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The Effects of Speech Production and Music Familiarity on Piano Performance: A Dual-Task Experiment

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ABSTRACT

This study investigated the effects of performing different speech tasks while playing unfamiliar or familiar piano pieces on the efficiency in performing each of these tasks. Participants gave unfamiliar or familiar performances of four short piano pieces, which refer to performances before and after practice. Participants performed a piece remaining silent in the control condition. While performing the remaining pieces, participants had to either answer a question in prose, or name words based on category (semantics) or rhyming sounds (phonetics). A control speech task was also conducted where participants spoke without playing. Music production efficiency and speech production efficiency were measured. The former included performance duration and musical error frequency; the latter word rate and filler word ratio. Familiarisation of a piece resulted in a higher music production efficiency, characterised by a shorter duration and fewer errors, but did not affect speech production efficiency, which instead varied according to the task, with the prose task yielding the highest word rate and lowest filler word ratio. Semantic naming also had a higher word rate than phonetic naming. These results suggest a task-specific facilitation effect of familiarisation on multitasking, which may be investigated with better controlled research in future.

INTRODUCTION

It is a common experience among musicians to find it difficult to play an instrument and hold a conversation simultaneously. Even while playing instruments which do not require mouth movements, such as the piano, one may find it difficult to speak. The most plausible explanation for this phenomenon is the division of attention between playing an instrument and verbal communication. Playing a musical instrument requires efficient interactions of vision, audition and motion (Zatorre, Chen & Penhune, 2007). Speech production, the utterance of articulated words, is also a complex process involving hearing, perception, information processing, and contraction of the vocal tract (Docio-Fernandez & Mateo, 2015). Speaking while playing an instrument falls within the definition of multitasking, which includes when a person attempts to perform two tasks simultaneously (American Psychological Association, 2006). According to the Attentional Load Hypothesis of the competition of attention, the competition of a representation depends on its representational strength and processing load (Rapp & Hendel, 2003). Therefore, the more salient and difficult an activity is, the more cognitive resource it will be allocated with. With instrument-playing and speaking both being complex and non-automatic processes, it is possible that when an individual is attending to one activity, very little cognitive resource remains available for the other activity, which would explain the difficulty in speaking and playing simultaneously.

It has been shown in psychological research that, for multitasking in general, the competition for cognitive resources ultimately leads to a reduction of productivity and increase in error rates in both tasks. The time required to perform two tasks simultaneously usually exceeds the time required when the tasks are separate (Rogers & Monsell, 1995), implying a decrease of efficiency in both tasks, possibly due to the effort required in "mentally juggling", or switching focus between tasks. The extent to which one task interferes with the other can be measured in terms of error rates and productivity levels. A study where participants had to press a button when hearing or seeing a target word which fits a rule, demonstrated through reaction time differences that participants showed a greater ability to divide attention between stimuli simultaneously presented to two sensory systems, vision and audition, than stimuli presented to a single sensory system (Treisman & Davies, 2012). Nonetheless, divided attention always led to a lower efficiency than focused attention. These results strongly supported the theory that efficiency in performing two different tasks is limited by both modality-specific and integrated attentional capacities, since multitasking between seeing and hearing worsened performance but was still more efficient than within-modality multitasking. However, it remains unclear whether this can be generalised to more complex tasks which involve more than one modality, such as music production.

Limited research could be found which focuses specifically on the dual-task of musical performance and speech. In one study which addressed this topic most closely, participants shadowed an aurally presented prose passage while sight-reading piano music (Allport, Antonis & Reynolds, 1972). Their efficiency in both tasks were measured in terms of the mean number of errors. This dual-task performance was rather unchallenging for the participants, as results showed little effect of divided attention on error rates. In other words, auditory speech shadowing and sight-reading on the piano could be performed simultaneously with a mostly maintained efficiency. This study effectively proved the possibility to multitask piano-playing and speech with no deterioration in performance. However, this study focused on refuting the "central bottleneck" hypothesis of attention and did not investigate the extent to which effective multitasking between the tasks was possible, or the task characteristics which may affect multitasking efficiency. In this study, a variation was briefly noted in subjects' ability to process prose passages semantically, which the authors suggested may depend on piano skills. While this observation was not elaborated upon, it hints that semantic processing of speech, as opposed to shadowing it, could increase the difficulty to perform the dual-task and worsen performance. The greater difficulty in processing speech semantically is possibly due to the larger amount of attention required to process the meaning in addition to the sounds of speech. According to research on depths of processing, a conception that the processing of perceptions exists in a hierarchy of stages (Craik & Lockhart, 1972), phonetic processing of a stimulus precedes semantic or cognitive processing, and thus is less "deep" and requires less cognitive resource. This is supported by research showing that semantic processing of speech activates more brain areas than phonetic processing (Demonet et al., 1992). Since understanding the meaning of speech is more cognitively taxing than judging the sounds of speech, it would require more attention and therefore would be more challenging in divided attention. How different types of speech processing affect speech-music dual-task is unclear in existing literature. The present study compared the efficiency of multitasking piano playing with three different speech tasks, namely phonetic naming, semantic naming and prose, to study the effects different speech tasks had on speech-music dual-task. Semantic naming was hypothesised to result in the lowest performance efficiency since it specifically focused on the meaning of words, which required a greater attention to process.

The effort required for music production may also play a part in the efficiency of speech-music dual-task performance, as implied by the larger attentional competition of difficult and salient tasks (Rapp & Hendel, 2003). In contrast to this, however, no significant effect was found in performance between using Grade II and Grade IV sight-reading pieces in the dual-task study mentioned above (Allport, Antonis & Reynolds, 1972). The lack of effect could be explained that the participants, as undergraduate music students, might have found the pieces rather easy to play. The small sample size of five could also have led to a slight effect being rendered insignificant in analysis. The grade level of a sight-reading piece may not be an accurate depiction of its perceived difficulty, since participants vary in piano skills. More proficient pianists, for instance, may find little difference in difficulty between lower-grade pieces. The present study varied difficulty by the familiarity of the piece, which determines the effort required to perform it. The relationship between familiarity and musical performance was delineated by Doğantan-Dack (2013), who summarised that familiarity allows for the automatization of many steps of information-processing and -retrieval, thus facilitating the achievement of cognitive tasks. In other words, the amount of cognitive effort required to understand and make decisions about a piece of music decreases as one familiarises oneself with it. Therefore, it is reasonable to hypothesise that when one familiarises oneself with a piece of music through practice, one should not only play better, but also be more efficient in multitasking while performing, including producing speech while playing.

METHODS

Participants. 6 Durham University students (5 females; 1 male) aged 21 – 27 years (M = 21.50, SD = 2.74) were recruited from the Psychology of Music lecture group and from Trevelyan College, with an inclusion criterion that they were able to read music and play the piano. All levels were welcomed. Participants' musical abilities were assessed using the Goldsmiths Musical Sophistication Index (Gold-MSI; Mullensiefen, Gingras, Musil & Stewart, 2014). All participants have had more than 10 years of formal training on the piano, which was their major instrument. On average, participants spent 77.50 minutes per day (SD = 47.83) listening to music. All participants gave informed consent to take part and approval for audio recording of their performances.

Materials. Four short pieces were extracted from the Specimen Sight-Reading Tests of Grade 7 Piano Examinations (ABRSM, 2008). To control for stimuli characteristics, selection was based on length and time signature. Pieces with a compound or odd meter were excluded; those with a similar length were then selected. Each of the final pieces consisted of 12 or 13 bars and had a 2/4 or a 3/4 meter. Titles of the pieces had been digitally removed to prevent interference with the speech tasks. The four pieces were presented to participants in a randomized order. A copy of the sheet music used is attached in the Appendix.

Table 1. *Details of the speech task which participants had to perform during piano performance in each condition*

Condition	Control	Prose	Semantic naming	Phonetic naming
Speech task	-	Answering a question in full sentences	Naming words which fall into a category	Naming words which rhyme with a word cue
Cues*	-	"What were you doing before this and how did you get here?" "What are you planning to do after this and where will you go?" "What is your favourite pastime and why?"	Colours Animals Sports	Tea Play Ate
Example answer	-	"So my favourite pastime is reading fiction books, especially crime fiction books because …"	"Red, blue, pink …"	"Bee, flee, me …"

*Each participant answered all three cues in each speech task condition in a random order across the control speech test and the unfamiliar and familiar performances.

Design. This is a within-subject design, where each participant took part in all conditions. Independent variables were the familiarity of music (with two levels: *familiar* and *unfamiliar*) and speech task (with four levels: *control*, *prose, semantic naming*, and *phonetic naming*). In the *unfamiliar* conditions, participants sight-read a piece on the piano after 30 seconds of preparation, whereas the *familiar* conditions referred to performances after practising the piece until confident to play. Regarding speech tasks, participants remained silent during their performance in the *control* condition. In *prose*, they were asked to answer a simple question in full sentences throughout their performance. In *semantic naming*, participants had to name as many words that fall into a category as they could, while in *phonetic naming,* they named words which rhymed with a word cue. The cues used are displayed in Table 1. Speech tasks were allocated to pieces in a pseudo-randomized order to counterbalance any influence which variations between pieces might have on speech, and vice versa.

Procedure. The experiment sessions took place in a practice room in the Music Department at Durham University. Participants first took part in the *control* speech task condition, where they were given 30 seconds to prepare for one piece, which they were then asked to play as smoothly as possible. Familiarisation then took place, where participants practised the same piece with no time limit, until confident and comfortable in playing it. The average duration of familiarisation was less than 7 minutes (*M* = 377.92s, *SD* = 329.74s). After familiarisation with the piece, participants performed it again.

The *prose, semantic naming* and *phonetic naming* follow, in a randomized order to balance out any effects of practice or fatigue on performance. The procedure of these conditions is similar to the *control*, with an additional speech task during piano performance. Participants were asked to name words or answer a question during both their *unfamiliar* and *familiar* performances (See Table 1). A control speech test was conducted at the start of each speech task condition, where participants spoke for one minute in the manner of that condition (e.g. answering a question for one minute in the *prose* condition). For speech tasks during performance, the word cue or question was presented immediately before the participant started playing. Finally, participants answered questions in the Gold-MSI (Mullensiefen et al., 2014) related to musical abilities. Age and gender were also noted.

The whole duration of the experiment was recorded. The experimenter subsequently encoded each participant's performance in terms of their music production efficiency and speech production efficiency in each condition. Assessments of music production efficiency included the duration of, and the number of mistakes made, characterised by wrong notes, in each performance. Speech production efficiency included the number of meaningful words uttered per minute (henceforth referred to as *word rate*) and the percentage of filler words in speech (henceforth referred to as *filler word ratio*). Filler words are defined in the present study as any apparently meaningless words, phrases, or sounds uttered during hesitations in speech, such as "um" and "like".

RESULTS

Participants' music production efficiency will first be described, in terms of performance duration and music error frequency. Regarding duration, participants across conditions took an average of 51.40 seconds (*SD* = 23.91) to play a single piece.

A 4 (speech task) x 2 (familiarity) repeated-measures ANOVA was conducted to compare the mean duration of *unfamiliar* and *familiar* performances across speech task conditions (Figure 1). Familiarity had a significant effect on duration, F (1,5) = 24.651, p = .004, η^2_p = .831. Post-hoc tests using the Bonferroni correction showed a significant decrease in duration from *unfamiliar* trials (*M* = 58.88, *SD* = 26.85) to *familiar* trials (*M* = 43.92, *SD* = 18.19), indicating that participants performed faster after familiarisation in general. Paired-samples t-tests conducted within each speech task condition revealed a significant post-familiarisation decrease in duration in *control*, t (5) = 3.560, p = .016*, semantic*, t (5) = 2.968, p = .031, and *phonetic* conditions, t (5) = 3.352, p = .020. In the *prose* condition, the decrease was also marginally significant, t (5) = 2.514, p = .054. The ANOVA showed no significant effects of speech task, F (3,15) = 2.892, p = .070, nor any interaction effect between speech task and familiarity, F (3,15) = 2.033, p = .152. Figure 1 seems to hint a longer performance duration in *phonetic* and *semantic* conditions than in *control*, however these effects are not statistically significant, possibly due to large between-subject variations.

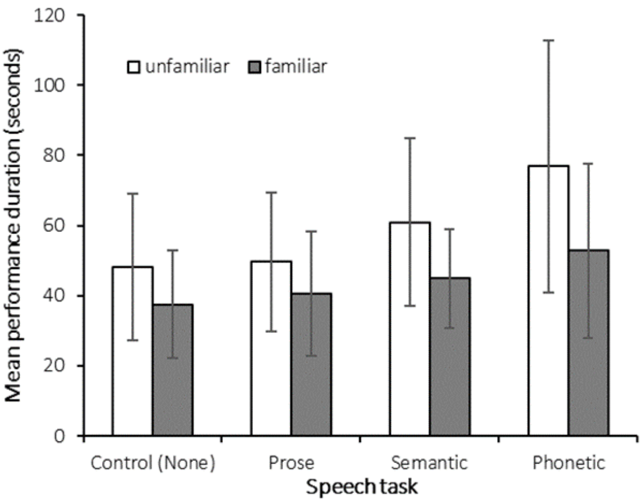

Figure 1. The mean amount of time (in seconds) participants took to perform one musical piece before and after familiarisation in each speech task condition. Error bars are standard deviations.

Another assessment of music production efficiency was the number of mistakes made during the performance of a piece. Error frequency is used for analysis instead of error rate (number of errors per minute) to avoid confounding effects of performance tempo. Since the pieces had a controlled number of bars (See *Materials*), the lengths of pieces should have little effect on error frequency. Any effect of piece characteristics would also have been counterbalanced by the random allocation of speech tasks to the pieces.

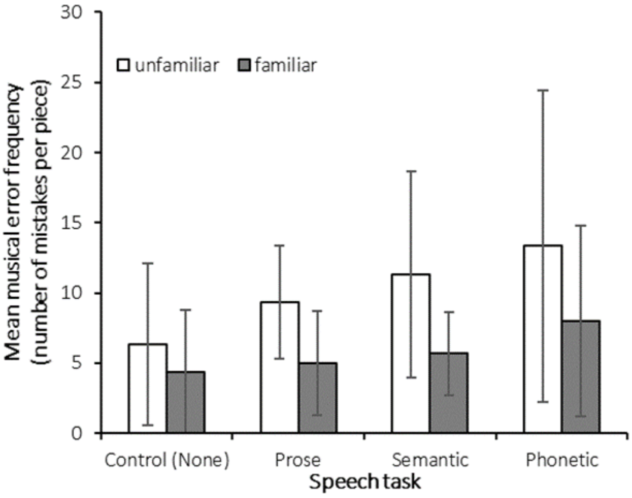

Figure 2. The mean number of musical errors participants made during performance of a piece before and after familiarisation in each speech task condition. Error bars are standard deviations.

On average, participants made 7.92 (*SD* = 6.54) musical errors in a single performance. A 4 (speech task) x 2 (familiarity) ANOVA was conducted to compare the mean error frequency across conditions (Figure 2). There was a significant effect of familiarity on error frequency, *F* (1,5) = 225.333, *p* = .007, η^2_p = .797, where error frequency decreased from *unfamiliar* trials (*M* = 10.08, *SD* = 7.50) to *familiar* trials (*M* = 5.75, *SD* = 4.61), indicating fewer mistakes after familiarisation. Paired-samples t-tests revealed a significant post-familiarisation decrease in error frequency in the *prose*, *t* (5) = 5.139, *p* = .004, and *semantic* conditions, *t* (5) = 2.751, *p* = .040. There was also a marginally significant decrease in the *phonetic* condition, *t* (5) = 2.530, *p* = .053. The effect in *control* was not significant, *t* (5) = 1.549, *p* = .182. There were no significant effects of speech task, *F* (3,15) = 1.654, *p* = .219, nor any interaction effects, *F* (3,15) = 1.136, *p* = .366. Figure 2 seems to indicate a larger error frequency in conditions with speech tasks as compared to the *control*, however these are not statistically significant.

Speech production efficiency was measured in terms of word rate and filler word ratio. In baseline measure via the control speech test, the *prose* speech task yielded a significantly higher word rate (*M* = 109.83, *SD* = 31.24) than the *semantic* task (*M* = 20.50, *SD* = 10.33), *p* < .001, and the *phonetic* task (*M* = 12.17, *SD* = 4.17), *p* < .001. The mean word rate in the *semantic* task was also significantly higher than *phonetic*, *p* = .045. As for filler word ratio, the *prose* task showed a significantly smaller percentage (*M* = 7.54, *SD* = 4.15) than *semantic* (*M* = 36.76, *SD* = 11.05), *p* < .001, and *phonetic* (*M* = 36.23, *SD* = 16.71), *p* = .006. However, there was no difference between *semantic* and *phonetic* tasks.

A 3 (speech task) x 3 (familiarity) repeated-measures ANOVA was conducted to compare the mean word rate across conditions (Figure 3). There was a significant effect of speech task on word rate, *F* (1.008,5.042) = 41.724, *p* = .001, η^2_p = .893. Post-hoc tests (Bonferroni) showed that the *prose* task yielded the highest mean word rate (*M* = 83.90, *SD* = 40.00), which was significantly higher than that in the *semantic* task (*M* = 15.55, *SD* = 8.61), *p* = .004, and that in the *phonetic* task (*M* = 7.00, *SD* = 4.77), *p* = .004. The mean word rate was also significantly higher in the *semantic* than in the *phonetic* task, *p* = .011. On the other hand, there was a significant effect of familiarity on word rate, *F* (2,10) = 7.509, *p* = .010, η^2_p = .600. The word rate in the *control* speech test (*M* = 47.50, *SD* = 48.92) was significantly higher than that during the *unfamiliar* performance (*M* = 27.68, *SD* = 38.60), *p* = .020, but not that during the *familiar* performance (*M* = 31.28, *SD* = 36.60), *p* = .166. There was no significant difference between *unfamiliar* and *familiar* trials, *p* = 1.000, nor any interaction effects between speech task and familiarity, *F* (1.942,9.712) = 2.620, *p* = .124. However, comparing mean word rates between *control, unfamiliar* and *familiar* performances via one-way repeated measures ANOVA within each speech task condition, there was a significant effect of familiarity in the *phonetic* condition, *F* (2,10) = 33.522, *p* < .001, η^2_p = .870, and in the *prose* condition, *F* (2,10) = 4.294, *p* = .045, η^2_p = .462. In *phonetic* naming, participants had a higher word rate in the *control* test (*M* = 12.17, *SD* = 4.17) than during the *unfamiliar* performance (*M* = 3.95, *SD* = 1.79), *p* = .007, and during the *familiar* performance (*M* = 4.89, *SD* = 2.90), *p* = .001. In *prose*, no simple effect was shown with the Bonferroni adjustment for multiple comparisons, despite a significant main effect. However, adopting the LSD adjustment, mean word rate was significantly higher in the *control* test than in during *unfamiliar* performance, *p* = .041.

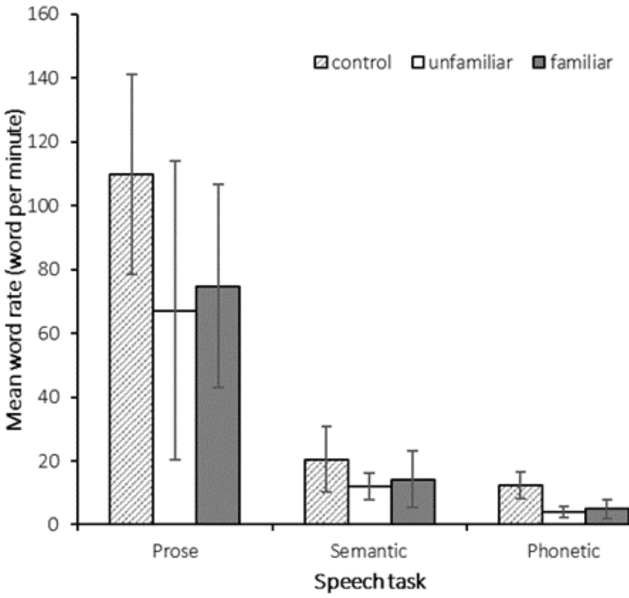

Figure 3. The mean number of meaningful words participants spoke per minute in each speech task condition, in the control speech test and during performance before and after familiarisation. Error bars are standard deviations.

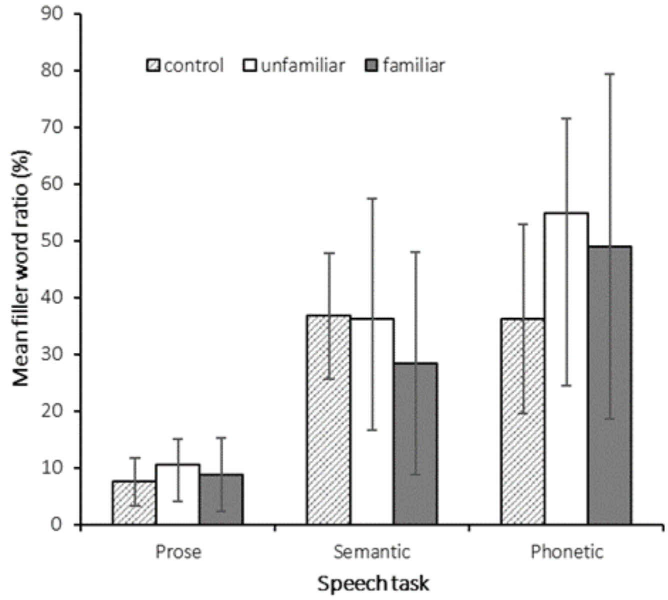

Figure 4. The mean percentage of filler words participants uttered in their speech in each speech task condition, in the control speech test and during performance before and after familiarisation. Error bars are standard deviations.

The last variable was filler word ratio (Figure 4), another indicator of music production efficiency. This was analysed similarly to word rates. There was a significant effect of speech task on filler word ratio, F (1.061,5.307) = 23.320, p = .004, η^2_p = .823. The *prose* task yielded the smallest filler word ratio (M = 8.93, SD = 4.96), which was significantly smaller than that in the *semantic* task (M = 33.80, SD = 17.27), p = .024, and that in the *phonetic* task (M = 46.71, SD = 22.37), p = .012. There was no significant difference between the two naming tasks. The main effect of familiarity on filler word ratio was not significant, F (2,10) = 1.600, p = .250, nor was the interaction effect, F (4,20) = 2.300, p = .094.

DISCUSSION

In summary of the results, familiarisation of a piece resulted in higher music production efficiency, characterised by a shorter performance duration and a smaller number of musical errors made. While the decrease in duration was found in all speech task conditions, the reduction of errors was only found in the conditions consisting of a speech task, but not *control*. Although participants played slower in silence when unfamiliar with the piece, they made around as many mistakes as they would after familiarisation. While multitasking, however, unfamiliarity resulted in not only a slower performance, but also more mistakes. Participants were possibly more cautious in playing an unfamiliar piece by reducing the speed and consciously avoiding mistakes when they had undivided attention on sight-reading, yet while simultaneously performing a speech task, monitoring for mistakes may have become a more straining task despite a slower tempo. It is important to note that although the difference in error frequency between *unfamiliar* and *familiar* control performances was not statistically significant, there was still a slight decrease after familiarisation, which may become significant with a larger sample or with a smaller between-subject variation in sight-reading skills.

Speech production efficiency varied according to speech tasks. Speaking in prose yielded the highest word rate, followed by *semantic* naming, then *phonetic* naming. Filler word ratio was lowest in *prose*, while that between *semantic* and *phonetic* naming tasks was similar. It is easily imaginable that speaking in prose would result in a greater quantity and fluency of speech than word-naming tasks, due to the limit on the type of words one can speak in the latter. Comparing *semantic* and *phonetic* naming, it is evident from word rate differences that it was generally easier to name words based on semantics than based on sound. The difficulty to name rhyming words may possibly be related to interference with sound processing while performing music. However, it is more likely that naming rhyming words is harder to begin with, as illustrated by a lower word rate than *semantic* naming in control speech tasks. Unlike music production efficiency, familiarisation with a piece had no effect on speech production efficiency. While participants spoke more in the *control* speech task than during some performances, particularly in the *prose* and *phonetic* conditions, there was no difference in word rate between *unfamiliar* and *familiar* performances, or any differences in filler word ratio.

The results that familiarisation led to a faster and more accurate performance match the hypothesis that familiarity would lead to a higher efficiency in music performance. While previous research has shown it was possible to maintain a normal efficiency in multitasking between piano performance and shadowing a prose passage (Allport et al., 1972), it is evident from the present study that the efficiency in performing music could vary with the effort required to perform it, as demonstrated by the lower music production efficiency in *unfamiliar* performances. This efficiency also varies slightly with the effort required to carry out the other task performed simultaneously, which was the speech task in the present study. Although the effect of speech task on music production efficiency was not statistically significant, there was an apparent difference between tasks, where *phonetic naming* resulted in a lower music production efficiency than *semantic naming*, followed by *prose* (See Figures 2 and 3). Combined with the results on speech production efficiency that the *phonetic* task was more challenging to perform than the *semantic* task and the *prose* task, it is possible that participants performed less efficiently while simultaneously performing more challenging speech tasks. In support of this, it is worthy to note that casual interviews with participants at the end of experiment sessions also showed that most participants found the *phonetic* task the most difficult to multitask.

The result that the naming of rhyming words was less efficient than categorical words went against the hypothesis that semantic naming would have the greatest effect on speech production efficiency. This may be due to the differences between perceiving words and producing words based on sound. In the production of naming words which rhyme with a certain word cue, participants first had to come up with a word-like sound, then evaluate whether or not it is a word. This implies that some semantic processing of words, as well as an internal monitoring process which possibly involves behavioural inhibition, had to take place to allow for correct naming of rhyming words. These processes are not required in the perception or discrimination of word sounds from passive stimuli, since only the evaluation of sound would be required. Previous studies demonstrating a lesser difficulty in phonetic speech processing did not differentiate between words and non-words (Treisman & Davies, 2012), or require any monitoring or semantic processing of speech (Allport et al., 1972). Asking participants to produce rhyming words, therefore, may in fact be a cognitively taxing task which required no less effort, if not more, than naming categorical words.

One unexpected result was that familiarisation did not result in a higher speech production efficiency, despite a higher music production efficiency. It was expected that while piano playing became automatized, a smaller amount of cognitive resource would be required to perform the pieces, hence a greater proportion of one's integrated attentional capacity could be allocated towards speech production. This does not seem true, as practising the pieces had no effect on speech performance. Familiarisation seemed only to lead to a higher efficiency in performing the task which was being familiarised, but had no effect on the task performed simultaneously. While it is possible that participants in the present study had not practised the pieces enough for automatization, it is also possible that the facilitation effects of familiarisation are modality or task-specific. It would be of interest to study whether this was true in future research, by examining whether familiarisation of speech, for example through reciting a short paragraph, would lead to a higher speech production efficiency but not a higher music production efficiency in a music-speech dual-task paradigm.

It is important to note the present study's limitations in terms of the sample. The small sample size of 6 may be insufficient to demonstrate the finer effects of multitasking. The musical abilities of participants were also not controlled for, due to anticipation of the difficulty in recruitment. This implied large individual differences in performance, which may similarly render fine effects insignificant. It may be more appropriate to recruit a sample with similar musical skills in future research.

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APPENDIX

Sheet Music of the Sight-Reading Pieces Used in the Present Study

The sheet music used in the present study was extracted from the Specimen Sight-Reading Tests of Grade 7 Piano Examinations (ABRSM, 2008). The title and number of each piece was digitally removed before the experiment, as shown below.

Piece 1. Piece 1 in the Specimen, named *Prelude*

Piece 2. Piece 7 in the Specimen, named *Minuet*

Piece 3. Piece 9 in the Specimen, named *Mouse in the House*

Piece 4. Piece 21 in the Specimen, named *Diamond Minuet*