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What makes background music distracting? Investigating the role of song lyrics using self-paced reading

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ABSTRACT
It has been suggested that listening to music during reading may be distracting, but the empirical results have remained inconclusive. One limitation of previous studies is that they have often had limited control over the number of lyrics present in the songs. We report 4 experiments that investigated whether song lyrics make music distracting. Participants read short paragraphs in a self-paced reading paradigm in three sound conditions: 1) silence; 2) lyrical songs at ~150 words per minute; and 3) the instrumental version of the same songs. The results showed that listening to instrumental music either did not affect reading times or led to slightly faster reading times compared to silence. However, lyrical music led to an increase in reading times in three experiments. We conclude that instrumental music does not lead to distraction during reading. Song lyrics appear to be distracting, even if the observed distraction is quite mild.

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Reading; music; distraction; lyrics; reading time

People often listen to music in the background while doing everyday activities. For instance, 62% of university students report listening to music while studying (David et al., 2015) and 80% of UK employees report listening to music at work (Haake, 2006). Because this is such a common occurrence, researchers and educators have long been interested in whether listening to music while studying causes distraction (e.g. Henderson et al., 1945; Miller, 1947). While there is some evidence to suggest that music may reduce reading comprehension accuracy (Kämpfe et al., 2011; Vasilev et al., 2018), the results have remained mixed and inconclusive. As a result, it is still not well understood whether music is distracting, or which factors are responsible for the observed distraction. One limitation of previous studies is that they have often had limited control over the number of lyrics present in the songs. The present research attempted to find out whether song lyrics are a key contributor to distraction by music.

Distraction by background music during reading

To study the effect of music on reading, researchers have typically presented background music to participants while they are engaged in a reading comprehension task. If participants show reduced comprehension when exposed to music compared to a silence baseline, this is then taken as evidence that music is distracting. While such studies have been conducted for more than 80 years (e.g. Fendrick, 1937; Henderson et al., 1945; Miller, 1947; Mitchell, 1949), it has remained frustratingly difficult to draw firm conclusions about what effect, if any, music has on reading comprehension. While some studies have shown certain types of music to be distracting (Anderson & Fuller, 2010; Avila et al., 2012; Daoussis & McKelvie, 1986; Doyle & Furnham, 2012; Etaugh & Michals, 1975; Etaugh & Ptasnik, 1982; Fendrick, 1937; Fogelson, 1973; Furnham & Bradley, 1997; Furnham & Strbac, 2002; Henderson et al., 1945; Johansson et al., 2012; Martin et al., 1988, Experiment 2; Perham & Currie, 2014; Quan & Kuo, 2022), others have found that it either has no effect on reading (Cauchard et al., 2012; Chitwood, 2018; Freeburne & Fleischer, 1952; Furnham & Allass, 1999; Furnham et al., 1999; Gillis, 2010; Kelly, 1994; Kou et al., 2018; Madsen, 1987; Martin et al., 1988, Experiment 1; Miller,

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1947; Mitchell, 1949; Tucker & Bushman, 1991), or that it actually improves reading performance (Falcon, 2017; Hall, 1952; Kiger, 1989; Mullikin & Henk, 1985; Que et al., 2020).

Reviews of the literature have often painted a similarly mixed picture. For instance, de la Mora Velasco and Hirumi (2020) conducted a systematic review on the effect of background music on learning and found the results to be inconclusive. They did, however, note the need to develop studies with more rigourous methods and to improve the overall reliability of measures. Hallam and MacDonald (2016) reviewed issues surrounding the literature and noted many structural, cultural, and associative influences that may play a role in explaining the effect of music on task performance. They proposed a theoretical framework that considers the characteristics of the music (e.g. genre, familiary, preference, complexity, level of stimulation), individual characteristics (e.g. personality, musical expertise, frequency of music use), as well as different emotional, arousal, mood, task, and environmental charestistics. Clearly, taking all these issues into account is difficult, which may well explain why the research literature has been so inconsistent.

Nevertheless, there have been attempts to look at some of these factors in isolation. For example, previous studies haved considered the effect of music genres (Kallinen, 2002; Miller, 2014; Miller & Schyb, 1989; Mullikin & Henk, 1985; Tucker & Bushman, 1991), tempo (Kallinen, 2002; Thompson et al., 2012), preference (Etaugh & Michals, 1975; Etaugh & Ptasnik, 1982; Johansson et al., 2012; Perham & Currie, 2014), and familiarity of the music (Chew et al., 2016; Hilliard & Tolin, 1979). An early study by Hilliard and Tolin (1979) found that familiar music reduced comprehension scores compared to unfamiliar music. However, a more recent study by Chew et al. (2016) has failed to support this finding, thus raising some doubts about the role of music familiarity in distraction.

Additionally, other studies have considered individual differences, such as introversion and extraversion (Avila et al., 2012; Daoussis & Mc Kelvie, 1986; Furnham et al., 1999; Furnham & Allass, 1999; Furnham & Bradley, 1997; Furnham & Stephenson, 2007; Furnham & Strbac, 2002; Gheewalla et al., 2020; Kou et al., 2018; Lim et al., 2022). While such studies have provided interesting initial results, more evidence is required to reach firmer conclusions (e.g. see Küssner, 2017). In summary, the literature has suggested that music may cause distraction during reading, but the results have remained mixed and more evidence is required to understand when such distraction may occur.

The effect of lyrics on distraction by background music

Meta-analyses have attempted to address some of these inconsistencies by pooling together all the available evidence and deriving a single estimate on the effect of music on reading. Kämpfe et al. (2011) reported an effect size of $r = -11$ ($d = -0.22$) based on 8 studies, indicating that music has a mild distracting effect. Vasilev et al. (2018) conducted a meta-analysis with 36 studies and found a similar result: the overall effect of music on reading comprehension was $d = -0.19$, again indicating mild distraction. Interestingly, however, a meta-regression analysis suggested that studies using lyrical music yielded much bigger distraction effects than studies using instrumental music (a mean difference of $d = -19$). While the effect size for lyrical music was $d = -0.35$, the effect size for instrumental music was effectively 0. Additionally, lyrical music was found to be just as distracting as intelligible background speech. In summary, Vasilev et al.'s (2018) findings suggest that lyrical music is distracting but that instrumental music does not cause any distraction.

Previous studies that have directly compared lyrical and instrumental music also lend some support to these results. For example, Martin et al. (1988) reported that the presence of sung or spoken lyrics (either accompanied by instrumentals or not) led to greater distraction compared to a no-lyrics condition. Additionally, Perham and Currie (2014) reported that both liked and disliked lyrical music was more distracting compared to instrumental music. Similarly, C. Miller (2014) presented classical and rock music that was either instrumental or lyrical. There was a marginally significant main effect of lyrics (lower comprehension in lyrical compared to instrumental music) and a significant interaction with genre- with the means suggesting a bigger difference between the lyrical and instrumental conditions for classical music. However, Gillis (2010) reported no difference between instrumental classical music and lyrical pop music. Avila et al. (2012) also found no difference in comprehension between the lyrical and instrumental version of the same songs, though performance in both conditions was significantly worse than silence. Similarly, Furnham et al. (1999) also found no difference in comprehension between lyrical and instrumental music, but the two conditions also did not differ from silence. In contrast, Reed (2019) reported that lyrical music led to lower comprehension compared to an instrumental version of the same songs.

More recently, Kyoung (2020) found that lyrical music led to a reduction in evoked brain potentials compared to silence. The timing of these effects suggested that they may be related to disruption in the orthographic and syntactic processing of the text. However, no difference was found between lyrical music and the instrumental version of the same music, or between instrumental music and silence. This suggests that the difference in their study may not be entirely due to the lyrics, but to some combination of lyrics and instrumentals. Therefore, while the results are again far from conclusive, there is at least some indication in the literature that song lyrics may contribute to the observed distraction.

Theoretical perspectives

The potential of lyrics to cause distraction is not surprising, given that irrelevant speech is well-known to disrupt reading (e.g. Baker & Madell, 1965; Hyönä & Ekholm, 2016; Martin et al., 1988; Sörqvist et al., 2010; Yan et al., 2018). In fact, recent evidence from eye-tracking has suggested that distraction by music may show very similar eye-movement signature to that of distraction by irrelevant speech (Zhang et al., 2018). If the meaning of lyrics is processed in a similar way to that of speech, distraction by lyrical music would also be expected.

There are different theories that could help explain why lyrics may be distracting. According to the duplex-mechanism account (Hughes, 2014), distraction can occur in two functionally different ways: 1) interference-by-process; and 2) attentional capture. *Interference-by-process* distraction (Jones & Tremblay, 2000; Marsh et al., 2008, 2009) occurs when both the main task and the distractor are drawing on similar cognitive processes, thus leading to interference between them. For instance, readers typically need to engage in semantic processing of the text to achieve sufficient understanding of it. However, if the lyrics from the music also undergo some semantic processing, this could interfere with the semantic processing of the text, leading to distraction.

Additionally, sounds that exhibit greater acoustic variation (e.g. "M K S B Z R") are more distracting in serial memory recall tasks compared to steady-state sounds (e.g. "M M M M M M") that do not exibit such acoustic variation (Hughes & Jones, 2001; Jones et al., 1992; Jones & Macken, 1993). This *changing-state* effect is viewed as an instance of intereference-by-process, as order information of the changing sounds is thought to interefere with maintainig order of the visually presented items in a serial recall task (Hughes, 2014). While the implications of such distraction to reading tasks is less clear, some models do pose that readers need to maintain the order of words in the text (e.g. Snell et al., 2018). Thus, sound order information could conceivably interfere with maintaining word order during reading.

The second type of distraction- *attentional capture*- occurs when a sound unexpectedly differs from an otherwise repetitve sequence of the same sound (Hughes et al., 2005; Parmentier, 2014; Schröger, 1996; Vachon et al., 2012). For instance, the sound "B" in the sequence "A A A A **B** A A" would capture attention as another "A" would be expected. This type of distraction is thought to trigger an orienting response, where attention is temporarily directed away from the main task and towards the unexpect sound (see Sokolov, 2001).

Finally, another relevant account is the *phonological inteference* theory (Salamé & Baddeley, 1982, 1987, 1989). It predicts that speech sounds gain obligatory access to the phonological loop of working memory and interfere with the phonological encoding and retrieval of visually presented items in the main task (Larsen & Baddeley, 2003). In this theory, the phonological loop acts as a filter that lets in speech sounds such as the language from the lyrics, but filters-out non-speech sounds such as the music instrumentals. While this theory has also been mostly developed in serial recall tasks, Salamé and Baddeley (1989) have speculated that it may also extend to other tasks such as reading that utilise the phonological loop. However, there is very little understanding of how the type of task may affect phonological interference.

Here, we will focus on the interference-by-process and phonological interference theories as they both make direct predictions for our study. Namely, both theories predict that lyrical music should be more distracting that instrumental music because it causes semantic or phonological interference, respectively, with the reading task. In interference-by-process, the semantic analysis of the lyrics would interfere with the semantic analysis of the text due to the use of shared processes. In the phonological interference view, the lyrics would gain automatic access to the phonological loop and interfere with the phonological encoding of the text. Therefore, while the two theories offer a different explanation for why distraction occurs, they agree that lyrical music should be more distracting than instrumental music.

Distraction by attentional capture and changing-state sounds will not be considered in detail, as they have mostly been demonstrated with discrete sounds. As such, it is less clear how they may occur with complex and continuous sounds such as music. It could be argued that certain unexpected instrumentals or vocals within the songs could capture attention, but most commercial songs are probably too complex to derive any meaningful predictions from this theory. Likewise, the changing-state account also does not immediately explain how songs with lyrics may exhibit more or less acusitic variation as their instrumentals are also likely too complex for such a distinction to be made.

Present research

Vasilev et al.'s (2018) meta-regression results, as well as findings from previous studies (Kyoung, 2020; Martin et al., 1988; Perham & Currie, 2014; Reed, 2019), suggest that song lyrics may be an important contributor to distraction by music. Nevertheless, there are few well-controlled studies that have investigated the role of lyrics in distraction. More broadly, studies have often had limited control over the acoustical properties of the music conditions that are being compared and the number of lyrics present in the songs. Therefore, the aim of the present research was to test whether lyrics are a key contributor to distraction in a more controlled manner.

Participants read short passages in three sound conditions: silence, instrumental music, and lyrical music. We used the lyrical and instrumental version of the same songs (Avila et al., 2012; Furnham et al., 1999; Kyoung, 2020), thus ensuring that any difference between the two conditions can be attributed solely to the presence of lyrics. The songs were selected to have an average lyrics rate of about 140–150 words per minute (wpm), about the same rate as normal speech (Brysbaert, 2019). This was because distraction by irrelevant speech is well established (e.g. Baker & Madell, 1965; Hyönä & Ekholm, 2016; Martin et al., 1988; Sörqvist et al., 2010) and we speculated that using music with a similar rate of language to that of normal speech would increase the chance of observing distraction.

Additionally, participants were asked to provide ratings on the familiarity, preference, pleasantness, offensiveness, and perceived distractibility of the music, as well as how many hours on average they spend listening to music each day, so that the influence of these variables on the results can be examined. This was of particular interest as there is little data on how the lyrical and instrumental version of the same songs are perceived by participants and how this may affect distraction. If there are differences in participants' perceptions, this could indicate that distraction may be driven not only by the processing of language within the lyrics, but also by how the presence of lyrics in the song changes the way the song is perceived. For instance, there is some evidence that vocal melodies are easier to recognise than instrumental ones (Weiss et al., 2016; Weiss et al., 2017; Weiss, Schellenberg, et al., 2015), which could mean that lyrical songs may be more recognisable and preferred by participants. The variables of familiarity, preference, pleasantness, offensiveness, perceived distractibility, and music listening frequency were selected as potential covariates because previous studies suggest that they may help explain the distracting effect of music on cognitive performance (Etaugh & Michals, 1975; Etaugh & Ptasnik, 1982; Perham & Currie, 2014; Perham & Sykora, 2012; Perham & Vizard, 2011).

The present research used a self-paced reading paradigm (Aaronson & Scarborough, 1976; Jegerski, 2014; Marsden et al., 2018), where participants pressed a button to reveal each new word in the text. This made it possible to calculate reaction times for each word in the text, as well as to measure overall comprehension accuracy at the end. This paradigm is useful for collecting word reading times when more complex methodology such as eye-tracking cannot be used (e.g. during the Covid-19 pandemic). Because previous research has suggested that word fixation times may be a more sensitive predictor of distraction by irrelevant speech than comprehension accuracy (Cauchard et al., 2012; Hyönä & Ekholm, 2016; Meng et al., 2020; Vasilev et al., 2019; Yan et al., 2018), we speculated that self-paced reading times of words may also be an useful measure of distraction. Therefore, our key predictions were based on word reading times, but we also collected comprehension accuracy data.

We report 4 experiments. Experiment 1a examined the effect of song lyrics when participants listened to familiar pop/rap songs in an online study. Experiment 1b repeated the same study in the lab. Experiments 2–3 examined the effect of unfamiliar pop/rap music in an online study. We expected that lyrical music will lead to an increase in reading times compared to instrumental music. If one takes Vasilev et al.'s (2018) results at face value, it can be predicted that there should be no difference between silence and the instrumental music condition. However, it is also possible that there could be a small difference between the two conditions if music instrumentals also contribute to the distraction.

Hypotheses

- **H1**: If the presence of lyrics makes background music distracting, lyrical music should result in longer self-paced reading times compared to instrumental music.
- **H2.1**: If lyrics are the only aspect of background music that causes distraction, then: 1) H1 should be supported; and 2) there should be NO difference in self-paced reading times between instrumental music and the silence baseline.
- **H2.2**: If instrumental music also causes at least some distraction, self-paced reading times should be longer in the instrumental music condition compared to the silence baseline.

Experiment 1a

The study protocol was pre-registered prior to data collection (https://osf.io/4gw63). Experiment 1a was conducted online due to the Covid-19 pandemic. Previous research has suggested that lab-based and online-based studies of distraction should yield comparable results (Elliott et al., 2022).

Method

Participants

Participants were recruited from two sources: a local university pool and Prolific.co. All participants were UK adults who reported English as their first language, normal (or corrected-to-normal) vision, normal hearing, and no prior diagnosis of reading disorders. University pool participants received course credits and Prolific participants were compensated at £7/ hour. Overall, 204 participants[1] took part (65.68% female, 33.33% male, 0.98% other genders; $N = 101$ Prolific; $N = 103$ university pool). Participants' average age was 25.32 years ($SD = 7.87$ years; range = 18- 49 years). In the university pool, 94.2% participants had completed A-levels (≈ high school) and 5.8% indicated they had already studied for (another) undergraduate degree. In the Prolific participants, 1% had completed primary school, 9.9% GCSEs, 26.73% A-levels, 46.53% an undergraduate degree, 12.87% a postgraduate degree, and 2.97% a PhD degree.[2] All experiments received ethical approval from the Bournemouth University Research Ethics Committee (ID: 36794). All participants provided informed electronic consent.

Prospective statistical power simulations using the *simr* R package v.1.0.5 (Green & Macleod, 2016) were done on a pilot dataset of 12 subjects (not included here). The simulation parameters were: 1) sample size that can detect a difference between the lyrical and instrumental music conditions with a 95% probability; 2) the expected effect size (a 12 ms difference) was reduced to 75% of that from the pilot data because small studies are known to overestimate the effect size (Albers & Lakens, 2018); 3) 10% random data loss was added to account for missing data and outliers. The results indicated that 156 participants are needed to reach 95% power. To be sure, the sample size was increased to 204 participants. The power simulations indicated no reliable difference between silence and instrumental music. A Bayesian model was found to be sufficiently precise with this sample size to find evidence in support of H0 for this effect. The same power calculation was used in all subsequent experiments.

[1] 11 more participants were tested but excluded based on the pre-registered criteria: 3 failed one or more of the listening comprehension "trap" trials, 3 admitted to not wearing headphones, and 5 were discarded due to missing or invalid data. Additionally, 5 more participants were excluded due to chance-level comprehension (<60%). While the comprehension accuracy criterion was not pre-registered, it was deemed necessary to ensure that participants were reading for comprehension.

[2] Prolific participants were, on average, more educated than the university pool, though they also had more varied educational backgrounds. They were also older ($M_{age} = 30.7$ years) than the university pool participants ($M_{age} = 20$ years). The Prolific participants also had a more balanced gender representation (48.5% female) compared to the university pool participants (82.5% female).

A) Example passage

I agree that California's "three strikes and you're out" law will be a financial disaster for taxpayers who care about education and other vital services. But it's far from clear that the law can even be credited with a reduction in crime in California. While it's true that crime declined in California last year, crime also dropped nationwide.

B) Self-paced reading illustration

```
I ----- ---- ------------ ------ ------- --- ------ ---- --- ---- -- - ---------

- agree ---- ------------ ------ ------- --- ------ ---- --- ---- -- - ---------

- ----- that ------------ ------ ------- --- ------ ---- --- ---- -- - ---------

- ----- ---- California's ------ ------- --- ------ ---- --- ---- -- - ---------

- ----- ---- ------------ "three ------- --- ------ ---- --- ---- -- - ---------
```

C) Comprehension assessment

1) The author agrees that the "three strikes and you're out" law will help taxpayers. TRUE/FALSE?

2) Last year, crime declined in California, but not nationwide. TRUE/FALSE?

D) Example trap trial

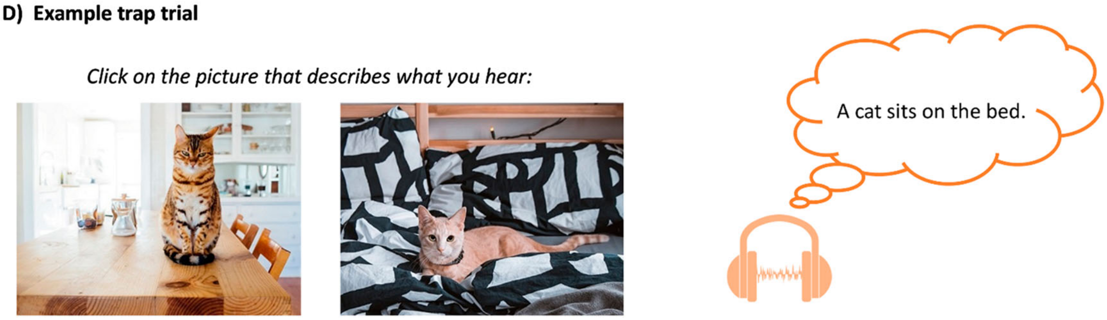

Figure 1. An illustration of the materials used in the experiments.

Design and materials

The study had a within-subject design with *sound condition* (silence, instrumental music, lyrical music) as the only factor. The reading stimuli consisted of 15 short passages (see Figure 1a) from the Provo corpus (Luke & Christianson, 2018). The passages were on average 53.4 words long (*SD* = 4.42 words; range: 46–62 words). The words in each passage were presented one-by-one using a self-paced reading paradigm (Aaronson & Scarborough, 1976; Jegerski, 2014; Mitchell & Green, 1978). A non-cumulative presentation was used, meaning that only the current word was visible at any given time and all other words were masked. This meant that participants could only move forward in the text and were not able to go back and revisit previously read words (i.e. make regressions). This paradigm made it possible to calculate a reaction time for each word, which roughly corresponds to the time participants spent processing it (including integrating it with previously read material). After each passage, participants answered 2 True/ False comprehension questions (see Figure 1c).

While reading, participants were exposed to the three background sound conditions. The music played in the experiment consisted of six pop/ rap songs. To avoid presenting any of the songs twice (once in the lyrical, and once in the instrumental condition), they were split into two sets. Half of the participants heard Set A in the lyrical music condition and Set B in the instrumental music condition; the other half heard Set A in the instrumental music condition and Set B in the lyrical music condition. Thus, the two sets were heard equally often across all participants and conditions, but participants heard each song only once. The songs in Set A were: 1) Eminem- The way I am; 2) Post Malone- WoW; 3) Nicki Minaj (feat. Rihanna)-Fly. The songs in Set B were: 1) Jessie J (feat. B.o.B)-Price tag; 2) Iggy Azalea (ft. Charli XCX)- Fancy; 3) Outkast- Ms. Jackson. The songs were always played in the same order. The songs were selected based on their high lyrics content and the availability of an officially released instrumental version that was identical to the original song. The songs in Set A had an average lyrics rate of 148.2 wpm ($SD = 37.7$) and the songs in Set B had an average lyrics rate of 145.8 wpm (SD = 6.4). There were no significant differences in lyrics rate between the two sets, $t(2.11) = 0.11$, $p = 0.9219$.

The sound conditions were blocked, and the order of blocks was counterbalanced across participants. Within each block, the five passages were presented in random order. The assignment of sound conditions to the passages was counterbalanced with a full Latin square design. At the start and end of a block, participants were presented with a listening comprehension "trap" trial, which was designed to catch participants who were not listening to the audio (see Figure 1d). During those trials, participants heard a spoken statement (e.g. "A cat sits on a bed") and had to choose the picture corresponding to the statement (e.g. A cat sitting on a bed vs. a cat sitting on a table).

After the reading task, participants completed a short questionnaire about their listening habits and the music played in the experiment (see https://osf.io/xub2v). First, they were asked about their preferred music genre(s) and their average daily time spent listening to music. Second, participants were presented with a 30s sample of all songs used in the experiment. After each sample, they were asked to rate the song on its familiarity, preference, pleasantness, offensiveness, and perceived distractibility on a scale from 1 (not at all familiar/ likable/ pleasant, offensive/ distracting) to 10 (very familiar/ likable/ pleasant, offensive/ distracting). These questions were adopted from previous research (see Perham & Currie, 2014; Perham & Sykora, 2012). The song samples always started at the first chorus and served to remind participants of the songs they heard in the experiment. Therefore, participants rated each song individually and did not have to rely on their memory of what they had heard in each music block. Participants were also asked to write down the name of the artist(s) and the song title (if they knew them) to test their actual knowledge of the songs.

Apparatus

The experiment was programmed in Lab.js (Henninger et al., 2022) and hosted online on Pavlovia.org. The passages were formatted in a Consolas monospaced font and appeared as black text over a white background. The width of each letter was set to be 2% of the width of the browser window size. The text was double-spaced and aligned to the left. Participants completed the experiment on their own laptop/ PC using headphones.

Procedure

Participants read the information sheet, provided electronic consent, and were forwarded to the online experiment, which started in full-screen mode on their browser. They were instructed to put on their headphones and perform a headphone screening and calibration procedure (Woods et al., 2017). Participants were asked to set the volume to a loud, but comfortable level. Afterwards, participants were instructed to read the passages for comprehension at their own pace. Participants were told to ignore the music and just focus on what they are reading. Following instructions, participants were presented with 2 practice trials, followed by the experimental trials (blocked by sound condition). In each block, the music started playing 15s before the first trial to allow participants to get used to it. Each trial started with only the first word visible and a prompt at the top of the screen reminding participants to press the SPACE bar to reveal the next word. Once the SPACE bar was pressed, the current word disappeared, and the next word was revealed. This procedure was repeated until the whole paragraph was presented (see Figure 1b). There were 2 comprehension questions after each paragraph, which were answered with a mouse click. Participants were given a maximum of 45s per question (they were not explicitly informed about the time limit, but they familiarised themselves with it during the practice). There was a 7-second break between trials. Before and after each sound block, one listening comprehension "trap" trial was presented. After the reading task, participants completed the music questionnaire and were asked if they wore headphones for the whole duration of the experiment.

Data analysis

There were two dependent measures: word *reaction time* (RT; time taken to press the button to move to a new word) and *comprehension accuracy*. RT was the main measure of interest. Comprehension accuracy was measured as a binary variable, where correct answers were scored as "1" and incorrect answers were scored as "0". Statistical analysis was done with (Generalised) Linear Mixed Models ((G)LLMs) using the "lme4" package v.1.1-29 (Bates et al., 2014) in R v.4.10 (R Core Team, 2022). Random intercepts were included for both participants and items (Baayen et al., 2008). Additionally, we attempted to include random slopes for sound condition for both participants and items (Barr et al., 2013). If the models failed to converge, the slopes were removed one by one until convergence was achieved. Reaction times were log-transformed in the analysis. Successive differences contrast was used from the MASS package (Venables & Ripley, 2002), which compared instrumental music to silence and lyrical music to instrumental music. The results were considered statistically significant if the $|t|$ and $|z|$ values were ≥ 1.96. Effect sizes are reported in Cohen's d (Cohen, 1988).

Additionally, Bayesian (G)LMMs were fit using the same model structure to calculate Bayes factors (BF_{10}). This was done with the *brms* R package v.2.16.1 (Bürkner, 2017, 2018) using the Stan software (Carpenter et al., 2017). Four chains were run with 5000 iterations each and 500 samples burn-in. Bayes factors (BF_{10}) were calculated using the Savage-Dickey density ratio method (Dickey & Lientz, 1970; Morey et al., 2011). In the reaction time model, priors of Normal(0, 6) and Normal(0, 0.05) were used for the intercept and slopes, respectively. The slope prior roughly corresponds to a maximum expected difference of 20-30 ms on the log scale. In the accuracy model, priors of Normal(0, 2) and Normal(0, 0.75) were used for the intercept and slopes, respectively. The slope prior roughly corresponds to a maximum expected difference of 10-12% on the logit scale.

Results

During pre-processing, 0.32% of the data was excluded due to outliers (RTs < 100 or > 5000 ms). Additionally, 4 trials (0.14%) were removed due to a lack of response on more than 5 words. This left 99.54% of the data for analysis. Descriptive statistics are shown in Table 1 and visualised in Figure 2. The results from the statistical analysis are shown in Tables 2 and 3.

There was no significant difference in RTs between instrumental music and silence, with the Bayesian model showing "substantial" evidence in support of the null hypothesis of no difference (Jeffreys, 1961; Wetzels et al., 2011). Similarly, there was also no difference in RTs between lyrical and instrumental music. The Bayesian model again favoured the null hypothesis of no difference, though the evidence for this was only anecdotal. In summary, neither music condition affected word RTs and there was no evidence of any distraction.

The comprehension accuracy measure revealed similar results, with no significant difference between instrumental music and silence or lyrical and instrumental music. The Bayesian models again favoured the null hypothesis of no difference, though the evidence was substantial only in the comparison between lyrical and instrumental music.

Table 1. Descriptive statistics for the reaction time and comprehension accuracy measures.

Sound	Mean reaction time in ms per word (SD)	Mean comprehension accuracy in % (SD)
Experiment 1a (familiar music, online)		
Silence	405 (241)	87.0 (33.6)
Instrumental music	403 (239)	85.1 (35.6)
Lyrical music	410 (257)	84.7 (36.0)
Experiment 1b (familiar music, lab replication)		
Silence	452 (255)	85.3 (35.4)
Instrumental music	451 (248)	84.0 (36.6)
Lyrical music	464 (262)	80.9 (39.3)
Experiment 2 (unfamiliar music, online)		
Silence	377 (248)	87.1 (33.5)
Instrumental music	365 (219)	87.1 (33.5)
Lyrical music	381 (240)	85.6 (35.1)
Experiment 3 (unfamiliar music + speech, online)		
Silence	370 (210)	87.7 (32.9)
Instrumental music	367 (201)	88.2 (32.2)
Lyrical music	376 (211)	85.9 (34.8)
Irrelevant speech	377 (219)	84.8 (35.9)

Note: *SD*: standard deviation.

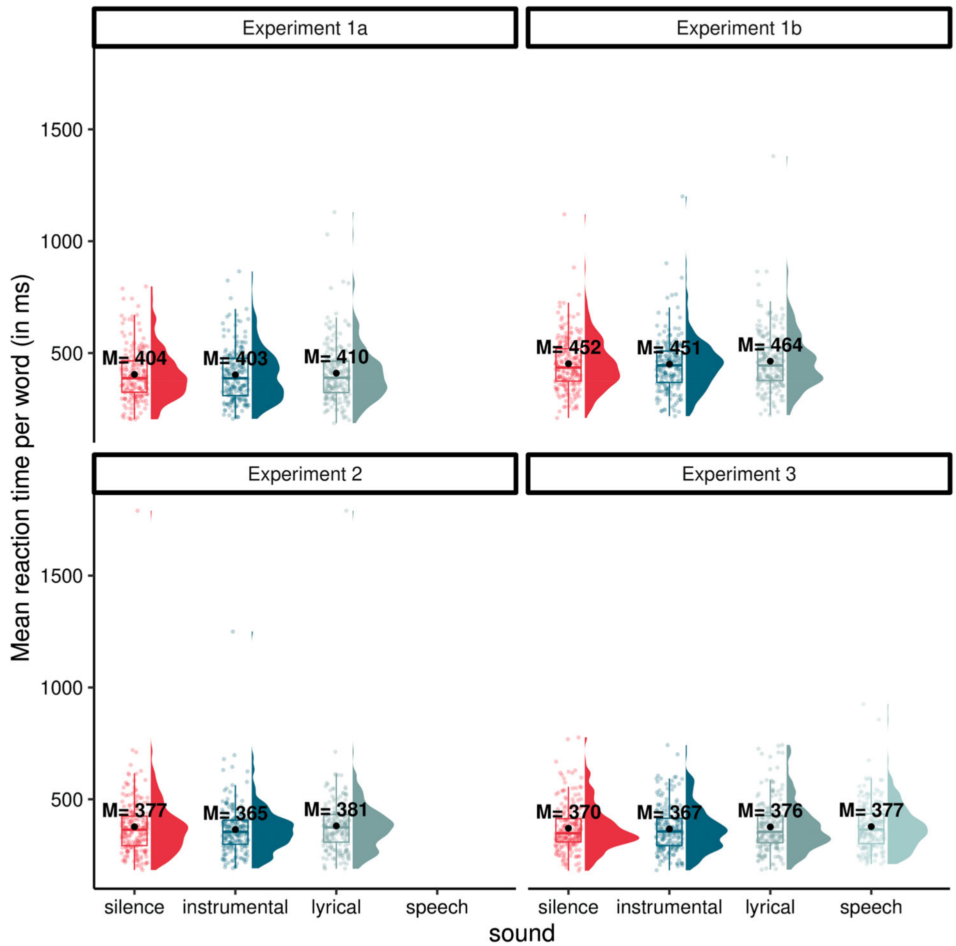

Figure 2. Distribution of word reaction times in the different sound conditions in all four experiments. Dots represent individual participant means for each condition.

Table 2. LMM results for reaction times in the experiments.

	Experiment 1a				Experiment 1b			
Fixed effects	b	SE	t	BF_{10}	b	SE	t	BF_{10}
Intercept	5.900	.0299	**196.8**		6.028	.0292	**206.5**	
Instrumental vs. Silence	−.006	.0076	−.774	**.2036**	−.0035	.0069	−.513	**.1503**
Lyrical vs. Instrumental	.0107	.0075	1.422	.3920	.0245	.0070	**3.505**	**52.17**
Random Effects	Var.	SD	Corr.		Var.	SD	Corr.	
Intercept (subjects)	.0663	.2575			.0504	.2245		
Instrumental vs. Silence (subjects)	.0110	.1048	.08		.0089	.0947	.11	
Lyrical vs. Instrumental (subjects)	.0107	.1034	− .02	− .45	.0093	.0963	.07	−.43
Intercept (items)	.0086	.0927			.0091	.0952		
Residual	.1040	.3225			.0959	.3097		
	Experiment 2				Experiment 3			
Fixed effects	b	SE	t	BF_{10}	b	SE	t	BF_{10}
Intercept	5.818	.0280	**207.9**		5.825	.0242	**240.32**	
Instrumental vs. Silence	−.0175	.0074	**−2.374**	2.145	−.0075	.0019	**−3.842**	**590.32**
Lyrical vs. Instrumental	.0323	.0071	**4.533**	**3.9×10^8**	.0187	.0019	**9.630**	**2.5×10^{16}**
Speech vs. Lyrical	N/A	N/A	N/A	N/A	.0011	.0019	0.561	**.0030**
Random Effects	Var.	SD.	Corr.		Var.	SD	Corr.	
Intercept (subjects)	.0687	.2621			.0629	.2508		
Instrumental vs. Silence (subjects)	.0103	.1014	−.22					
Lyrical vs. Instrumental (subjects)	.0096	.0979	.18	−.54				
Intercept (items)	.0067	.0818			.0057	.0754		
Residual	.0998	.3158			.1008	.3174		

Note: Statistically significant t-values are formatted in **bold**. N/A: speech condition was not present in Experiment 2. BF_{10}: Bayes factor comparing the alternative to the null hypothesis; values <1 indicate evidence in support of the null hypothesis and values > 1 indicate evidence in support of the alternative hypothesis. Bayes factors of <1/3 or >3 are highlighted in **bold**.

Table 3. GLMM results for reading comprehension accuracy in the experiments.

Fixed effect	b	SE	z	BF_{10}	b	SE	z	BF_{10}
	Experiment 1a				Experiment 1b			
Intercept	2.161	.2356	**9.173**		1.916	.2259	**8.483**	
Instrumental vs. Silence	−.1861	.0950	−1.959	.5766	−.0793	.1071	−.740	**.2141**
Lyrical vs. Instrumental	−.0327	.0917	−0.355	**.1291**	−.2591	.0968	**−2.677**	**3.967**
Random Effects	Var.	SD	Corr.		Var.	SD	Corr.	
Intercept (subjects)	.4238	.6510			.2220	.4712		
Instrumental vs. Silence (subjects)					.2370	.4868	.36	
Lyrical vs. Instrumental (subjects)					.0404	.2010	−.23	−.34
Intercept (items)	.7644	.8743			.7167	.8466		
	Experiment 2				Experiment 3			
Fixed effect	b	SE	z	BF_{10}	b	SE	z	BF_{10}
Intercept	2.305	.2730	**8.442**		2.308	.2145	**10.76**	
Instrumental vs. Silence	−.0085	.0996	−.085	**.1489**	.1027	.1017	1.010	**.1877**
Lyrical vs. Instrumental	−.1416	.0973	−1.455	.3781	−.2487	.0992	**−2.506**	1.128
Speech vs. Lyrical	N/A	N/A	N/A	N/A	−.1296	.0944	−1.373	.3589
Random Effects	Var.	SD	Corr.		Var.	SD	Corr.	
Intercept (subjects)	.2723	.5218			.5005	.7074		
Intercept (items)	1.055	1.027			.8316	.9119		

Note: Statistically significant z-values are formatted in **bold**. N/A: speech condition was not present in Experiment 2. $BF_{10:}$ Bayes factor comparing the alternative to the null hypothesis; values <1 indicate evidence in support of the null hypothesis and values > 1 indicate evidence in support of the alternative hypothesis. Bayes factors of <1/3 or >3 are highlighted in **bold**.

Discussion

Experiment 1a did not show any evidence of distraction by either instrumental or lyrical music, thus failing to support any of the study hypotheses. The results generally favoured the null hypothesis of no difference, though the evidence for this was anecdotal in half of the comparisons. Therefore, while the results were not perfectly conclusive, they generally suggest that lyrical and instrumental music do not cause distraction during self-paced reading.

One possible explanation for the lack of difference in Experiment 1a is that the online data collection may have affected the validity of the results. While there is evidence that online testing yields similar (albeit smaller) auditory distraction effects compared to in-person testing (Elliott et al., 2022), this has not been studied in the present paradigm. To evaluate the same hypotheses in standardised conditions, the experiment was repeated in the lab.

Experiment 1b

Method

The study protocol was pre-registered prior to data collection (https://osf.io/6d3fj). The method was the same as Experiment 1a, except for the following differences.

Participants

A total of 204 Bournemouth University students[3] took part in return for course credits (80.88% female; 17.65% male; 0.98% other genders; 0.49% no answer). None of them took part in Experiment 1a. Participants' average age was 20.64 years (*SD* = 5.29 years; range = 18- 50 years). Most participants (92.15%) had completed A-levels, 0.98% had completed GCSEs, and 6.86% indicated they had already studied for (another) undergraduate degree.

Design, materials, apparatus, procedure, and data analysis

Participants completed the study in an individual lab cubicle at Bournemouth University. The music was played at 67 ± 1.5 dB(A) via Bose QuietComfort 25 noise-cancelling headphones. The study was run on a Chrome web browser on a Hewlett-Packard EliteDesk 800 G1 SFF computer with 8GB RAM (running on Windows 7). The monitor was a 24″ BENQ XL2411 with a 1920 × 1080-pixel resolution and a 60 Hz refresh rate. Participants sat about 60-70 cm from the monitor. All other aspects were identical to Experiment 1a.

Results

During pre-processing, 0.15% of the data was excluded due to outliers (RTs < 100 or > 5000 ms). Additionally, 1 trial (0.03%) was removed due to a lack of response on more than 5 words. This left 99.85% of the data for analysis. Descriptive statistics are shown in Table 1 and the statistical analyses are shown in Tables 2 and 3.

[3]Another 6 participants were tested but excluded (2 because they failed one or more of the trap trials and 4 due to chance-level accuracy (<60%; accuracy criterion not pre-registered).

Similar to Experiment 1a, there was no significant difference in RTs between instrumental music and silence. The Bayesian model showed substantial evidence in support of the null hypothesis of no difference. However, the lyrical music condition led to significantly longer RTs compared to instrumental music ($d = 0.05$), thus supporting **H1**. The Bayesian model showed very strong support for the alternative hypothesis that there is a difference between the two conditions. Therefore, lyrical music was more distracting than instrumental music, but instrumental music did not differ from the silence baseline, which supports **H2.1**.

The reading comprehension data showed the same pattern of results. While there was no significant difference between instrumental music and silence, lyrical music led to significantly lower comprehension accuracy compared to instrumental music ($d = -0.082$).

Discussion

Experiment 1b showed that lyrical music led to longer word RTs compared to instrumental music. This suggests that song lyrics caused distraction and increased overall word reading times. Additionally, comprehension accuracy was lower in lyrical compared to instrumental music, replicating previous findings (Martin et al., 1988, Experiment 2; Miller, 2014; Perham & Currie, 2014; Reed, 2019). However, no difference emerged in the comparison between instrumental music and silence, suggesting that the presence of instrumentals alone had no effect on self-paced reading. This is consistent with studies showing no difference between instrumental music and silence (e.g. Cauchard et al., 2012; Martin et al., 1988, Experiment 1).

Overall, Experiment 1b was successful in showing reliable distraction by lyrical music in the lab, even if the effect sizes were quite small. Because no significant difference was found in the online version of the study (Experiment1a), it may be tempting to attribute the conflicting results to the mode of testing. However, it is important to keep in mind that Experiment 1a also contained a mixed sample (one half was from a student pool and the other half was from Prolific). A post-hoc comparison of the RT measure between Experiment 1b and the student-pool sub-sample from Experiment 1a revealed an overall difference between lyrical and instrumental music in both experiments, but no interaction with Experiment (see the Supplemental Files). This suggests that the distraction effect was also present in the student sub-sample of Experiment 1a and it did not differ from the lab-based testing conditions in Experiment 1b. Therefore, these results corroborate Elliott et al.'s (2022) finding that lab-based and online-based distraction experiments yield similar results, with the caveat that the same participant population is used.

Experiment 2

Experiments 1a and 1b used music that was rated as familiar and roughly half of all participants could correctly identify the songs/ artists (see Figure 4 and Table 4 below). However, it is not known if similar results would be obtained with a set of unfamiliar songs. Therefore, Experiment 2 attempted to replicate the results from Experiment 1b, but with unfamiliar songs.

Song familiarity is an important, but little understood factor. Consumers often prefer to listen to familiar over less familiar music and this preference is a positive predictor of their music choice (Ward et al., 2014). Familiarity with the music created through repetition increases its preference (Ali & Peynircioğlu, 2010) and can affect emotional responses (Witvliet & Vrana, 2007). Familiar music also leads to activation of emotion- and reward-related brain circuits, potentially making participants more engaged with the music (Pereira et al., 2011). While some evidence has suggested that music familiarity does not affect the semantic processing of lyrics (Chien & Chan, 2015), there is limited understanding of whether familiarity can influence distraction.

To our knowledge, only two studies have directly examined this question. Hilliard and Tolin (1979) presented participants with either familiar or unfamiliar music. To induce "familiarity", they presented a music piece 15 min before the test session and then repeated the same piece during the test phase (meaning, participants had already heard it once). In the unfamiliar music condition, they played a new, previously unheard piece. They reported that unfamiliar music led to lower comprehension test scores compared to familiar music. Chew et al. (2016) also manipulated the familiarity of the music (along with the language of the songs), but did so based on whether participants already knew the songs before the experiment. In the familiar condition, they used a famous song that participants likely already know ("My Heart Will Go On" by Celine Dion) and, in the unfamiliar

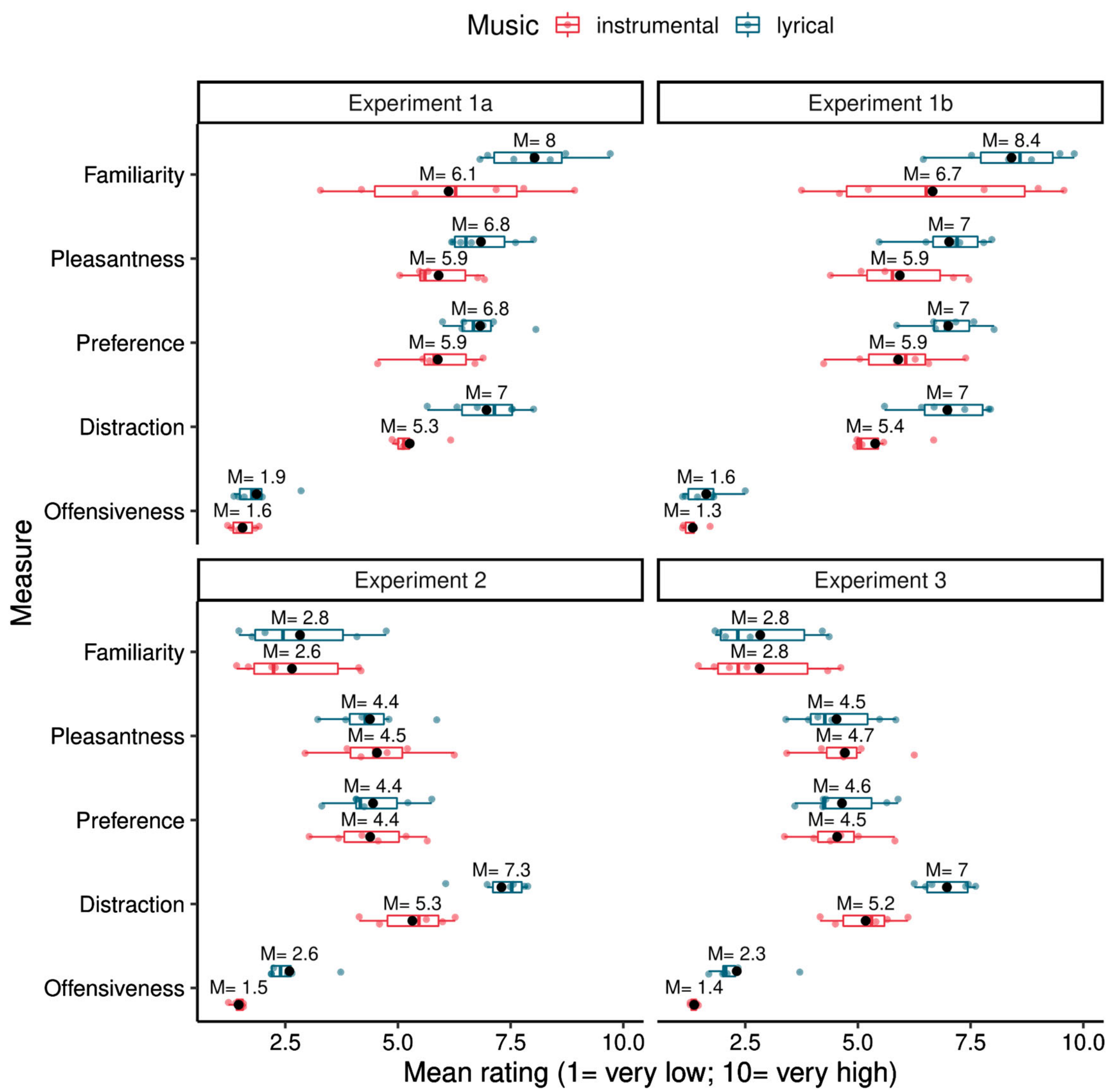

Figure 4. Participants' rating of the songs split by music type (instrumental vs lyrical version of the songs). The means are plotted and shown by a black dot.

music condition, they used a song that participants are unlikely to have heard before (a rendition of the Italian song "Volare"). They found no difference between familiar and unfamiliar music in a reading comprehension task (though unfamiliar music reduced word memory test scores compared to familiar music). Therefore, the results are inconclusive as to whether song familiarity plays a role in distraction. Interestingly, some studies have actively avoided using familiar music (e.g. Furnham et al., 1999; Furnham & Allass, 1999; Kyoung, 2020), presumably because it was thought that unfamiliar music will yield stronger distraction. However, the actual impact of music familiarity remains poorly understood.

Table 4. Percentage of the experimental songs for which participants could correctly identify the artist(s) and song title.

Experiment	Song version	Artist accuracy (%)	Song accuracy (%)
1a	Lyrical	67.8 (46.7)	61.1 (48.8)
1a	Instrumental	38.4 (48.7)	37.3 (48.4)
1b	Lyrical	65.5 (47.6)	54.9 (49.8)
1b	Instrumental	42.8 (49.5)	41.5 (49.3)
2	Lyrical	0.33 (5.71)	0.33 (5.71)
2	Instrumental	0.16 (4.04)	0.16 (4.04)
3	Lyrical	0.80 (8.92)	0.48 (6.92)
3	Instrumental	0 (0)	0 (0)

Note: Participants were given a 30s sample of each song after the experiment and were asked to write down the artist(s) and song title, if they know them.

Experiment 2 used unfamiliar songs that had the same genre(s) and number of lyrics as those in Experiments 1a and 1b. As a result, it was not a direct test of music familiarity, but an attempt to replicate and extend the results from Experiment 1b to a set of unfamiliar songs. Due to the constraints of the Covid-19 pandemic, Experiments 2–3 were run online.

Method

The study protocol was pre-registered prior to data collection (https://osf.io/b38hn).

Participants

A total of 204 UK adults[4] recruited from Prolific.co participated in return for compensation at £7/ hour (60.3% female; 39.2% male; 0.49% other genders). None of them took part in the previous experiments. Participants had an average age of 31.6 years ($SD =$ 11 years; range: 18–50 years). In terms of education, 0.49% had completed primary school, 4.41% had completed GCSEs, 28.43% had completed A-levels, 44.61% had completed an undergraduate degree, 19.61% had completed a postgraduate degree, and 2.45% had completed a PhD degree.

Design, materials, apparatus, procedure, and data analysis

All aspects of the study were identical to Experiment 1a, except that a new set of (unfamiliar) songs was used. Set A contained the following songs: 1) Sa-Roc- Starseed; 2) Johnie Bee ft. Rasco- In My Prime; 3) Evidence- Throw It All Away. Set B contained: 1) The Four Owls- Old Earth; 2) Aesop Rock- Molecules; 3) Atmosphere- Just for show. Set A had an average lyrics rate of 148.9 wpm ($SD = 9.6$) and set B had an average lyrics rate of 149.1 wpm ($SD = 24.1$). There were no differences in lyrics rate between Set A and Set B ($t(2.624) =$ -.017, $p = .987$) or between the songs used in Experiments 1a-1b and Experiment 2 ($t(8.784) = -0.171$, $p = .868$). The songs were selected so that they are matched on lyrics rate and overall genre to those used in Experiments 1a-1b, but that they have a low likelihood of being known to participants (judged by their number of views on YouTube.com). The results confirmed that recognition of the songs was < 1% (see Table 4).

Results

During pre-processing, 0.32% of the data was excluded due to outliers (RTs < 100 or > 5000 ms). Additionally, 3 trials (0.10%) were removed due to a lack of response on more than 5 words. This left 99.58% of the data for analysis. Descriptive statistics are shown in Table 1 and the results are presented in Tables 2 and 3.

Similar to Experiment 1b, lyrical music led to longer word RTs compared to instrumental music ($d = 0.071$). This supports **H1**. However, contrary to the other predictions, instrumental music led to significantly *lower* word RTs compared to silence ($d = -0.052$). Therefore, instrumental music led to an unexpected facilitation where reading was faster compared to the silence baseline. The difference between instrumental music and silence showed only "anecdotal" evidence (Jeffreys, 1961; Wetzels et al., 2011) in support of the alternative hypothesis in the Bayesian model, thus suggesting the result was reliable only in the frequentist model.

The comprehension accuracy analysis showed no significant differences between instrumental music and silence or between lyrical music and instrumental music. The Bayesian model supported the null hypothesis of no difference, though the evidence was "substantial" only in the comparison between instrumental music and silence.

Discussion

Experiment 2 replicated the key finding from Experiment 1b, where lyrical music led to longer word RTs compared to instrumental music. Therefore, there was more evidence to suggest that the presence of lyrics in songs leads to distraction. Because Experiment 2 used unfamiliar songs, the findings also show that this result extends to music that is unknown to participants. The effect size was similar to that of Experiment 1b, which suggests that the amount of distraction between the two studies was roughly comparable.

Experiment 2 also showed one unexpected finding: instrumental music led to *faster* word reading times compared to silence. While the source of this facilitation effect is unknown, there have been sporadic reports of classical (instrumental) music leading to improved reading performance compared to silence (e.g. Falcon, 2017; Mullikin & Henk, 1985). To ensure this facilitation effect is reliable, we attempted to replicate it in Experiment 3.

Experiment 3

The goal of Experiment 3 was to replicate and extend the results from Experiment 2. The study was

[4]5 more participants were tested but excluded (3 because they failed one or more trap trials and 2 due to missing or invalid data).

identical, except that a new condition of irrelevant background speech was added. Experiments 1b and 2 demonstrated that lyrical music is more distracting than instrumental music, thus showing that the processing of lyrics in music interferes with reading efficiency. However, it is not known if lyrics lead to the same distraction as irrelevant speech. Vasilev et al.'s (2018) results suggest that lyrical music is just as distracting as intelligible background speech. However, their findings were only observational in nature, so this prediction has never been tested directly. Because the present research used songs with a rate of lyrics that approximates the rate of normal speech, it can be predicted that lyrical music and intelligible speech would cause the same amount of distraction. Therefore, the second goal of Experiment 3 was to test if lyrical music and irrelevant speech cause equivalent distraction when they are matched on language rate. However, it is also possible that the instrumentals present in songs may partially mask the distracting effect of the lyrics, thus leading to smaller distraction in lyrical music compared to irrelevant speech. As a result, two new hypotheses were formed:

- **H3.1**: If lyrical music yields the same distraction as spoken language (when language rate is controlled), there should be no difference in self-paced reading times between the irrelevant speech and lyrical music conditions.
- **H3.2**: If certain properties of the music (e.g. instrumentals) partially mask the distracting nature of the lyrics, the irrelevant speech condition should result in longer self-paced reading times compared to the lyrical music condition.

The study protocol was pre-registered prior to data collection (https://osf.io/ztpb6).

Method

Participants

A total of 208 UK adults[5] recruited from Prolific.co participated in return for compensation at £7/hour (54.3% female; 44.2% male; 1.44% other genders). This was the nearest counter-balanced number to 204 (used in the previous experiments). None of them took part in the previous experiments. Participants had an average age of 34.25 years ($SD = 8.28$ years; range: 18- 50 years). Participants' educational background was: 12% had completed GCSEs, 24.5% had completed A-levels, 43.8% had completed an undergraduate degree, 15.9% had completed a postgraduate degree, 3.8% had completed a PhD degree.

Design, materials, apparatus, procedure, and data analysis

The study was the same as Experiment 2, except that a new condition of irrelevant speech was added. This condition consisted of short spoken statements, concatenated together in Adobe Audition 2019 to create about 10 min of audio (e.g. "This theory has implications for spatial illusions such as the visual angle illusion", "They will take the Piccadilly Line to Covent Garden from Leicester Square", "Concentrated solar power uses molten salt energy storage in a tower or in trough configurations"). The speech files were taken from the LibriSpeech ASR corpus (Panayotov et al., 2015), available through the Open Speech and Language Resources project (https://www.openslr.org/12). The rate of speech in the irrelevant speech condition ($M = 149.1$; $SD = 4.979$) was matched to that of the unfamiliar songs ($M = 149.01$; $SD = 16.391$), $t(5.559) = .0117$, $p = 0.991$. To maintain the same statistical power as the previous experiments, 5 more passages were added from the Provo corpus (Luke & Christianson, 2018). Thus, 20 items were used in total (5 per condition). In the statistical models, a new contrast was added for the comparison between Irrelevant speech and Lyrical music.

Results

During pre-processing, 0.31% of the data was excluded due to outliers (RTs < 100 or > 5000 ms). Additionally, 5 trials (0.12%) were removed due to a lack of response on more than 5 words. This left 99.57% of the data for analysis. Descriptive statistics are shown in Table 1 and the statistical results are presented in Tables 2 and 3.

Consistent with **H1**, lyrical music led to longer word RTs compared to instrumental music ($d = 0.044$). Additionally, consistent with Experiment 2, but contrary to predictions, instrumental music led to faster word RTs compared to the silence baseline

[5] 8 more participants were tested but excluded based on the pre-registered criteria (2 participants admitted to not wearing headphones, 3 participants failed one or more of the trap trials, 2 participants had missing or incomplete data). Additionally, 2 more participants were excluded due to chance-level comprehension (<60%; comprehension criterion was not pre-registered).

($d = -0.016$). This time, the Bayesian model showed "decisive" evidence (Jeffreys, 1961; Wetzels et al., 2011) in support of the alternative hypothesis. Finally, there was no significant difference between irrelevant speech and lyrical music; the Bayesian model showed "decisive" evidence for the null hypothesis of no difference. Therefore, this supports **H3.1** and suggests that distraction by lyrical music and irrelevant speech was equivalent.

In the comprehension accuracy measure, there was no difference in accuracy between silence and instrumental music; The Bayesian model showed "substantial" support for the null hypothesis. Lyrical music led to a significant decrease in comprehension accuracy compared to instrumental music ($d = -0.016$), though the Bayesian model showed inconclusive evidence for either the null or alternative. Finally, there was no difference in comprehension accuracy between speech and lyrical music; the Bayesian model favoured the null hypothesis, though the evidence was "anecdotal". In summary, there was no reliable evidence for distraction in comprehension accuracy.

Discussion

Experiment 3 replicated the two key findings from Experiment 2: 1) lyrical music led to longer RTs compared to instrumental music; and 2) instrumental music led to *shorter* RTs compared to silence. Thus, the unexpected facilitation of instrumental music from Experiment 2 was confirmed in a new sample. We will return to this in the General Discussion.

Interestingly, irrelevant speech did not differ from lyrical music in RTs, which suggests that the amount of distraction was equivalent between the two conditions. This supports Vasilev et al.'s (2018) results that lyrical music is just as distracting as speech. We now turn to the covariate analyses looking at whether properties of the songs affected differences between the lyrical and instrumental music conditions.

Covariate analyses with song ratings, song knowledge, and daily music use

Participants' music genre preferences are shown in Figure 3. Participants reported listening to music each day for an average of 2.7 h in Experiment 1a (*SD* = 2.09; *range* = 0 - 12 h), 2.92 h in Experiment 1b (*SD* = 1.82; *range* = 0-14 h), 2.39 h in Experiment 2 (*SD* = 2.04; *range* = 0-15 h), and 2.16 h in Experiment 3 (*SD* = 1.89; *range* = 0-13 h). Participants' ratings of the songs are shown in Figure 4 and their correlations are visualised in Figure 5. Participants actual knowledge of the songs is shown in Table 4.

As Figure 4 shows, the average ratings of the songs were remarkably consistent across each pair of experiments that used the same music (i.e. Experiment 1a and 1b using the "familiar" songs and Experiments 2 and 3 using the "unfamiliar" songs). This suggests that there was some internal consistency in how participants rated the music on the five dimensions. Interestingly, the preference and pleasantness ratings were almost perfectly correlated with each other, suggesting that participants understood them to mean a similar thing.

Covariate analysis

The goal of the pre-registered co-variate analysis was to test if the difference between lyrical and instrumental music is still significant after adjusting for the effect of the covariates. In this analysis, the silence condition was excluded from the data, thus leaving only the comparison between lyrical and instrumental music (the speech condition was also excluded from Experiment 3). This is because only the two music conditions received ratings of the songs that could be used in the analysis. The following covariates were then added to the model: music familiarity, preference, offensiveness, perceived distractibility, song knowledge (composite measure of artist accuracy and song title accuracy), and daily music use frequency. Music pleasantness was not included because the measure was almost perfectly correlated with the music preference ratings (see Figure 5). Additionally, song knowledge was removed as a covariate in Experiments 2–3 because almost no participants knew the songs, so the model parameters could not be reliably estimated. Finally, perceived distractibility was removed from the Experiment 3 model due to multicollinearity issues with the sound condition. All covariates were converted into z-scores to deal with multi-collinearity and improve the scaling of the models. The results are visualised in Figure 6.

In Experiment 1a, the difference between lyrical and instrumental music in RTs was still not significant (even though it was just under the .05 threshold). Therefore, the conclusions from the main analysis remained unchanged. Interestingly, music offensiveness reached statistical significance. This result showed that greater

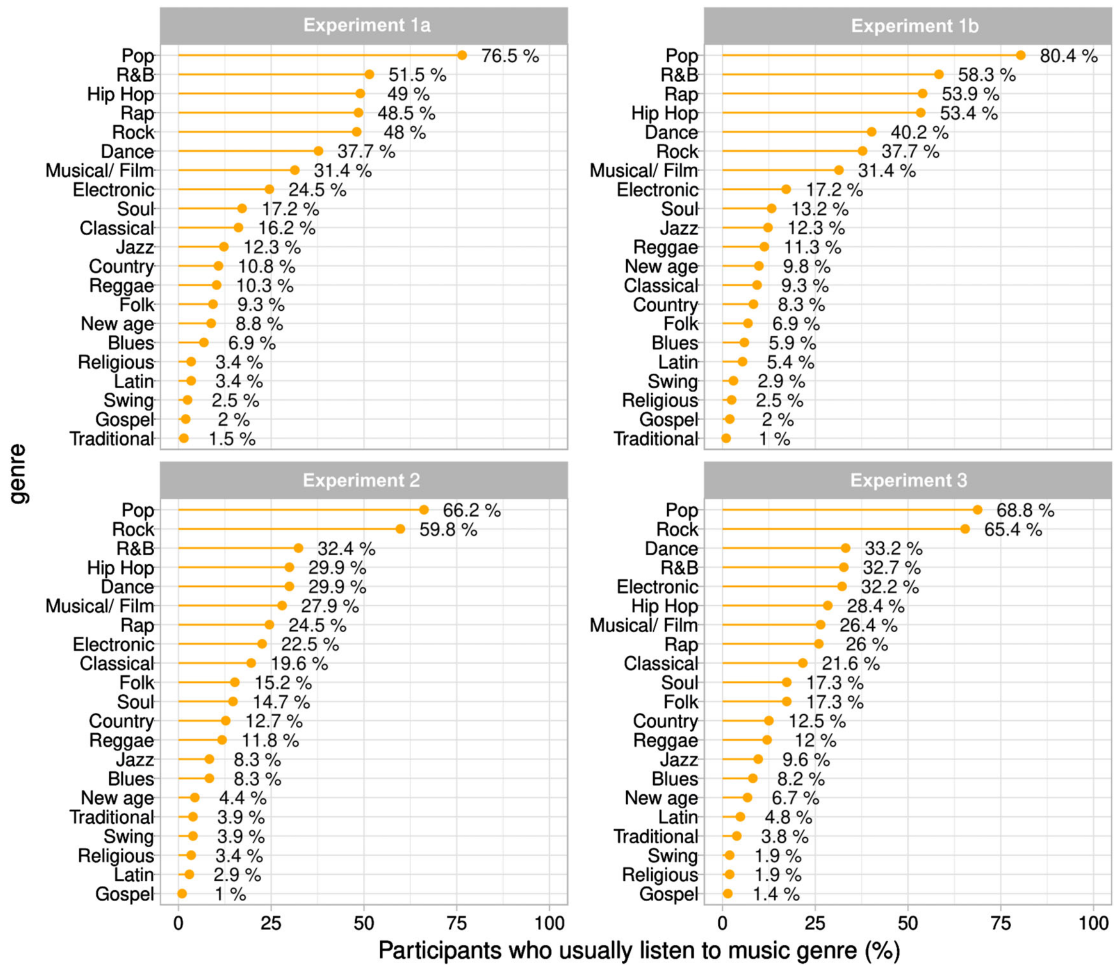

Figure 3. Music genre preference of participants in the four experiments. Participants were asked to indicate *all* genres that they usually listen to. The percentages show the proportion of participants who selected a given genre and thus the numbers do not add up to 100%.

offensiveness of the music was associated with faster reading times.

In Experiment 1b, the difference between lyrical and instrumental music was still significant and thus the model results also remained unchanged. Interestingly, however, familiarity, offensiveness and song knowledge reached significance. Reading times were longer when the music was rated as more familiar and more offensive. Thus, the offensiveness effect was in the opposite direction to that of Experiment 1a. Additionally, greater knowledge of the song that was playing was associated with slightly lower RTs (i.e. faster reading). Therefore, familiarity and song knowledge both had a significant but opposite effect on words RTs (greater song knowledge *reduced* RTs, whereas greater familiarity *increased* RTs). A post-hoc model that included an interaction term between familiarity and song knowledge showed that song knowledge had an effect on RTs only when familiarity was low (see Figure S2 in the Supplemental files). Thus, song knowledge appears to capture additional variability in RTs mostly when participants rated the songs low on familiarity.

The offensiveness ratings in Experiment 1a and Experiment 1b had the opposite effect. This is particularly surprising as the same music was used in both experiments. An increase in offensiveness may lead to faster reading times if participants are offended by the music and try to finish the trial faster. On the other hand, an increase in offensiveness may also lead to *slower* reading times if participants find it more distracting. The present study can't distinguish between these two possibilities and more research is needed to better understand this effect.

In Experiments 2 and 3, the significant difference between lyrical and instrumental music remained

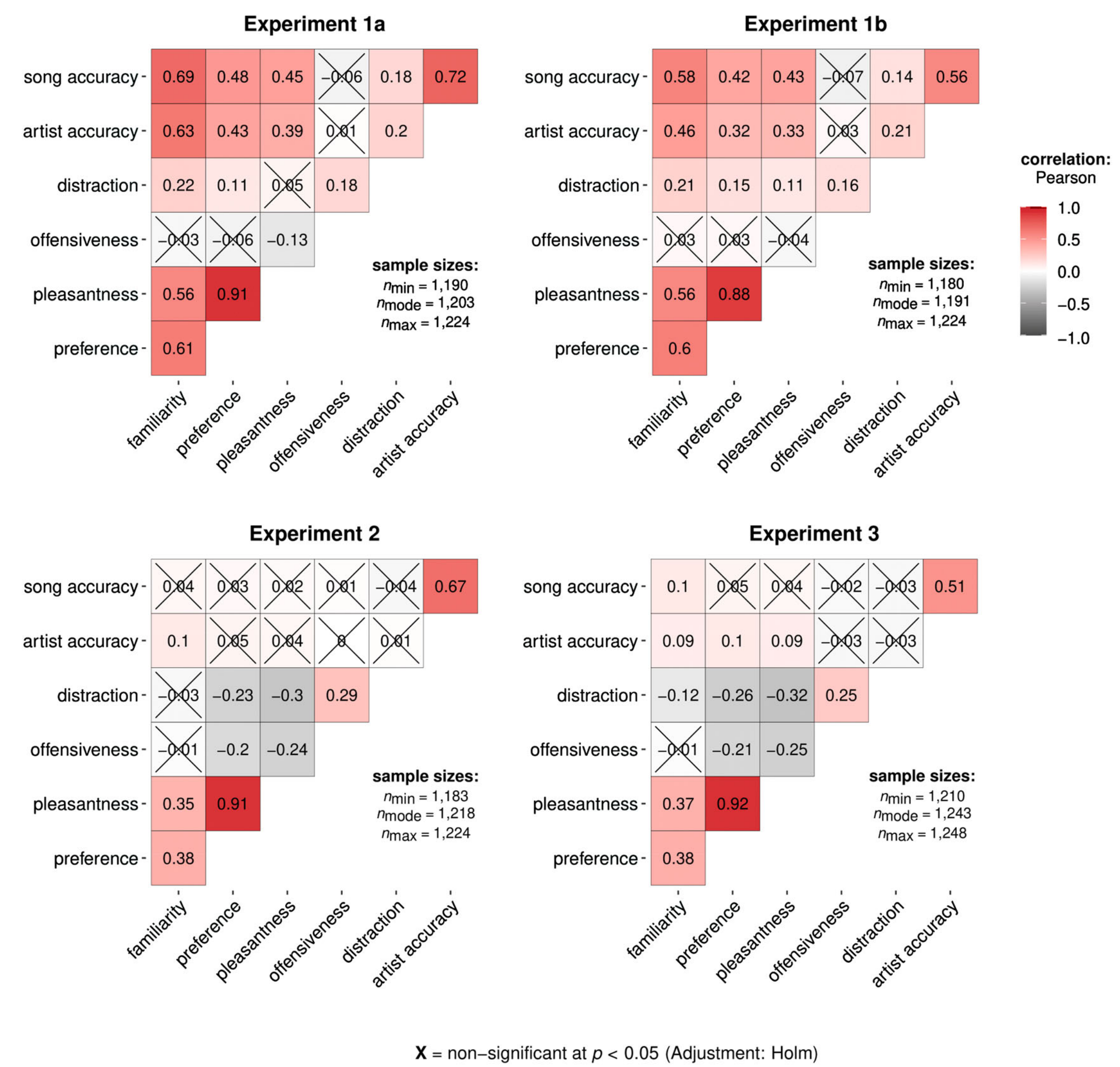

Figure 5. Correlation matrix plot of the music rating and song/artist accuracy variables in the experiments. Experiments 1a-1b contained familiar music and Experiments 2–3 contained unfamiliar music.

unchanged after adjusting for the covariates. Experiment 3 also revealed a significant music preference effect, where music that was rated as more preferred by participants resulted in longer reading times. This suggests that music preference inflated reading times on top of the effect of lyrics. In summary, the main results remained unchanged after adjusting for the covariates, but some of the song ratings had an additional influence on word RTs in three of the four experiments.

Analysis of music ratings as function of music type (instrumental vs lyrical)

Finally, we analysed the music ratings as dependent variables to understand how participants rated the songs based on whether they heard the lyrical or the instrumental version of them. The ratings were collapsed across experiments based on whether participants were rating the "familiar" music (Experiments 1a-1b) or the "unfamiliar" music (Experiments 2-3). In the "familiar" music dataset, participants rated the lyrical version of songs as significantly more familiar ($b = 1.835$, $SE = 0.524$, $t = 3.50$), more preferred ($b = 1.024$, $SE = 0.196$, $t = 5.224$), more offensive ($b = 0.309$, $SE = 0.1520$, $t = 2.031$), and more distracting ($b = 1.661$, $SE = 0.352$, $t = 4.725$) than the instrumental version of songs (see Figure 4). Additionally, they were significantly more likely to correctly recall the artist (s) ($b = 1.637$, $SE = 0.4433$, $t = 3.692$) and song name ($b = 1.384$, $SE = 0.132$, $z = 10.480$) when they heard the lyrical compared to the instrumental version of songs. Clearly, these results suggest that

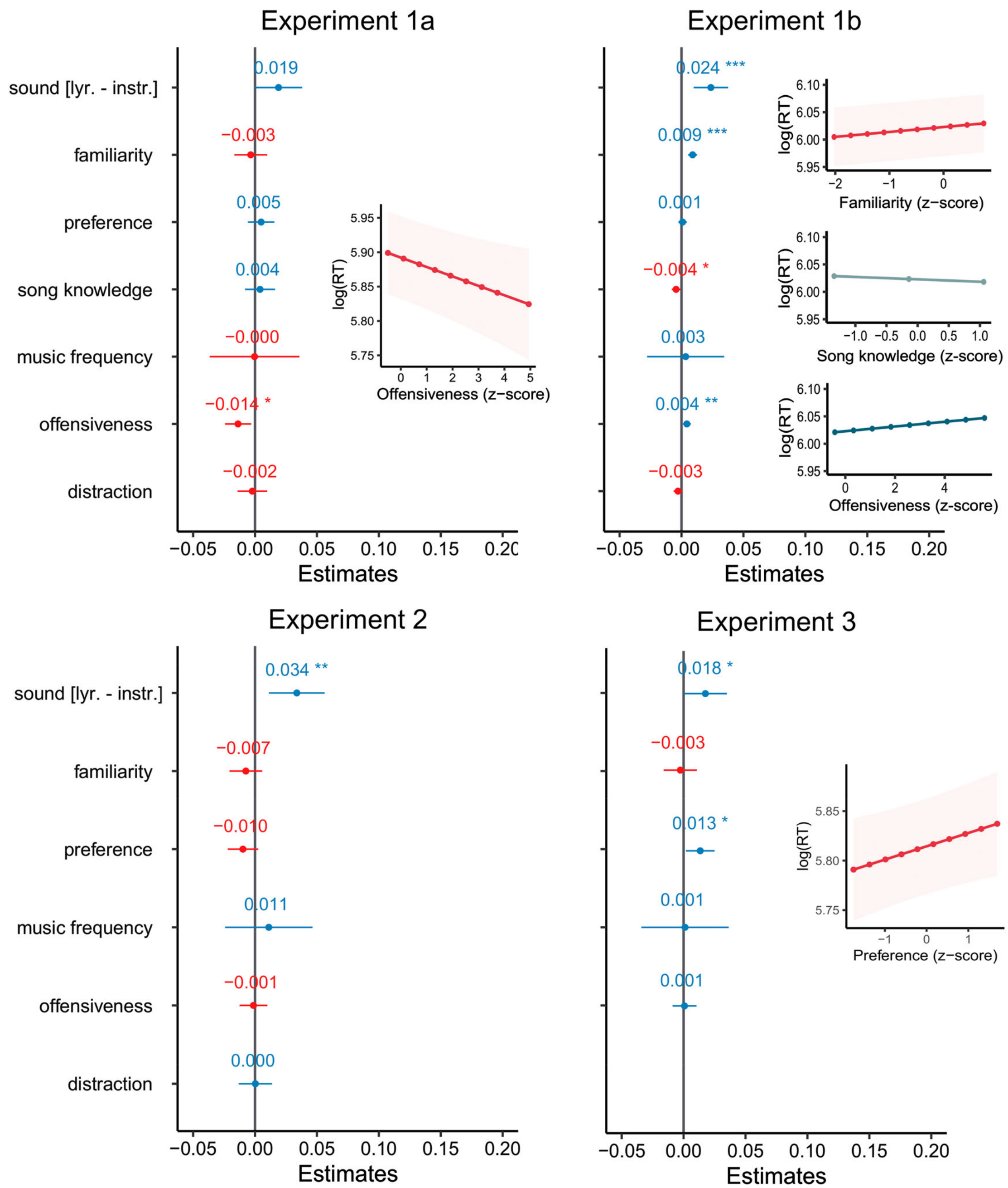

Figure 6. Results from the pre-planned covariate analyses using participants' ratings of the songs, their song knowledge (a composite measure of song title and artist accuracy), and daily music use frequency. Note that only the lyrical and instrumental music conditions are included, as no ratings were possible in the silence and speech conditions. Plotted are the LMM estimates for each predictor in the model. Each slope reflects the unique effect of a given variable, when all other variables in the model are accounted for. The subplots on the right of each panel show a visualisation of the significant effects for that model. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

participants partly derive the identity of songs (as well their familiarity, preference, perceived offensiveness, and distraction) from the lyrics.

In the "unfamiliar" music dataset, the lyrical version of songs was rated as significantly more offensive ($b = 1.028$, $SE = 0.258$, $t = 3.976$) and more distracting ($b = 1.888$, $SE = 0.275$, $t = 6.876$) than the instrumental version. However, there were no significant differences in the other variables (all $|t|$s and $|z|$s ≤ 1.21). Therefore, this suggests that participants' preference for the unfamiliar songs was not confounded by the presence of lyrics, but participants still perceived lyrical music to be more distracting and offensive.

General discussion

The present study used self-paced reading to test whether song lyrics play a key role in distraction by background music. The results from three out of four experiments showed that lyrical music led to slower word reading times, thus indicating that the presence of lyrics in songs caused distraction and reduced overall reading efficiency. Despite this increase in reading times, there was no associated decrease in comprehension in most of the experiments (only Experiment 1b indicated a decrease in comprehension in lyrical compared to instrumental music).

The reading time data generally support previous findings showing that lyrical music is more distracting than instrumental music (Martin et al., 1988; Miller, 2014; Perham & Currie, 2014; Reed, 2019; Vasilev et al., 2018) but contradict others that have shown no such difference (Avila et al., 2012; Furnham et al., 1999; Kyoung, 2020). Still, it is important to keep in mind that Experiment 1a showed no overall evidence of distraction by lyrical music. Therefore, while the present results were also "mixed", on balance, the evidence seems to suggest that lyrics can give rise to distraction.

The inconsistency in the data largely related to the fact that the subsample of participants recruited from Prolific in Experiment 1a did not show distraction by lyrical music. These participants were a much more heterogeneous sample than the university students and were generally older and more educated. Because the samples differed in many ways, it is not possible to pinpoint exactly why a different pattern of results was observed. Still, it may be surprising that the participants in Experiments 2 and 3 did show distraction by lyrical music even though they were also recruited from Prolific. However, it is worth keeping in mind that Experiments 2 and 3 also used different music, so the results are not directly comparable. Therefore, more exact replications are needed to answer this question. Future research examining individual differences such as working memory capacity (e.g. Christopher & Shelton, 2017; Hughes et al., 2013; Robison & Unsworth, 2015; Sörqvist, 2010a, 2010b) may also be worthwhile in explaining why samples taken from different populations may differ from each other, though we note that individual differences are not the only possible explanation for this discrepancy.

It may also be surprising that comprehension accuracy remained unaffected in most of the experiments. We speculate that this may have to do with the nature of the reading stimuli. Because the texts were relatively short, they may not have posed great comprehension demands on participants compared to other previous studies that have used more traditional standardised comprehension tests (e.g. Anderson & Fuller, 2010; Furnham & Bradley, 1997; Martin et al., 1988; Perham & Currie, 2014). Nevertheless, the current research clearly demonstrates that lyrics can interfere with word-level reading processes, as measured by word reading times. This is consistent with eye-tracking evidence showing distraction by irrelevant speech (Cauchard et al., 2012; Hyönä & Ekholm, 2016; Meng et al., 2020; Vasilev et al., 2019; Yan et al., 2018) and music (Zhang et al., 2018) in word fixation times, but not necessarily in comprehension (although see Johansson et al., 2012). In this sense, word reading times can sometimes be sensitive to distraction even when overall comprehension is not affected.

Why are lyrics distracting?

The increase in reading times in lyrical compared to instrumental music can be readily explained by both semantic (Jones & Tremblay, 2000; Marsh et al., 2008, 2009; Martin et al., 1988) and phonological interference theories (Salamé & Baddeley, 1982, 1987, 1989), which assume that either the semantic or phonological content of the lyrics is processed inadvertently and causes interference with the main task due to the use of shared processes. Critically, both theories assume that this interference is language-related.

Language-related distraction fits well with established findings, such as the fact that irrelevant speech interferes with reading processes and that this interference appears to be mostly semantic in nature (Hyönä & Ekholm, 2016; Martin et al., 1988; Meng et al., 2020; Vasilev et al., 2019). This suggests that language (either spoken or sung) may undergo obligatory processing (Crinion et al., 2003; Marsh & Jones, 2010) and interfere with the task at hand. This interpretation is consistent with the results of Experiment 3, where intelligible speech was just as distracting as lyrical music when the two were matched on language rate. At present, it is not clear if phonological or semantic information from the lyrics was responsible for the observed distraction. However, future studies comparing the same song in different languages (e.g. Chew et al., 2016) may possibly adjudicate between the two views.

While the phonological interference theory predicts that even a foreign language would gain access to the phonological loop and cause distraction (e.g. Baddeley & Salamé, 1986), it is not clear if all foreign languages should be equally distracting. For example, it can be argued that languages with more dissimilar phonology to one's native language may be less distracting due to differences in phonemes and phonological rules. There is some evidence from serial recall that greater phonological similarity between the irrelevant sound and the to-be-recalled stimuli does not necessarily increase distraction (e.g. Jones & Macken, 1995; Larsen et al., 2000; LeCompte et al., 1997). However, the phonological structure of the language has generally not been considered, particularly for more complex sounds such as speech and music. Therefore, this is a potential issue that needs to be considered in future research.

Additionally, we used music with a lyrics rate of ~150 wpm, but it is not clear if songs with a lower lyrics rate (say, 50–75 wpm) would cause less distraction. We speculate that this may be the case as such songs should engage the cognitive processes used in the main task to a lesser extent. For instance, in the framework of semantic/ phonological interference theories, songs with a lower lyrics rate may engage semantic/ phonological processes to a lesser extent and thus cause less interference between the task-irrelevant auditory stream and task-relevant visual stream. However, whether this is the case, remains to be tested.

It is interesting to note that language-related theories reduce distraction to the processing of the language within the lyrics, but ignore other factors such as the musical prosody of the lyrics and the way they are sung. To our knowledge, Martin et al. (1988, Experiment 2) is the only study to consider this question. They found no difference between sung and spoken lyrics, which led them to believe that the musicality of the sung lyrics played no role in distraction. However, lyrics clearly contain other information as well, such as the voice, vocal characteristic, and identity of the singer. This information could in turn influence participants' memory and perception of the music.

The song ratings demonstrated this very clearly. The "familiar" set of songs used in Experiments 1a-1b were more recognisable and were rated as more preferred, pleasant, and familiar when heard in the lyrical compared to the instrumental condition. No such difference was observed for the "unfamiliar" set of songs used in Experiments 2-3, which virtually no participants could recognise. These results suggest that, for "familiar" songs, participants' perception and recollection of the music is intrinsically linked to the lyrics, thereby introducing potential confounds when trying to isolate the unique role of language. These results agree with previous research showing that the recognition of melodies is better when they are presented vocally rather than instrumentally (Weiss et al., 2012; Weiss, Schellenberg, et al., 2015; Weiss, Vanzella, et al., 2015), even if the melody is sung in a different voice (Weiss et al., 2017). Therefore, it is not surprising that participants partly derive the identity of the songs from their lyrics.

Clearly, this poses a problem as any performance differences between lyrical and instrumental music could simply occur because the two conditions are perceived differently by participants. One way to avoid such confounds is to use only unfamiliar music, as some studies have done in the past (e.g. Furnham et al., 1999; Furnham & Allass, 1999; Kyoung, 2020). Another way is to statistically control for such variables, which was the approach taken here. The covariate analysis suggested that the main results remained unchanged after accounting for the effect of song knowledge and music ratings. However, some effects of familiarity, preference, offensiveness, and song knowledge emerged. These effects were not consistently observed across all experiments, so their implications are not immediately clear. While more research is needed to better understand their effect on distraction, the present study does show that there is some value in tracking such variables.

Is instrumental music distracting?

One interesting result in the present research was that instrumental music did not cause any distraction compared to the silence baseline. This agrees with previous meta-analysis results showing that instrumental music also does not cause distraction in comprehension accuracy compared to silence (Vasilev et al., 2018). Nevertheless, the primary literature has shown somewhat mixed results. For instance, while some studies have reported no difference between instrumental music and silence (Cauchard et al., 2012; Martin et al., 1988; Perham & Currie, 2014), others have reported that instrumental music causes distraction (Avila et al., 2012), and yet others have reported that instrumental music improves performance compared to silence (Falcon, 2017; Mullikin & Henk, 1985). The present research showed a combination of no effects and positive effects, but crucially no hint of any distraction. This suggests that music instrumentals are not sufficient on their own to negatively affect reading performance. Therefore, given that students (Calderwood et al., 2014; David et al., 2015) and office employees (Haake, 2006) often report listening to music while studying or doing work, it seems prudent to recommend listening to instrumental rather than lyrical music when reading.

One unexpected finding was that instrumental music improved performance compared to the silence baseline, though this was statistically reliable only in Experiment 3 (a similar trend in the data was also present in Experiment 2). One possible explanation for this finding is that instrumental music may lead to an increase in arousal (Dillman Carpentier & Potter, 2007; Furnham et al., 1999), which could temporarily boost performance. We speculate that such improvements may be more difficult to sustain with tasks that involve reading longer texts. However, more research is needed to better understand this issue.

Limitations and future directions

The present study also had a few limitations. First, the reading stimuli consisted of passages that were short and easy to read. This was done to ensure that the stimuli can be read quickly in an online study format, as longer experiment times can negatively affect data quality (Sauter et al., 2020). However, one consequence of this is that the stimuli may not have been very challenging for our participants, potentially leading to smaller distraction effects.

Second, because previous words in the text were masked, participants could not go back to re-read them (i.e. make regressions). We chose to mask previous words because it prevents participants from pressing the button in quick bursts to reveal the whole text, before they actually start reading it (Just et al., 1982). This was especially important as most participants completed the task in an unsupervised environment at home. However, this had the consequence that the task deviated from "natural" reading. We argue that the present paradigm is still useful in understanding reading processes in an online environment where more complex methodology (e.g. eye-tracking) cannot be used. The fact that we were able to observe distraction after all shows that such effects occur even in the absence of regressions. Future studies could address this limitation by using bi-directional self-paced reading (Paape & Vasishth, 2022), where participants can move both forward and backwards in the text.

Nevertheless, it is interesting to note that Vasilev et al. (2019, Experiment 3) used a similar masking paradigm and found that comprehension accuracy was disrupted by irrelevant speech, but that there was limited distraction in first-pass fixation durations. While the present study generally did not find distraction in comprehension (perhaps due to the simpler reading stimuli), we did find mild distraction in reading times that curiously had similar effect sizes in Cohen's *d* to those reported by Vasilev et al. in their first-pass fixation data. Of course, the present self-paced reading times are not directly comparable to first-pass fixation durations. Self-paced reading times are generally longer due to the need for a manual response and processing effects can be delayed and spill over to the next word (Jegerski, 2014). However, what both studies show is that distractors such as music and speech have very mild effect on the initial reading of individual words. Of course, even such mild delays can begin to add up when many words need to be read.

Third, the present study also differed in that it used more heterogeneous samples compared to the typical university student population. This arguably made it more difficult to interpret the results and compare them to those of previous studies. We do not necessarily view this as a limitation because any distraction effects that are meaningful in practice should be replicable in different populations, paradigms, and testing conditions. Clearly, online data testing has the potential to reach more diverse populations of readers and we believe that this will prove important for understanding how distraction occurs in the real world.

Finally, participants' ratings of the songs were based on single items that have not been standardised or psychometrically validated. While such items have often been used in previous research (e.g. Perham & Currie, 2014; Perham & Sykora, 2012), more precise scales should be developed in the future to better capture participants' perception of the songs.

Conclusion

The present study tested whether song lyrics are a key component of what makes background music distracting. In three out of four experiments, we observed that lyrical music led to longer self-paced reading times compared to instrumental music. This suggests that lyrics interfere with reading by making it slightly less efficient. Despite this, the observed effects were quite mild, suggesting that readers were mostly able to overcome the music distraction. On the other hand, instrumental music did not lead to any distraction, which seems to suggest that it has no negative influence on how participants process the text. Finally, the study also uncovered that "familiar" lyrical songs are both more recognisable and rated differently compared to the instrumental version of the same songs. This suggests that future studies need to take these differences into account. In summary, the present research provides some initial evidence that lyrics can cause distraction, but more research is needed to better understand why this is the case.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability

The data and materials from this study are available at: https://osf.io/8zw4x/.

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