recognition  
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7 single task (1 Nonmusician and 1 Musician) more than 2 standard deviations from the group  
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9 average (Visual Pattern Test) or at or below chance level (Music Recognition test). Accordingly,  
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11 the data from 5 out of 40 participants were excluded from final analyses. One additional Musician  
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13 was excluded as his data were incomplete. Data from the remaining 35 (18 Musicians and 17  
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15 Nonmusicians) were entered in the final analyses.  
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### 22 *Visual Pattern test*

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24 Visual Pattern Span was very similar in the two groups. Musicians obtained an average span of 7.28  
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26 (sd=.83; range: 6-9) and Nonmusicians obtained an average span of 6.76 (sd=1.1; range: 5-9). A t-  
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28 test showed no significant difference between the two groups (t-crit= 1.574; p=ns).  
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32 Data for the VPT were analysed to investigate performance during single and dual tasks. In  
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34 addition, performance during dual tasks was analysed separately for VPT-Enc (i.e., when the  
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36 participant was simultaneously encoding the melody for the secondary task) and for VPT-Dis (i.e.,  
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38 when the participant was simultaneously discriminating the two melodies). Mean percentages (and  
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40 SDs) for each condition are shown in Table 1. VPT data related to ID&DC musical trials were  
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42 considered for Nonmusicians, whereas those related to ID&SC trials were considered for  
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44 Musicians, as noted earlier. A 2 (group) X 3 condition (single, VPT-Enc, VPT-Dis) ANOVA  
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46 showed a significant effect of condition ( $F(2,33)=44.16$ ;  $p<.001$ ). Considering Bonferroni  
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48 correction for multiple comparisons ( $p$  value =  $0.05/3=.017$ ), post-hoc analyses showed that Single  
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50 task performance was significantly higher than the dual task under VPT-Enc (t-crit= 3.103;  $p<.005$ )  
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52 and VPT-Dis (t-crit=6.451;  $p<.001$ ) and that performance on VPT-Enc was significantly higher  
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54 than VPT-Dis (t-crit=4.191;  $p<.001$ ). No significant effect of group ( $F(1, 33)=0.521$ ;  $p=n.s.$ ) or  
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56 interaction ( $F(2,33)=2.607$ ;  $p=n.s.$ ) was found. These findings suggest that both groups performed  
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3 similarly during single tasks and both showed a significant decrement in performing dual tasks, in  
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5 particular during the discrimination phase of the secondary task.  
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10 --- Insert Table 1 about here ---  
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15 To capture the overall changes in performance across single and dual tasks, we also  
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17 considered the combined percentage of change in accuracy as in previous studies (e.g., Logie et al.,  
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19 2004), following the formula:  
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24 *Percentage of change = ((Single task performance – dual task performance) / Single task performance) x 100*  
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29 We then calculated the change between single and VPT-Enc and the change between single  
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31 and VPT-Dis.  
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34 Figure 3 shows the decline in performance from single tasks for both dual task conditions and  
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36 for both groups. A 2 (group) x 2 (condition: VPT-Enc, VPT-Dis) ANOVA showed a significant  
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38 effect of condition ( $F(1, 33) = 21.05$ ;  $p < .001$ ) and an interaction between group and condition  
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40 ( $F(1,33) = 4.770$ ;  $p < .05$ ) but no effect of group ( $F(1,33) = .394$ ;  $p = n.s.$ ). Post-hoc analyses between  
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42 groups and VPT-Enc and VPT-Dis showed only a significant difference between Musicians'  
43  
44 decline in VPT-Enc and Nonmusicians' decline in VPT-Dis ( $t\text{-crit} = 2.55$ ;  $p < .02$ ). No significant  
45  
46 group differences were observed between VPT-Enc and VPT-Dis. These findings suggest that both  
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48 groups showed significantly poorer performance during the dual task situation, especially during the  
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50 discrimination phase of the music task.  
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--- Insert Figure 3 about here ---

### *Music Recognition Task*

Data for the Musical Recognition Task were analysed to investigate performance during single and dual tasks. As expected, Musicians showed a ceiling for the ‘easy- different’ trials (i.e., DC; average accuracy= 92.2%; sd=10.0) whereas Nonmusicians showed a floor effect (i.e. at or below chance level) for the ‘difficult-different’ trials (i.e., SC; average accuracy=43.5%; sd=31.0), validating the titration approach. Table 2 illustrates the groups’ performance during single and dual tasks. A 2 (group) X 2 condition (single, dual) ANOVA showed a significant effect of condition ( $F(1,33)=5.431$ ;  $p<.05$ ). No significant effect of group ( $F(1,33)= 3.547$ ;  $p=n.s.$ ) nor interaction ( $F(1,33)=2.081$ ;  $p=n.s.$ ) were found.

--- Insert Table 2 about here ---

As for the Visual Pattern Test, we also calculated the percentage of change from single to dual task performance using the above formula. Musicians showed a larger change (mean=12.38; sd=21.0) than Nonmusicians (mean=1.70; sd=17.6); however a t-test analysis did not show a significant effect ( $t\text{-crit}= 1.622$ ;  $p=n.s.$ ).

### *Visual Pattern test and Music Recognition task – combined change*

Although separate analyses of dual task performance for each task can provide detailed information about that specific skill, they do not provide insight about the combined impact of the tasks on individuals’ performance. Therefore, we also calculated the combined percentage change of the Visual Pattern Test and the Music Recognition task as follows (e.g., Logie et al., 2004):

Combined percentage change =  $100 - ((\text{Percentage change VPT} + \text{Percentage change Musical task})/2)$

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5 For the Visual Pattern Test the combined change was calculated averaging the combined  
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7 change for VPT-Enc and VPT-Dis. Despite the Musicians showing a slightly higher decrement  
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9 (mean=15.04; sd=15.1) than Nonmusicians (mean=12.10; sd=16.7), the difference between groups  
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11 was far from significant ( $t$ -crit=.546;  $p$ =n.s.).  
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14  
15 Finally, the correlation between the level of musical expertise (in terms of years of music  
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17 lesson) and the overall dual task cost was very weak (Spearman's  $r$ =.06;  $p$ =n.s.).  
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### 20 21 22 *Signal detection theory*

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24 Since the two groups differed on musical expertise, it was important to examine possible  
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26 differences in approaches to the tasks by Musicians and Nonmusicians. Following a similar  
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28 procedure in Baddeley, Cocchini, Della Sala, Logie and Spinnler (1999), we carried out Signal  
29  
30 Detection Analysis on single and dual task performance. In calculating the Hit and FA rates we  
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32 considered ID and SC trials for Musicians, and ID and DC trials for Nonmusicians for both single  
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34 and dual tasks.  
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38 As in previous studies (e.g., Baddeley et al., 1999; Brazzelli, Cocchini, Della Sala, &  
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40 Spinnler, 1994; Guilford, 1954), when the number of hits was at ceiling we applied the function  $f =$   
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42  $(N \times 2 - K)/2$ , whereas when the number of false alarms was at zero, we applied the function  $f =$   $(N \times$   
43  
44  $2 + K)/2$  (Bock & Jones, 1968); where  $N$  is the number of hits/false alarms and  $K$  is equal to 1.  
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48 Table 3 reports both sensitivity ( $d'$ ) and criterion ( $\beta$ ) data. A 2 (group) X 2 (condition: single  
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50 versus dual) ANOVA on  $d'$  data showed a significant effect of condition ( $F(1,33)=4.484$ ;  $p<.05$ ) and  
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52 group ( $F(1,33)= 4.383$ ;  $p<.05$ ), but no interaction ( $F(1,33)=.918$ ;  $p$ =n.s.). A similar ANOVA on  $\beta$   
53  
54 showed a significant effect of condition ( $F(1,33)=8.061$ ;  $p<.01$ ), but no effect of group  
55  
56 ( $F(1,33)=1.021$ ;  $p$ =n.s.) nor interaction ( $F(1,33)=.583$ ;  $p$ =n.s.). These findings suggest that, though  
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58 Musicians showed a generally lower sensitivity than Nonmusicians, probably due to their  
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3 performing a slightly more difficult musical task, both groups showed a comparable reduction of  
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5 sensitivity between single and dual tasks. Moreover, both groups showed similar criterion and shift  
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7 towards a more stringent criterion (i.e., more inclined to respond 'same' even when the melody was  
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9 different) during dual tasks.  
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## 21 22 **DISCUSSION**

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25 Previous studies suggested that decrements in performance during dual tasks, where two tasks  
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27 require resources from different pools, reflect the cost of a co-ordination process (e.g., Logie et al.,  
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29 2004; Wickens, 1992). Applying the working memory framework, the central executive acts as co-  
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31 ordinator and is impermeable to individuals' level of familiarisation with a task (Foley et al., 2015).  
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33 Our study investigated the extent of the practice effect considering extensive life-long professional  
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35 training and involvement.  
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40 **Since intensive training may lead to a widespread improvement of various cognitive**  
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42 **processes, including spatial tasks (Bialystok & Depape, 2009), we ensured that resource demands**  
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44 **during both initial single tasks were comparable across individuals and between the two groups with**  
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46 **different musical expertise.** VPT difficulty level was titrated according to individual ability, and  
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48 musical trials of different difficulty were considered for the two groups. As a result, group  
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50 performance on both single tests was similar, and relatively high without being at ceiling (between  
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52 76 and 81% correct). We can assume then that the initial task difficulty was reasonably well  
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54 equated across the two groups. This was an important procedure to follow as ceiling or floor effects  
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56 may hide potential differences across conditions or groups.  
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3 Although one could argue that titration may have diminished the expertise effect, we consider  
4 this unlikely, as the titration equated the initial resources for a task, not the co-ordination  
5 component nor the time-sharing. Indeed, titration of single tasks still revealed group differences  
6 between Alzheimer's patients and controls during dual tasks (e.g., Logie et al., 2004; Della Sala,  
7 Cocchini, Logie, Allerhand, & MacPherson, 2010a ), suggesting that equating single task resources  
8 does not significantly affect the co-ordination of dual tasks.  
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11 Moreover, our research question also included whether differential expertise would lead to  
12 qualitative differences in the organisation of the resources during dual tasks. Comparing VPT single  
13 and dual task performance, both groups showed a significant and similar decrement during dual  
14 tasking. Both groups also showed a dual task decrement for music tasks. In this case, Musicians  
15 showed a slightly higher dual task cost than Nonmusicians but the difference was not significant.  
16 More importantly, when the combined effect of dual tasks was considered across the two tasks, both  
17 groups showed a very similar overall decrement of between 10% and 15%, which is comparable to  
18 the dual task cost reported in other studies using similar paradigms (e.g. Della Sala et al., 2010a).  
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20  
21 One conclusion from these data is that the dual task cost is relatively limited, though  
22 persistent. As pointed out by previous studies (e.g. Logie et al., 2004), a relatively limited drop  
23 (lower than 15% ) seems more in line with the hypothesis that the dual task decrement represents  
24 the cost of an additional process to co-ordinate the task-specific resources rather than task-switching  
25 of a single attentional resource. Logie (2016) has recently suggested that this 'additional process',  
26 usually considered as one of the central executive role, may rely on neural connectivity between  
27 task-specific brain areas. Sigman and Dehane (2008) have recently observed parallel activation, at  
28 least in the initial phase of dual tasking, of different brain areas when individuals performed two  
29 different tasks. Similar findings have been observed in more recent studies (Alavash et al., 2016;  
30 Marti et al., 2015). Taking these observations together, we propose that dual task performance  
31 reflects co-ordination of task specific resources. As also pointed out by Logie (2016), we cannot  
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3 exclude however that a task-switching process, and related higher dual task cost, may become more  
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5 relevant the more the tasks overlap type of representations and processes required.  
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8 Secondly, the degree of expertise amongst Musicians seemed unrelated to overall dual task  
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10 cost and both groups showed a similar degree of cost of concurrency. We can assume that practice  
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12 of one task may have reduced the resources required for that particular task; however, this may not  
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14 have affected the co-ordinator. The lack of group effect cannot be easily attributed to lack of power,  
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16 as both groups showed a significant decline of performance during dual tasks, underlying a reduced  
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18 sensitivity and a shift toward a more stringent criterion when tasks were performed  
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20 simultaneously. In addition, the Musicians showed a trend suggesting a slightly higher cost of  
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22 concurrency (i.e. overall cost 15%) than Nonmusicians (i.e. 10%), in contrast to the practice  
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24 advantage hypothesis. Therefore, our findings suggest that the level of task expertise has little  
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26 effect, if any, on the co-ordination function during dual tasks, implying that the role of the central  
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28 executive during dual tasking is also impermeable to very intensive training and life-long  
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30 experience, combined with musical skills predisposition.  
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36 It should, however, be considered whether a similar degree of decrement in performance  
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38 across the two groups could hide a different combinations of task decrement in each group. In other  
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40 words, it may be possible that differential expertise may have led to a different way of organising  
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42 the co-ordination of task specific resources. Two sources of data suggest that this is unlikely. First,  
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44 both groups showed a similar modulation of the criterion during single and dual tasks, indicating a  
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46 similar approach and co-ordination of resources. Second, both groups showed a significant (and  
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48 similar) higher decrement during the VPT-Dis than VPT-Enc. The discrimination phase of the  
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50 musical task had the strongest impact on the secondary task. This is in line with previous studies  
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52 showing higher dual task cost during the memory retrieval phase than encoding phase (Della Sala et  
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54 al., 2010a). This could be due to a higher co-ordination demand when both tasks required a  
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56 response (Logie, 2016). Whatever the reason for a higher dual task concurrency during VPT-Dis,  
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3 the important aspect is that both groups showed a similar pattern of data. Results from the signal  
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5 detection measures also suggest a similar performance profile across the two groups. Despite the  
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7 fact that Musicians showed a lower sensitivity, probably due to the higher difficulty of their musical  
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9 task, the sensitivity decreased similarly and consistently during dual tasks in both groups. In  
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11 addition, the criterion became more stringent when participants were asked to perform the dual task  
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13 compared to single task. These findings seem in line with the hypothesis of relatively stable  
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15 organisation of the co-ordination process regardless of long-life experience, both groups adopted  
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17 the same ‘strategy’ in term of criterion and showed similar reduced sensitivity.  
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22 The weak role of practice/expertise in reducing dual task decrement is in line with the  
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24 ‘difficulty insensitivity’ of dual task (Wickens, Sandry, & Vidulich, 1983). Indeed, Wickens (1976)  
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26 showed that easier tasks (e.g., maintaining constant pressure on a stick during a visual motor task)  
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28 could be more deleterious than tasks perceived as more difficult (e.g. detecting an auditory  
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30 stimulus). In another study, Logie et al. (2004) modulated the difficulty of each task (by  
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32 decreasing/increasing the number of digits to remember or the speed of a visual tracking task). The  
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34 authors observed no impact of task difficulty on dual task performance. These findings, together  
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36 with the lack of practice effect suggest that people do not have a single supply of undifferentiated  
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38 resources, but multiple pools of attentional resources. Of course, if two tasks require the same  
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40 resource, or part of it (overlapping), a dual task cost would instead reflect the cost of sharing the  
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42 same attentional pool. Thus the specific tasks to be combined may determine the dual task cost  
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44 rather than the overall cognitive demand (Baddeley & Logie, 1999; Cocchini et al., 2002; Farmer,  
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46 Berman, & Fletcher, 1986; Logie et al., 2004; Logie, Zucco & Baddeley, 1990; Wickens & Yeh,  
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48 1983). Interestingly, expertise in music can be achieved by means of different learning methods that  
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50 can capitalise on different combinations of share/unshared attentional resources. For instance, some  
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52 musicians rely on score reading more than others (such as jazz musicians). This may be an  
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54 interesting aspects to explore for future studies.  
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3 To conclude, even when testing tasks that pertain to experts' area of skill, we found i) a  
4 relatively limited overall dual task cost; ii) a similar degree of concurrency across groups and iii) a  
5 qualitative similar co-ordination process of task resources regardless participants' expertise. These  
6 findings are in line with the hypothesis that when two tasks require little (if any) overlap of  
7 resources, dual task cost reflects the cost of a separate cognitive function required to co-ordinate  
8 task specific resources, and task specific expertise does not affect the degree of efficiency nor the  
9 way how specific task resources are co-ordinated.  
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**Figure Captions**

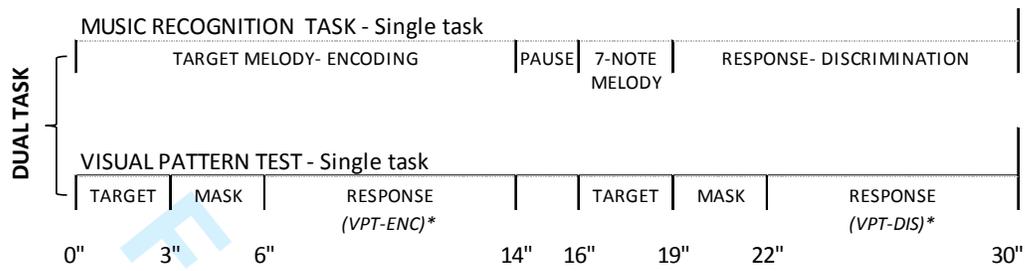
Figure 1. Single and Dual task paradigms

Figure 2. Target melody with 7-note samples for ID, SC and DC types of trials

Figure 3. Averages (SDs) of VPT-Enc and VPT\_Dis dual task cost for Musicians and Nonmusicians

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Figure 1. Single and Dual task paradigms



\* Relevant for Dual task only

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Figure 2. Target melody with 7-note samples for ID, SC and DC types of trials

### Target Melody



### ID



### SC



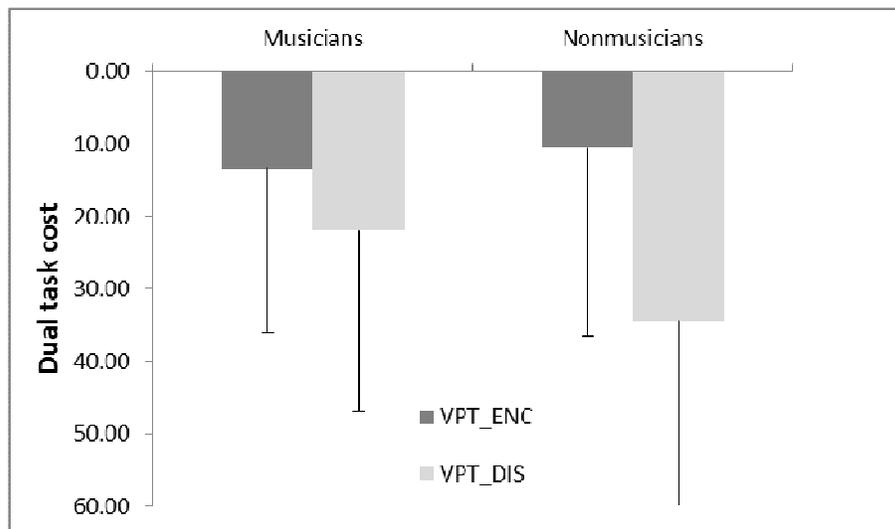
### DC



Circles indicate change of notes in SC and DC conditions.

only

Figure 3. Averages (SDs) of VPT-Enc and VPT\_Dis dual task cost for Musicians and Nonmusicians



**Table 1. Mean percentages (SDs) of correct responses on the Visual Pattern Task**

	<b>VISUAL PATTERN TASK</b>		
	<b>Single task</b>	<b>Dual-Enc</b>	<b>Dual-Dis</b>
<b>Musicians</b>	80.93 (10.0)	70.81 (21.5)	64.44 (25.0)
<b>Nonmusicians</b>	80.0 (10.3)	71.3 (21.0)	52.94 (22.3)

**Table 2. Mean percentages (SDs) of correct responses on the Music Recognition Task**

	<b>MUSIC RECOGNITION TASK</b>	
	<b>Single task</b>	<b>Dual task</b>
	<i>ID&amp;SC</i>	
<b>Musicians</b>	76.7 (11.9)	66.7 (17.5)
	<i>ID&amp;DC</i>	
<b>Nonmusicians</b>	80.6 (13.4)	78.2 (14.2)

Table 3. Average (SD) sensitivity ( $d'$ ) and criterion ( $\beta$ ) values for Musician and Nonmusician groups

	<u>SENSITIVITY (<math>d'</math>)</u>		<u>CRITERION (<math>\beta</math>)</u>	
	Single task	Dual task	Single task	Dual task
<b>Musicians</b>	1.40 (.65)	.96 (.96)	1.65 (.59)	1.22 (.47)
<b>Nonmusicians</b>	1.72 (.69)	1.56 (.79)	1.43 (.58)	1.18 (.41)