Abstract

We report two experiments exploring whether imagining music improves spatial rotation via increases in arousal and mood levels (Schellenberg, 2005). To aid their imagination, participants were given instructions (none, basic or detailed) and lyrics (present or absent). Experiment 1 showed no effect of instructions or lyrics on performance although participants felt that the presence of the lyrics helped. Experiment 2 was identical to Experiment 1 except that the participants were musicians (as evidenced by musical experience and/or qualification). This time there was a significant effect of instructions in that those who received the detailed instructions performed significantly better than the no instruction condition although the presence of lyrics did not help. Further research is required to establish the similarity of the imagination to the traditional arousal and mood effect but the phenomenon may be useful for short-term boosts in spatial rotation activities.

142 words

Music is intricately entwined with human culture as evidenced by the use of our vocal apparatus and instruments dating back thousands of years (Brown, Merker, & Wallin, 2000). In more recent times, music has been shown to have a variety of effects on our behaviour. For example, in the area of retail, fast-tempo background music increases customers' positive mood and the number of items they buy (Milliman, 1982) as well as producing a faster waiter service (Milliman, 1986). This tempo of music also results in faster driving speed and a greater number of traffic violations (Brodsky, 2002). Amongst teenagers, exposure to sexual content in music is associated with greater sexual activity and risk of engaging in early sexual intercourse (Brown, L'Engle, Pardun, Guo, Kenneavy, & Jackson, 2006). On a more positive note, listening to an excerpt of Vivaldi's 'Four Seasons' led to a positive outcome on older adults' working memory (Mammarella et al. 2007), Alzheimer's patients who listened to Vivaldi's 'Spring Movement' showed an increase in autobiographical memories (Irish et al. 2006) and cancer patients' mood improved from listening to music (Cassileth, Vickers, & McGill, 2003). However, recent research shows that concurrent listening to music and task engagement is detrimental to performance as it produces the irrelevant sound effect – the reduction in short-term memory performance in the presence of background sound (Perham & Sykora, 2012; Perham & Vizard, 2010).

Perhaps the most famous example of the impact of music on human behaviour gained prominence in the early 1990s with the publication of Rauscher, Shaw, and Ky's (1993) paper in the prestigious science journal, *Nature*. They observed that participants' spatial awareness abilities (as measured by the paper folding and cutting task) was better when participants had been listening to Mozart's Sonata for Two Pianos in D Major (K.488) for ten minutes compared to listening to a relaxation tape or sitting in silence, although the effects only lasted for ten to fifteen minutes. The increase in performance on the spatial awareness task was explained at the time by the already-founded trion model of cerebral cortex (Leng & Shaw, 1991). This stated that the process of listening to music created a pattern of firing neurons that was similar to the pattern created when performing spatial-temporal tasks (Jones et al., 2006). It was thought that listening to Mozart activated this neural pattern, and so the neurons were already firing when participants started their spatial reasoning task which caused an increase in performance. However, as Husain et al. (2002) later pointed out, this priming explanation was fundamentally flawed in that priming tended to happen when both stimuli were related – such as facilitatory recall of the colour word "red" whilst having been presented with the word "blood" compared to having been presented with the word "snow". Further, the similarity between either the content or processing of the spatial awareness task and the music itself is currently unspecified. A meta-analysis of other studies exploring the Mozart effect revealed little evidence for it (Chabris et al., 1999). Later, Schellenberg and colleagues proposed the arousal-and-mood hypothesis based on an increase in the participant's mood and arousal levels due to listening to music that they prefer. For example, spatial rotation performance increased following listening to Schubert (Nantais & Schellenberg, 1999) and, in children, listening to more contemporary music like Blur (Schellenberg & Hallam, 2005). Interestingly, the increase was not restricted to music as participants who preferred listening to a narrated Stephen King story revealed a 'Stephen King effect' (Nantais & Schellenberg, 1999).

As well as actively listening to music, humans also *hear* or imagine music in their minds. In some instances this music can become quite annoying as sometimes they become 'stuck' – known as 'earworms' (Beaman, 2010). Further, research has shown that the auditory cortex, which is activated through hearing music, can also be activated through just imagining it (King, 2006). Given our ability to imagine music, would it be possible to elicit the mood and arousal effect purely by imagining music? The importance of such a curious finding relates to the possibility of increasing one's spatial awareness abilities, if only for a short period of time, which could benefit examination or work performance.

It is known that the imagination of a motor action produces a similar activation of the autonomic nervous system (ANS) as the real action when measuring skin conductance responses (Critchley et al., 2000; Deschaumes-Molinaro et al., 1991; Roure et al., 1998). For example, actual participation in shooting competitions and the mental rehearsal of the same task elicits similar changes skin temperature, conductance and blood flow (Deschaumes-Molinaro et al., 1991). Similarly, other research has found that the same autonomic channels were being used when participants were playing volleyball and when they were mentally imagining the activity (Roure et al., 1998).

Imagery is simply our ability to draw upon perceptual information from our long-term memory, and is often referred to as "seeing with the mind's eye" (Kosslyn et al., 2001). It has played a central role in theories of mental functioning since the time of Plato, with the majority of research into mental imagery mainly concentrated on motor and visual imagery (Smith et al. 1995). However, more recently several studies have assessed the ability of auditory imagery, also known as the "inner ear" or the "inner voice" (Aleman et al., 2000). The ability of auditory imagery is the subjective experience of hearing in the absence of external auditory stimulation, in other words hearing in the absence of sound. Auditory imagery appears in a variety of forms such as silent reading, speech perception, auditory hallucinations in schizophrenia and in conversations with spiritual beings, earworms and most relevant to this study, musical imagery (Barrett & Etheridge, 1992; Beaman, 2000; Harley, 2010; Kraemer et al., 2005; Luckoff, 2007; McGuire, Silbersweig, Wright, Murray, Frackowiak, & Frith, 1996).

For example, Kraemer et al. (2005) monitored participants using an fMRI scanner and asked them to passively listen to excerpts of familiar songs such as 'Satisfaction' by The Rolling Stones and The Pink Panther theme tune as well as other less familiar songs. At numerous points throughout the songs, short sections (2 to 5 seconds long) were removed and replaced with silence. During these excerpts of silence, participants' neural activities were monitored, showing greater activation in the auditory cortex during the gaps of silence in familiar songs than non-familiar songs. Further evidence that the auditory cortex was activated in the absence of an external auditory stimulus was revealed by Halpern and Zatorre, (1999) who asked participants to listen to excerpts of familiar songs and imagine the continuation of the melodies. They found that the right auditory cortex was activated during the imagery period after the musical excerpt.

Given the exploratory nature of the current investigation, we needed to provide every opportunity to observe the effect. To facilitate this, two manipulations were introduced – instructions and lyrics. It has been noted that during mental rehearsal of motor tasks, the greater the quality of the mental rehearsal the greater the chances of an improvement in performance (Deschaumes-Molinaro et al., 1991). We sought to enhance the quality of participants' auditory imagery by providing two levels of instructions. The first set of instructions simply asked the participants to imagine a song that they liked in their head. A second set of instructions built upon this request by giving more detail and help about how to do this such as focusing on the instruments (see Materials and Appendix for more details). The second manipulation focused on the written presence of the lyrics to aid imagery (Bailes, 2007). Thus, it was predicted that more detailed instructions and the presence of written lyrics, either separately or in combination with detailed instructions, would elicit the greatest improvement in spatial awareness performance compared to a control condition in which participants just performed the spatial awareness task without imagining music or the presence of lyrics. In addition to the objective measurement of spatial awareness performance, we were also interested in how well the participants thought the instructions (basic and detailed) helped them to imagine the songs. To do this, a questionnaire was given to participants after the experiment was completed and one question asked "How closely did the imagined song mimic the real song?" for each instruction condition.

Experiment 1

Method

Participants

Forty-five students from a south Wales university participated for course credit with fifteen participants allocated to each of the levels of the between variable. This comprised thirty females and fifteen males, with an age range of 18 to 25.

Design

This study used a mixed design with one between independent variable of instruction type (control condition, basic instructions and detailed instructions) and one within variable of lyrics (lyrics and no lyrics) – lyrics obviously did not apply to the control condition in which no imagination of music took place and was thus absent from the analysis of instruction type and lyrics. Three dependent variables were measured. The first was correct performance (ranging from 0-50) on a spatial rotation task (deciding whether two three-dimensional shapes were identical or not) and was recorded by the researcher. The second was how well the participant perceived their ability to imagine the song in their minds ranging from 0-10. Finally, the third dependent variable was how well the participant thought they did on the spatial rotation task. This score ranged from 0-100%. Half of participants completed the task with lyrics first and no lyrics second and the other half of participants completed the task in the reverse order.

Materials

The computer program PsyCOG (Wyttenbach, 2006) was used to run the spatial awareness task on a Viglen Genie with an Intel Core 2 processor running Windows XP. For each trial the program produced two three-dimensional shapes made up of a series of cubes attached to one another. The overall shapes were either the same as each other or the opposite. On each of these trials one of the shapes would be rotated to 0˚, 30˚, 60˚, 90˚, 120˚, 150˚ or 180˚ - based on Shepard and Metzler's (1971) study.

Participants were required to mentally rotate one of the shapes and decide whether it matched or reflected the second shape by pressing the relative arrow key on the computer keyboard. After the completion of each individual trial PsyCOG provided feedback on their answer by presenting the word 'correct' or 'incorrect'. The program produced 140 trials, of which 40 trials were completed as practice trials and 100 trials were completed as part of the analysed correct responses. Trial presentation was random so it was unknown what proportion of trials contained which degree of rotation and no time-out was required as participants gave responses to all their trials (see Perham & Withey, 2012, for comparable design and materials).

Although music was required for this study, no actual music was played. Participants were told beforehand to arrive on the day of the study with the names of two of their favourite songs and the printed lyrics to one of them (e.g. Pixie Lott – Broken Arrow, Red Hot Chili Peppers – Under The Bridge, Jimi Hendrix – All Along The Watchtower, Ellie Goulding – Your Song; see Appendix for full list). This was their responsibility and if they failed to arrive with these materials they could not participate in the experiment.

Three instruction sheets were created – one for each instruction condition. The control condition instructions informed the participant that they would be completing a spatial rotation task (see Procedure for more detail). The instructions for the basic and detailed instruction conditions differed slightly from the control condition instructions regarding the engagement of the participant in the imagination of music and the completion of a questionnaire. Briefly, the basic instructions just required participants to imagine music they liked whereas the detailed instructions asked participants to think more intensely about the music they were going to imagine, by providing cues to invoke thoughts about the music that they may not have considered beforehand (see Appendix for complete instructions). These varied from cues that addressed the musicality of the song, such as bringing attention to the melody, the instruments used, and the tempo, to more subjective feelings about the music, such as which parts of the song were their favourite, and focusing on how the song made them feel.

Due to the repetitive nature of the study (each participant completed two sets of spatial rotation trials under two conditions), it was possible that arousal increase in the first condition could affect performance during the second condition. To minimise this, a filler task was used, in the form of a word search, which was designed to take participants no more than 5 minutes to complete.

To address the issue of 'knowing' if participants were engaging in the task of auditory imagination, a questionnaire was designed (see Appendix). There were 11 questions of which ten used a 7-point Likert scale and were seeking information on how well the participant felt they had engaged in the task and the impact they felt the instructions and lyrics had on their ability to mentally imagine the song –for example, how well they felt they had imagined the song, how many times they went through the song, and how useful and helpful they felt the lyrics were. Question 8 asked how closely participants thought their auditory imagery of the song mimicked the real song. This question was key to the study as it provided a subjective view on how well participants felt they had imagined the song in relation to the real song. This suggested that the higher they rated their imagery on this question the greater its quality, which should lead to a more improved score on the spatial rotation task. This question was concealed among the other questions to reduce any speculation about the aim of the study. The 11th question was a scale from 0% to 100%, which asked for the participants' subjective opinion on how well they felt they had done. Each participant completed two questionnaires, after each block of spatial rotation trials.

Procedure

All participants, regardless of which condition they were allocated to, were told to try to avoid listening to music just prior to taking part in the experiment to minimise any increases in arousal due to listening to music rather than imagining music that would occur during the experiment. Upon arrival, participants were randomly allocated to one of the three conditions and directed to a small, quiet room/laboratory where they were tested individually or in pairs (facing away from each other and two researchers were present also). Although each participant arrived with two songs of their choice and the lyrics to one of them, only those allocated to the basic or detailed instruction conditions actually used them.

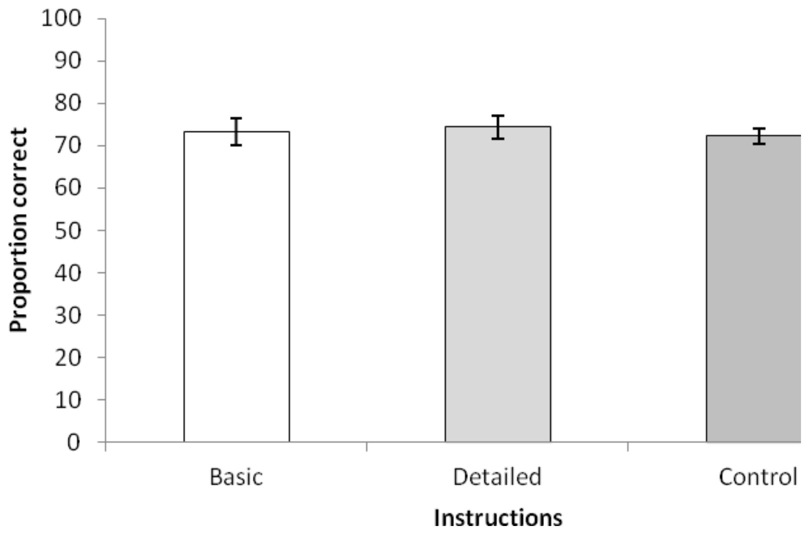
All participants read through the appropriate instructions which informed them that they would complete 40 practice trials of spatial rotation followed by two blocks of 50 trials each. Those in the basic and detailed instructions conditions were additionally told that they would be imagining music and using lyrics to aid them to do this depending upon which condition they were in. Before the experiment started proper, participants completed some demographic information on their response form. In between the practice session and the first experimental block of trials, participants were told to sit in silence for 5 minutes while the researcher waited outside the room. Those in the basic and detailed instruction conditions imagined music whereas those in the control condition were not given any instructions to do anything. Half of these participants were able to use the lyrics they had brought in to help them and the other half were not. Once the 5 minutes was over the experimenter re-entered the room and the participants were asked to start the spatial rotation task. The participants' correct and incorrect answers were recorded on their answer sheet by the researcher (who was seated for enough away from the participant so as not to increase their arousal but close enough to be able to see the responses on the screen) until the participant had completed 50 trials. Next they were told they were being given 5 minutes to complete the word search filler task. This was timed by the researcher who stayed in the room. Prior to commencement of the second block of spatial rotation tasks, those in the control condition were again left alone for 5 minutes and those in the basic and detailed instruction conditions were told to imagine music – once again the researcher left the room. Those had used the lyrics they had brought in for the first block of spatial rotation trials were now unable to use them and those who had not previously used them were now able to.

Results

Data was collected for all 45 participants, and all participants completed 100 trials of the spatial rotation task of which each trial was marked as correct or incorrect, and their overall score represented the total correct trials. Analyses of variance were conducted on these correct scores as well as the question 8 from the questionnaire (How closely did the imagined song mimic the real song?) and participants' subjective estimation of the percentage of trials they correctly solved. Finally, correlations were conducted between objective and subjective scores for the instruction conditions.

Correct Scores

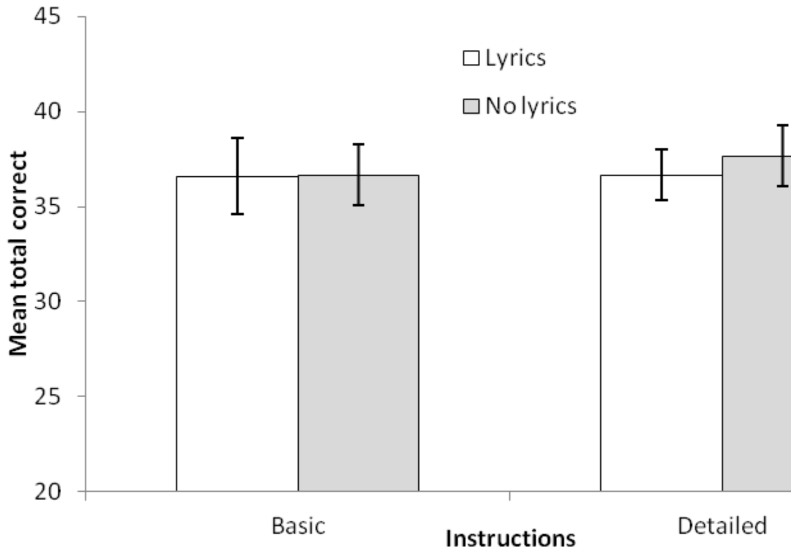
Figure 1. Mean percentage of correct responses for each instruction type (control, basic or detailed)



From Figure 1 it can be seen that the detailed instruction condition had the highest mean overall score. The basic instruction condition scored slightly less on average, followed by the control condition, which scored the lowest in comparison. A one-way between subjects ANOVA revealed that there was no significant effect of instruction type on correct score, $F(2, 42) = .15$, $MSE = 16.02$, $\eta^2 = .01$, $p > .05$.

To explore whether the presence or absence of lyrics interacted with the instruction type, the control condition was removed. Figure 2 shows, for both instruction conditions, that the mean score for the absence of lyrics was greater than the mean score for the presence of lyrics, with the greatest difference in the complex instruction condition.

Figure 2. Mean percentage of correct responses by lyrics (presence or absence) and instruction type (basic or detailed)

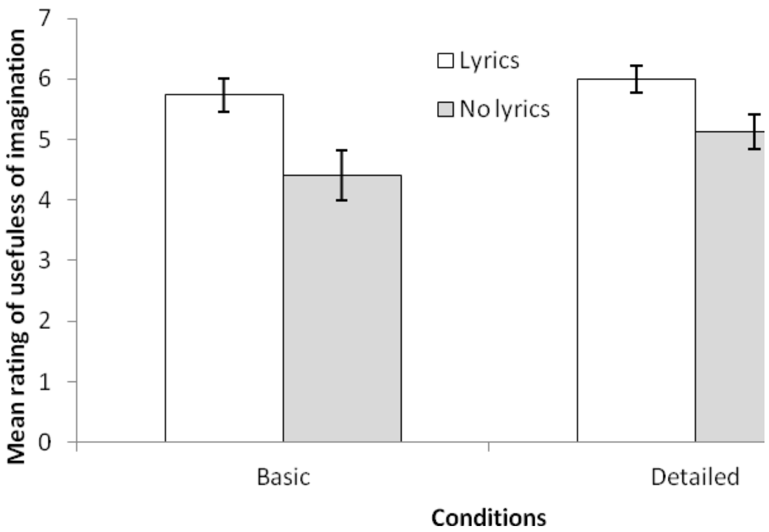


A two-way mixed subjects ANOVA showed no main effect of lyrics, $F(1, 28) = .32$, $MSE = 4.27$, $\eta^2 = .01$, $p > .05$, no main effect of instructions, $F(1, 28) = .06$, $MSE = 4.27$, $\eta^2 = .02$, $p > .05$, and no significant lyrics by instructions interaction, $F(1, 28) = .25$, $MSE = 3.27$, $\eta^2 = .01$, $p > .05$.

Mimic Question

Question 8 in the questionnaire asked the participants how well they felt they had mimicked the real song during the auditory imagery task in order to ascertain whether they felt the instruction procedures and the presence of lyrics had actually worked. The question had a maximum score of seven. The mean scores for participants in the basic instruction condition with lyrics and without lyrics, and the complex instruction condition with lyrics and without lyrics were all above four which is greater than 50%. One sample t-tests on all conditions revealed that these scores were significantly different from 0, suggesting the participants subjectively felt they were achieving auditory imagination (basic with lyrics, $F(14) = 20.19$, $p < .001$; basic with no lyrics, $F(14) = 10.69$, $p < .001$; detailed with lyrics, $F(14) = 27.5$, $p < .001$; detailed no lyrics, $F(14) = 17.67$, $p < .001$). It can be seen from Figure 3 that the presence of lyrics had a greater mean score on the mimic question compared to no lyrics for both instruction conditions. The complex instruction condition scored higher on question 8 with the lyrics compared to the basic instruction condition, with the same pattern showing for no lyrics.

Figure 3. Mean scores for Question 8 (How closely did the imagined song mimic the real song?) by lyrics (presence or absence) and instruction type (basic or detailed)

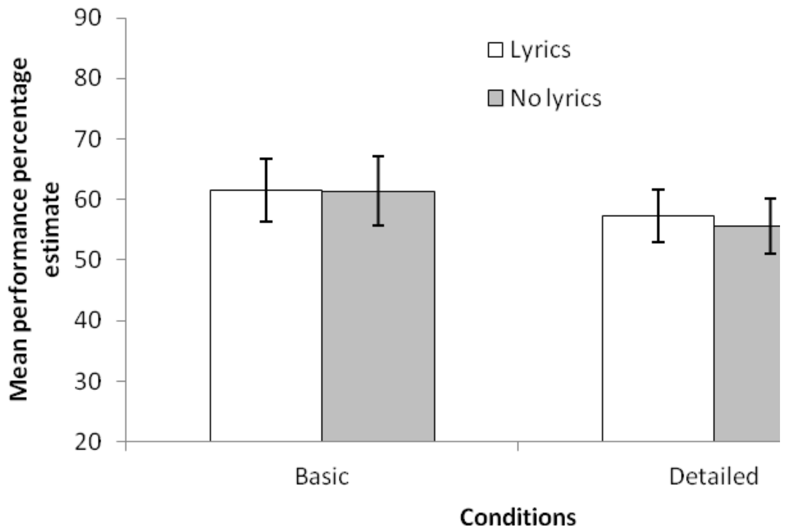


A two-way mixed subjects ANOVA revealed a significant main effect of lyrics, $F(1, 28) = 19.9$, $MSE = 18.15$, $\eta^2 = .42$, $p < .01$, with the presence of lyrics making participants feel that the music they imagined closely resembled the music they chose. No significant main effect of instructions was observed, $F(1, 28) = 1.92$, $MSE = 3.75$, $\eta^2 = .06$, $p > .05$, nor was there was a significant lyrics by instructions interaction, $F(1, 28) = .9$, $MSE = .82$, $\eta^2 = .03$, $p > .05$.

Performance estimate

A final question in the questionnaire asked participants how well they thought they performed in the imagination conditions by providing an estimate of their correct percentage. A two-way mixed subjects ANOVA revealed no significant main effect of lyrics, $F(1, 28) = .16$, $MSE = 12.15$, $\eta^2 = .01$, $p > .05$, no significant main effect of instructions, $F(1, 28) = .55$, *MSE* = 370.02, η^2 = .02 *p* > .05, and no significant lyrics by instructions interaction, *F*(1, 28) = .12, *MSE* = 8.82, η^2 = 0, *p* > .05.

Figure 4. Mean correct percentage performance estimates by lyrics (presence or absence) and instruction type (basic or detailed)



Correlations between subjective and objective performance for each condition

Participant's actual performance for basic instructions with lyrics, basic instructions without lyrics, complex instructions with lyrics and complex instructions without lyrics was correlated with their own estimates of how well they performed in these conditions. Only significant positive correlations between objective and subjective performance were only observed for basic instructions with lyrics, basic instructions with no lyrics and complex instructions with no lyrics (see Table 1). However, the other positive correlation (detailed instructions and no lyrics) was almost significant.

Objective and subjective, basic instructions, no lyrics	*r* = .81, *p* = .000 **

Objective and subjective, basic instructions, lyrics	*r* = .86, *p* = .000 **
Objective and subjective, detailed instructions, no lyrics	*r* = .49, *p* = .06
Objective and subjective, detailed instructions, lyrics	*r* = .63, *p* = .01 **

** Correlation was significant at the 0.01 level (two-tailed)

* Correlation was significant at the 0.05 level (two-tailed)

Table 1. Pearson's product-moment correlations and p-values for objective and subjective performance across conditions

In sum, as the complexity of instruction type increased from control to basic to detailed, increases in mean scores were seen but were not significant. The presence of lyrics showed no significant increase in mean scores compared to no lyrics. With regards to the participants' subjective beliefs that they were able to mimic the songs, participants felt that the presence of lyrics significantly improved their ability to imagine the songs. Estimated performance was roughly equivalent regardless of the instruction condition and the presence of lyrics. Finally, there were positive relationships between objective and subjective estimates of performance across all conditions with three being significant.

Experiment 2

Experiment 1 showed that the presence of instructions (basic or detailed) had no effect on spatial rotation performance. Further, the presence of lyrics to aid musical imagination did not significantly improve performance either. One explanation why no effect of instructions was found may be due to the (in)ability of participants to imagine music in their heads. As far as we were aware, none of the participants were musicians yet research suggests that musicians are best equipped to perform such musical imagery. For example, musically-trained participants were superior to non-musically trained participants at being able to decide, through musical imagery, which of the presented familiar lyrics was in a higher or lower pitch (Aleman et al., 2000). Bailes (2007) investigated the use of musical imagery in the everyday lives of music students. Through using experienced sampling methods (ESM) Bailes assessed when and potentially why they performed musical imagery. The results showed that the participants reported ‘musical imagery episodes’ on a daily basis, with the most prominent features of imagery episodes being lyrics. Participants believed the reason behind imagining the songs they did was due to either hearing or performing them recently. Bailes proposed that the more a person was exposed to a specific song, the more they were likely to imagine music. This suggests that as musicians are more likely to rehearse and listen to music then they are probably better at musical imagery than non-musicians. Thus, Experiment 2 repeated Experiment 1 but this time using participants who were musicians as evidenced by a minimum of Grade 3 accomplishment in their chosen instrument or a GCSE in music.

Method

Participants

Participants comprised forty five musicians from a variety of different musical groups such as orchestras including string and symphony orchestras, music societies specifically jazz and several rock bands, based in and around the south Wales area. This included 28 males and 17 females with an age range of 18-79. All participants had been playing their chosen instrument for at least three years with experience ranging from 3 to 71 years and had attained at least Grade 3 in their chosen instrument or a GCSE – qualifications ranged from Grade 3 to Grade 8 and from GCSE to Degree level.

Design

The Design was identical to that in Experiment 1.

Materials

The Materials were identical to those in Experiment1 with the exception of different songs being imagined - e.g. Eminem – Stan, The Beatles – While My Guitar Gently Weeps, Damian Rice – Cannonball, Frank Sinatra – My Way, Metallica – Enter Sandman, Michael Jackson – Wanna Be Startin' Somethin', Rihanna – We Found Love and Stevie Wonder – Superstition (see Appendix for full list).

Procedure

The same Procedure was adopted as used in Experiment 1.

Results

The same analyses were conducted as in Experiment 1.

Correct Scores

Figure 5. Mean percentage of correct responses for each instruction type (control, basic or detailed)

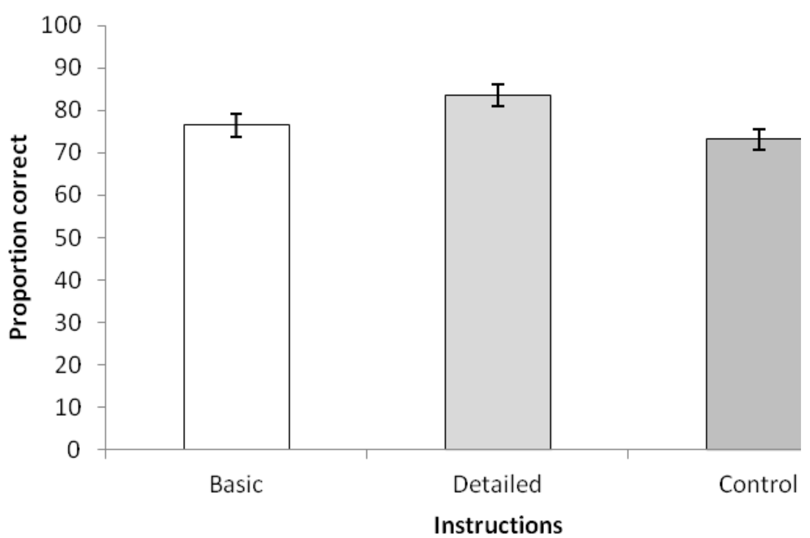
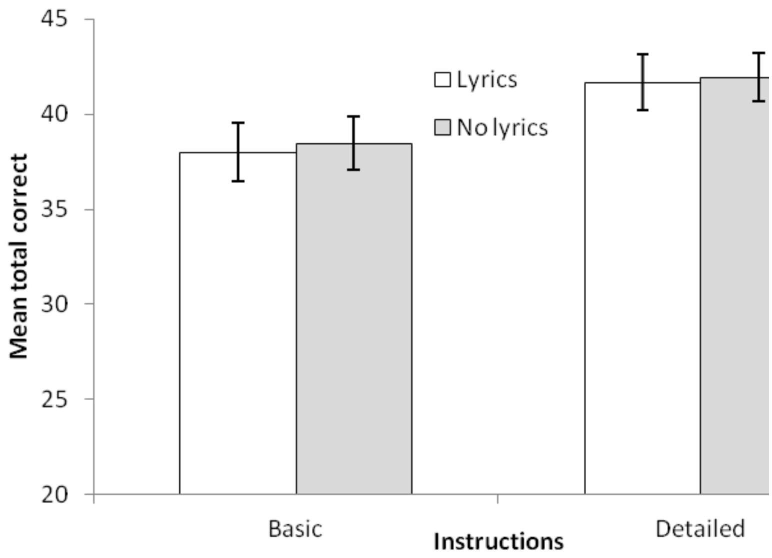


Figure 5. shows that performance was better in the detailed instructions condition followed by the basic instructions and then the control condition. A one-way ANOVA revealed a significant main effect of instructions, *F*(2, 42) = 4.3, *MSE* = 107.22, $\eta^2 = .17$, $p < .05$. Post-hoc Bonferroni tests showed that only the detailed and control conditions were significantly different from each ($p < .05$) with performance being greater in the detailed condition.

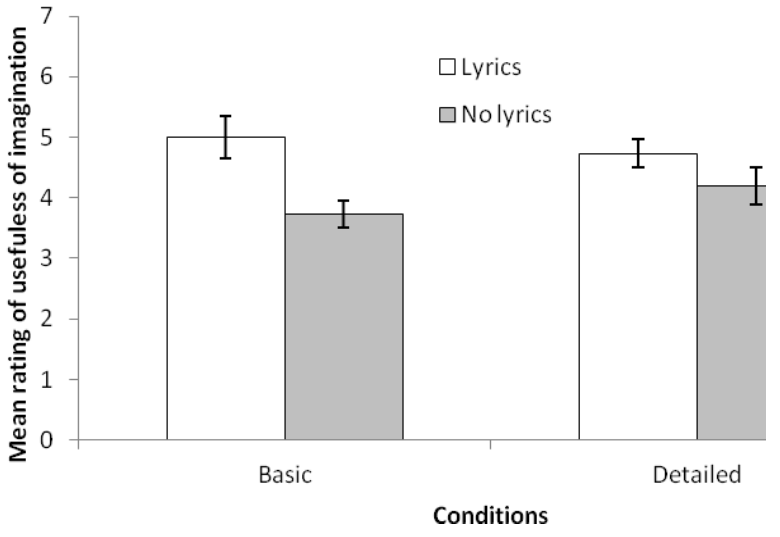
Figure 6. Mean percentage of correct responses by lyrics (presence or absence) and instruction type (basic or detailed)



A two-way mixed subjects ANOVA revealed no significant main effect of lyrics, *F*(1, 28) = .34, *MSE* = 2.02, $\eta^2 = .01$, $p > .05$, no significant main effect of instructions, *F*(1, 28) = 3.49, *MSE* = 190.82, $\eta^2 = .11$, $p > .05$, and no significant lyrics by instructions interaction, *F*(1, 28) = .03, *MSE* = .15, $\eta^2 = 0$, $p > .05$.

Mimic Question

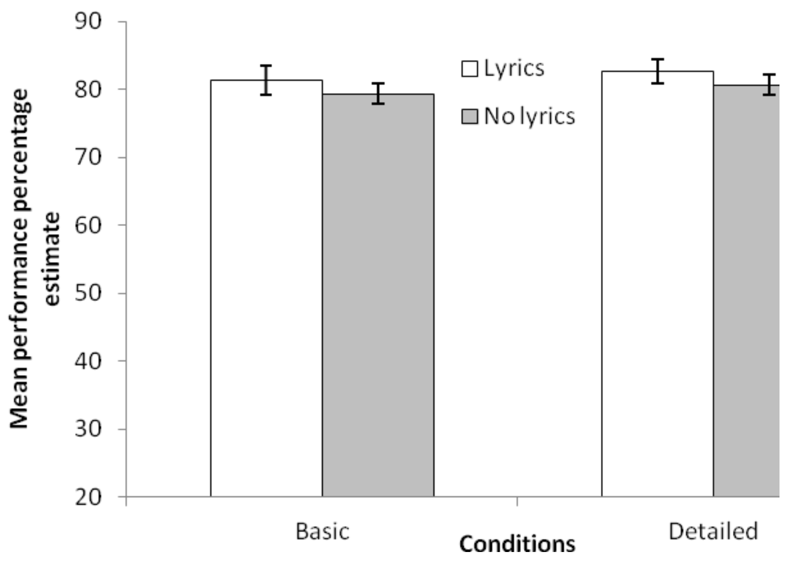
Figure 7. Mean scores for Question 8 (How closely did the imagined song mimic the real song?) by lyrics (presence or absence) and instruction type (basic or detailed)



One sample t-tests on all conditions revealed that these scores were significantly different from 0, suggesting the participants subjectively felt they were achieving auditory imagination (basic with lyrics, $F(14) = 14.1$, $p < .001$; basic with no lyrics, $F(14) = 16.36$, $p < .001$; detailed with lyrics, $F(14) = 20.74$, $p < .001$; detailed no lyrics, $F(14) = 13.48$, $p < .001$). A two-way mixed subjects ANOVA revealed a significant main effect of lyrics, $F(1, 28) = 17.6$, $MSE = 12.15$, $\eta^2 = .39$, $p < .01$, in which the presence of lyrics made the participants feel that the imagined music closely resembled the songs they chose, but no significant main effect of instructions, $F(1, 28) = .09$, $MSE = .15$, $\eta^2 = .09$, $p > .05$. Finally, no significant lyrics by instructions interaction was observed, $F(1, 28) = 2.92$, $MSE = 2.02$, $\eta^2 = .09$, $p > .05$.

Performance estimate

Figure 8. Mean correct percentage performance estimates by lyrics (presence or absence) and instruction type (basic or detailed)



A two-way mixed subjects ANOVA revealed no significant main effect of lyrics, $F(1, 28) = 3.11$, $MSE = 60$, $\eta^2 = .01$, $p > .05$, no significant main effect of instructions, $F(1, 28) = .35$, $MSE = 26.67$, $\eta^2 = .01$, $p > .05$, and no significant lyrics by instructions interaction, $F(1, 28) = 0$, $MSE = 0$, $\eta^2 = 0$, $p > .05$.

Correlations between subjective and objective performance for each condition

Participant's actual performance for basic instructions with lyrics, basic instructions without lyrics, complex instructions with lyrics and complex instructions without lyrics was correlated with their own estimates of how well they performed in these conditions. The only significant correlation was the positive correlation for detailed instructions with lyrics (see Table 2). However, the other correlations were also positive and two were close to significance.

Objective and subjective, basic instructions, no lyrics	$r = .42$, $p = .12$
Objective and subjective, basic instructions, lyrics	$r = .49$, $p = .07$
Objective and subjective, detailed instructions, no lyrics	$r = .55$, $p = .03$ *

Objective and subjective, detailed instructions, lyrics	*r* = .5, *p* =.06

** Correlation was significant at the 0.01 level (two-tailed)

* Correlation was significant at the 0.05 level (two-tailed)

Table 2. Pearson's product-moment correlations and p-values for objective and subjective performance across conditions

In sum, the pattern of data was similar to that observed in Experiment 1: there was an increase in spatial rotation performance as the complexity of the instructions (none, basic, detailed) increased. However, this time a significant difference was observed between the control and detailed instructions conditions showing that, compared to no auditory imagery, spatial rotation performance was significantly improved when participants were instructed to imagine the music in great detail. The presence of lyrics again showed no improvement on performance. As with Experiment 1, participants once again felt that the presence of lyrics enabled them to imagine the song better. Estimated performance did not differ between instructions conditions or the presence or absence of lyrics, and neither did these variables interact with each other. Finally, although there were positive relationships between objective and subjective estimates of performance across all conditions, only one was significant (detailed instructions with no lyrics).

Discussion

Two experiments explored whether just using musical imagery could elicit the mood and arousal effect on spatial rotation performance by giving participants basic or detailed instructions to aid them with this imagery and allowing them to read the lyrics to the song they imagined. Experiment 1 showed no effect of instructions on spatial rotation performance. Experiment 2 repeated Experiment 1 but used musicians (as evidenced by number of years of experience and/or musical qualification) and showed the same pattern in performance. More importantly was the observation of a significant difference between the control and detailed instructions condition. Use of lyrics did not have an effect on performance in either experiment. However, participants felt that the presence of lyrics significantly enabled them to imagine the music. Further, in general, there was a positive relationship between objective spatial rotation performance and subjective, estimated performance across all conditions.

Listening to music is well known to have beneficial effects on a variety of factors (Cassileth et al., 2003; Rickard et al., 2005; Siedlecki & Good, 2006,) and one of the most publicised has been the mood and arousal effect. Previously known as the ‘Mozart effect’, it is the interesting phenomenon whereby listening to music (or engaging in any positive activity, Schellenberg, 2005) that one likes improves spatial rotation performance via the mechanism of elevating mood and arousal levels (Nantais & Schellenberg, 1999). The current experiments sought to replicate this purely through musical imagery – that is, by asking participants to simply imagine, rather than listen, to their preferred music. Only musicians (Experiment 2) improved their spatial rotation performance after reading detailed instructions on how to do so.

Although it is known that imagination of an action can create similar motor responses as the actual motoric action (Deschaumes-Molinaro et al., 1991; Roure et al., 1998) and that imagining music elicits the same neural activity as actually listening to music (Halpern & Zatorre, 1999; Kraemer et al., 2005), the current study, as far as the current authors are aware, provides the first instance demonstrating that the mood and arousal effect can be elicited purely by imagining music. Potential benefits relate to improving spatial rotation performance in certain occupations (e.g. architecture, artist, graphic designer, athletics), academic disciplines (e.g. art, design, mathematics, sports) that require the manipulation of spatially-related objects. However, it is unknown how long this improvement to spatial functioning lasts. It is quite likely that it would not last any longer than the fifteen minutes attributed to the mood and arousal effect (Rauscher et al., 1993). Further, it may also affect tasks requiring processing speed or creativity (Schellenberg, 2005) or even infants' performance on short-term cognitive tasks (Shenfield, Trehub, & Nakata, 2003).

It seems that the use of the more detailed instructions did improve the quality of musical imagery as suggested by the greater performance in this condition. Thus, asking participants to focus on aspects of the musical composition such as what instruments were present, how the song started, what the melody and tempo were like as well as how it made them feel, allowed the experienced musician to more effectively imagine what the music sounded like and, theoretically, increased their mood and arousal levels (Nantais & Schellenberg, 1999; Schellenberg, 2005). Further confirmation of this could come from mood ratings and physiological changes in electrodermal activity.

It may be suggested that participants' arousal levels could have been increased due to the presence of the researchers in the laboratory to record participants' responses (PsyCOG did not record the responses unfortunately). This is possible although we tried to ensure that researchers were as unobtrusive as possible by being out of sight and participants seemed to be fully engaged in the task at all times. As this procedure occurred for all conditions, it is unlikely to have been the cause of any differences between the two experiments. A similar methodology has been employed previously in two studies where mood inductions took place with the researcher present in the room. In both cases, the presence of the researcher did not adversely affect participants in the control condition as measured by state anxiety (Perham & Oaksford, 2006; Perham & Rosser, 2012).

The current findings lend further support to the notion that the mood and arousal effect cannot be restricted to music by Mozart or other classical musicians. As with Perham and Withey (2012), participants were allowed to choose whichever music they preferred and their choices covered a range of genres such as thrash metal, soul, dance and pop. According to Schellenberg (2005), the same effect should be observed with other activities that increase mood and arousal such as listening to music without lyrics, giving participants a hot beverage or a small bag of sweets (e.g. Isen, 2000; Smith, Osborne, Mann, Jones, & White, 2004).

The fact that musicians improved their spatial rotation performance following the detailed instructions whereas non-musicians (we assume) did not, may reignite the debate regarding music and, more specifically, the qualities of music, being responsible for the effect (see Hetland, 2000). The main argument against the (imagined) music priming spatial rotation performance comes from the fact that priming tends to occur when both the prime and the target share some stimulus similarity. However, it is currently unclear what this similarity is supposed to be in the mood and arousal effect. Further, if, as Schellenberg (2005) argues, other activities are able to boost mood and arousal and thus produce the same effect, then it would be even more inconceivable that priming would be an adequate explanation. The fact that only musicians showed the effect may suggest that their increased ability to imagine music increased their mood and arousal more than non-musicians.

One might suggest that participants were able to deduce the purpose of the study and therefore responding accordingly. That is, by realizing that the use of imagined music was likely to increase spatial rotation performance participants may have tried harder when they were asked to imagine the music. Two points would refute this. Firstly, as it was a between groups design, each participant was only privy to one condition and so never had the opportunity to adjust their spatial rotation performance in accordance with the condition. Secondly, given that two conditions required participants to imagine the music it would be expected that both of those would show significantly greater performance compared to the control condition whereas only the detailed instructions showed this.

Obviously this was an exploratory set of experiments with a rather rudimentary (albeit successful) set of instructions on how to imagine the music. A number of issues could be explored in the future such as exactly how much improvement could be gained with better instructions and/or imagination, how long the effect lasts, and whether non-musicians could be trained to imagine music as effectively as musicians.

In summary, we show that imagining music reveals improvements to spatial rotation in musicians only. Although non-musicians showed the same increase, it was not significant. We believe that this is the first demonstration of this effect and it may prove beneficial for individuals working or studying in an area where the manipulation of spatial information is a key requirement.

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