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Background music stints creativity: Evidence from compound remote associate tasks

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Summary

Background music has been claimed to enhance people's creativity. In three experiments, we investigated the impact of background music on performance of Compound Remote Associate Tasks (CRATs), which are widely thought to tap creativity. Background music with foreign (unfamiliar) lyrics (Experiment 1), instrumental music without lyrics (Experiment 2), and music with familiar lyrics (Experiment 3) all significantly impaired CRAT performance in comparison with quiet background conditions. Furthermore, Experiment 3 demonstrated that background music impaired CRAT performance regardless of whether the music induced a positive mood or whether participants typically studied in the presence of music. The findings challenge the view that background music enhances creativity and are discussed in terms of an auditory distraction account (interference-by-process) and the processing disfluency account.

KEYWORDS

Compound Remote Associate Tasks, creativity, distraction, insight, music

Creativity is a vital aspect of cognition underpinning activities such as innovative product design, scientific advancement, and effective advertising and marketing communications. Background music is an environmental stimulus known to influence cognitive performance, which has also been claimed to enhance people's creativity for tasks involving spatial abilities such as drawing (see Schellenberg, Nakata, Hunter, & Tamoto, 2007). We argue, however, that there is limited empirical support for the claimed benefits of background music on creativity, with to our knowledge only one other study (i.e., Ritter & Ferguson, 2017) demonstrating a facilitatory effect on creativity of background music that participants were free to attend to for a task that involved participants listing novel, alternative uses for a common object (i.e., a brick). Another reason to be cautious regarding the notion that background music can enhance performance on tasks tapping creative cognition is the presence of a substantial research base demonstrating that *to-be-ignored* background sound impairs task performance (Beaman, 2005; Hughes & Jones, 2003).

In the present paper, we critically examine the claim that background music enhances creativity by employing variants of widely used verbal problem solving tasks that are typically used to study creativity (Ansburg, 2000; Fodor, 1999; Mednick & Mednick, 1967; Mehta, Zhu, & Cheema, 2012; Mikulincer & Sheffi, 2000; Storm, Angello, & Bjork, 2011) being indexed by, and solved via, a process of insight: Compound Remote Associate Tasks (CRATs; e.g., see Bowden, Jung-Beeman, Fleck, & Kounios, 2005; see below for further explanation). We contrast two competing accounts of the impact of background music on creative problem solving: (a) the processing disfluency account (Mehta et al., 2012), in which background music potentially enhances creativity by engendering processing disfluency and thence increased task engagement; and (b) the auditory distraction (interference-by-process) account (e.g., Jones & Tremblay, 2000; Marsh, Hughes, & Jones, 2009; Perham & Vizard, 2010), which assumes that the presence of any type of auditory

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distractor sequence will disrupt cognitive task performance providing it demonstrates changing-state characteristics. That is, auditory sequences in which a series of elements differ from one element to the next (such as tones, syllables, and words) in terms of frequency/pitch/timbre are more disruptive than a series within which the same element is repeated such as the same tone, syllable, or word. It has been shown, for example, that the latter, steady-state stimuli typically fail to disrupt short-term memory performance (e.g., Jones & Macken, 1993). It is worth noting here that in addition to this "acoustic interference-by-process," an interference-by-process can also operate at a semantic level due to a clash between two concurrent semantic processes: a deliberate one applied to the to-be-remembered material and one applied automatically to the to-be-ignored auditory material (Marsh et al., 2009; Marsh, Hughes, & Jones, 2008). The focus of the current paper, however, is on the acoustic interference-by-process (e.g., Jones & Tremblay, 2000).

Prior to considering the relationship between background music and creative problem solving performance, it is useful to note that researchers have traditionally made a key distinction between two types of creative thinking, that is, divergent thinking versus convergent thinking (Guilford, 1967). Divergent thinking refers to a strategy whereby multiple creative ideas are produced and appraised within a short period of time in order to generate potential solutions for a given problem. A typical task involving divergent thinking is the Alternative Uses Task, wherein participants are required to think of as many uses as possible for a simple, everyday object such as a brick or paperclip (cf. the aforementioned study of music and creativity by Ritter & Ferguson, 2017). Convergent thinking, on the other hand, permits the connection of different ideas to determine a single, correct solution to a problem. Importantly, tasks involving creative convergent thinking—including the CRATs that we employed in the present study, as discussed below—may do so on the basis of associations and potential solutions generated through divergent thought.

It is additionally important to note that creative problem solving, whether underpinned by divergent or convergent thinking, is often characterised by the ability to perceive a problem space in new ways by discovering hidden patterns or by connecting seemingly unrelated ideas (e.g., Ohlsson, 2011). One key way in which creative problem solving comes about is by means of so-called *insight*, with tasks involving creative thinking typically being solved via insight processes. Accounts of insight in problem solving such as the "special-process theory" (e.g., Ball & Stevens, 2009; Bowden et al., 2005) argue that problems that tend to be solved via an insight process call upon very different processing mechanisms to "noninsight" problems. For example, Jung-Beeman et al. (2004) identified neural patterns just prior to the emergence of insight that demonstrate a hemispheric shift in processing occurring at this point. Jung-Beeman et al. (2004) propose that during insight problem solving loose associative processing occurring nonconsciously in the right temporal lobe takes precedence over finer-grained processing in the left hemisphere, implying that neural areas linked with diffuse associative processing are critical for the emergence of creative insight (for a recent review of related findings, see Shen, Yuan, Liu, & Luo, 2017).

Several researchers suppose that an insight sequence defines creative thinking and that any advance in thought that is not characterised by such a sequence is therefore not creative (e.g., Ohlsson, 2011; Perkins, 2000; Wiley & Jarosz, 2012; but see Weisberg, 2015). This unique sequence of events that defines insight in problem solving comprises: presentation of the problem, repeated failure, impasse, restructuring, and an "Aha!" experience that is associated with solution generation. According to this sequence of events, failed attempts to solve a problem can lead to an *impasse*, whereby the participant, after several unsuccessful attempts at solving the problem, feels they are unable to move forward to reach a solution. After a period of failing to make progress, an abandoning of the original problem structure occurs and a new representation of the problem is formed through restructuring, which may itself be based on processes such as spreading activation in associative networks (see Shen et al., 2017). Such problem restructuring may then lead to the emergence of a solution. Crucially, problems that are typically solved by insight often cannot readily be solved via routine search processes. This is because the starting conditions, goals, and possible sequences of actions are ambiguous (i.e., a heuristic-type search within the *original* problem representation will not yield a solution).

As we have noted, our present research used CRATs as a measure of insight-based creative problem solving (Bowden & Jung-Beeman, 1998). A CRAT involves a participant being shown three words (e.g., dress, dial, and flower), with the requirement being to find a single associated word (in this case "sun") that can be combined with each presented word (either being placed before it or after it) to make a common word or phrase (i.e., sundress, sundial, and sunflower in the present example). CRATs are variants of problems referred to as Remote Associate Tasks (RATs; see Mednick, 1962; Mednick & Mednick, 1967), for which the solution can be associated with each of the provided three words in different ways. For example, a RAT (e.g., same, tennis, and head), in contrast to a CRAT, can be solved by means of semantic association (tennis match), synonymy (same = match) and, as with CRATs, the formation of compound words (matchhead).

Nowadays, both RATs and CRATs are commonly used tests of creativity within psychology and cognitive neuroscience. They have been employed, for example, to examine creativity in relation to sleep (e.g., Cai, Mednick, Harrison, Kanady, & Mednick, 2009), memory (e.g., Storm et al., 2011), attention (e.g., Ansburg & Hill, 2003), and attentional deficit hyperactivity disorder (e.g., White & Shah, 2011), and they have additionally been employed in neuroimaging studies of creativity (e.g., Arden, Chavez, Grazioplene, & Jung, 2010). According to Bowden and Jung-Beeman (2003), the popularity of these problems resides in the fact that they have an unambiguous, single-word answer, and that multiple items can be solved in a single session. Furthermore, RATs and CRATs are less complex than classic insight problems such as the candle problem or two-string problem (see Weisberg, 1995), such that they are less susceptible to confounding of variables. These characteristics made these problems very appealing for the current investigation.

Problem solving performance on RATs and CRATs has been found to correlate with performance on other creative tasks such as rebus puzzles (MacGregor & Cunningham, 2008; see Threadgold, Marsh, & Ball, 2018, for further discussion) and classic insight tasks (Schooler & Melcher, 1995; but see Webb, Little, Cropper, & Ruze, 2017). Such patterns of association suggest that RATs and CRATs represent effective tests of creativity. Moreover, these problems also appear to involve "the same component processes critical for, and the same phenomenological experience of, insight solutions to more complex problems" (Bowden & Jung-Beeman, 2003, p. 634; see also Bowden & Jung-Beeman, 2007). For example, the problems initially misdirect or fail to direct retrieval processes, thereby leading to an impasse. In addition, solvers often report an "Aha!" experience on task completion. As well as being characterised by the insight sequence, RATs and CRATs also appear to be underpinned by a range of other processes, including unconscious spreading activation in associative networks (Smith, Huber, & Vul, 2013), conscious verbal processes such as subvocal rehearsal (Ball & Stevens, 2009), and executive processes such as those that inhibit incorrect solution ideas and enable the active manipulation of information in working memory (Chein & Weisberg, 2014; Storm & Angello, 2010).

Although there is a paucity of research examining the effects of background music on creativity, there is a small literature on the impact of noise on creative cognition, with this research having typically used RATs, but occasionally other creative tasks too (Hillier, Alexander, & Beversdorf, 2006; Kasof, 1997; Martindale & Greenough, 1973; Mehta et al., 2012). For example, aperiodic noise such as white noise and pink noise has been shown to affect creativity, as measured using RATs. For example, Martindale and Greenough (1973; 75 dB) and Hillier et al. (2006; 90 dB) showed that a high intensity white noise, compared with a no noise control condition, impaired task performance. Moreover, Kasof (1997) reported that a high level (85 dB[A]) of intermittent, compared with continuous, pink noise reduced creativity as measured with a poetry writing task. In contrast, Toplyn and Maguire (1991) found that highly creative participants (as gauged by their performance on RATs) demonstrated greater creativity on other tasks when exposed to 80 dB white noise, compared with when exposed to 60 or 100 dB white noise.

Mehta et al. (2012) used more naturalistic, ambient noises to resemble restaurant noise, wherein distant construction noise, multitalker babble, and roadside traffic were blended and reported that a moderate level of noise (70 dB), as compared with low level noise (50 dB), improved performance on creative tasks. These tasks included RATs (Experiment 1), a task wherein participants generated novel ideas for improving mattress comfort (Experiment 2), a task requiring the generation of alternative uses for a brick (Experiment 3), and a task concerning how to clean scuffed shoes with no polish (Experiment 4). Of relevance to the present study, participants generated more correct answers to RATs in the presence of moderate noise compared with a low level of noise and a high level of noise (85 dB).

We note here, however, that in contrast with the RATs, the other tasks used by Mehta et al. (2012) arguably make less demands on verbal working memory. Indeed, these tasks tap divergent thinking in that they require the production of multiple responses in a manner similar to standard verbal fluency tasks. Verbal fluency tasks require the production of numerous responses given a phonemic (produce words beginning with the letter "F") or semantic (produce as many examples of "Fruit") cue within a time limit (Jones, Marsh, & Hughes, 2012; Marsh, Crawford, Pilgrim, Sörqvist, & Hughes, 2017). Although some aspects of the task, such as the requirement to maintain memory for previously produced responses to avoid repetition tap verbal working memory, these tasks are not characterised by continuous generation and testing of word combinations and maintenance of intermediate solutions that distinguish the convergent thinking underpinning the RAT. Indeed, perhaps it is no surprise that tasks that tap divergent thinking such as category fluency tend to be immune to disruption produced by changing-state background sound, unless it conveys semantic content (Jones et al., 2012). In this respect, our focus was on the variant of the RAT (i.e., the CRAT), since in contrast to divergent thinking tasks, CRATs should be more sensitive to disruption produced by the changing-state acoustic properties of background sound.

An alternative account of the relationship between background sound and creativity holds that benefits to cognitive task performance can be observed through mood and arousal (for a review, see Schellenberg, 2005). For example, Thompson, Schellenberg, and Husain (2001) showed that performance on tests of spatial abilities was improved when the tasks were executed after listening to music rated as "liked" by participants, as opposed to being exposed to quiet. Moreover, the improvement in performance was driven by changes in arousal and mood produced by listening to the music. It is important to note that mood and arousal are not the same construct. For example, mood can be decreased and arousal can be increased when music is disliked. It is possible that the effects of music on cognitive task performance are driven by changes to both mood and arousal, with increases in both leading to enhanced performance.

A recent study by Ritter and Ferguson (2017) required participants to undertake tasks involving creative cognition while concurrently listening to music or exposure to quiet. In a between-participants design, Ritter and Ferguson showed that a beneficial effect of music on creative task performance was limited to a comparison between a silent condition and a so-called "happy music" condition (Vivaldi's "Four Seasons"). Exposure to "calm music," "sad music," and "anxious music" had no impact on creative task performance compared with quiet (but see Perham & Withey, 2012, for evidence of enhanced spatial rotation performance following listening to slow-tempo, sad music of a participant's own choosing compared with a slow-tempo control excerpt). In line with the notion that changes to mood and arousal may collectively enhance creative task performance, participants in Ritter and Ferguson's (2017) study assigned more positive mood and higher arousal to the happy music condition in comparison with the other conditions. Therefore, the benefit to creative task performance could have been driven by increases in mood and arousal rather than the presence of the music per se.

Although the notion that increases in both mood and arousal can benefit creativity has some appeal, we note that Ritter and Ferguson (2017) did not report statistical comparisons between all of the music conditions in their between-participants design, which potentially undermines their conclusions. Furthermore, Mehta et al. (2012) propose that arousal-based explanations of the impact of to-be-ignored noise on creativity are insufficient because over a longer period of exposure to the sound, physiological arousal levels should normalise and cease to have a consistent influence. Thus, Mehta et al. argue that arousal is not the key contributing factor to the impact of to-be-ignored noise on creativity. They instead propose that moderate noise levels increase *processing disfluency*, with this processing disfluency increasing *construal levels*, thereby promoting more abstract thinking. More specifically, when construal levels are high, then individuals will engage in abstract thought to consider the "bigger picture" rather than focus on specific details (e.g., see Burgoon, Henderson, & Markman, 2013). Such high-level construal involves a focus on the commonality and central features of a situation such that its overall gist can be extracted. In contrast, the overall gist of a situation is less likely to be extracted when construal levels are low because people focus on peripheral (or secondary) features. In support of the influence of high-level construal on creativity, research has demonstrated that performance on a wide range of creativity tasks can benefit from the experimental induction of abstract levels of thought (Friedman & Förster, 2002; Förster, Friedman, & Liberman, 2004).

The processing disfluency account has its conceptual basis within research on metacognition, which focuses on processes that monitor and control cognition (Ackerman & Thompson, 2017a,b). Such metacognitive processes are involved in people's subjective judgements of how well a current task is being, could be, or has been performed. Metacognitive control processes about one's current task can be applied to initiate, terminate, or change the allocation of time, effort, and cognitive resources to the task (Ackerman & Thompson, 2017a). One of a variety of cues on which metacognitive monitoring is based is the subjective ease of processing (fluent vs. disfluent; easy vs. difficult) that derives from one's own experience at attempting the task. Subjective experiences of task difficulty can catalyse a shift in processing and engender increased task engagement (e.g., Alter, Oppenheimer, Epley, & Eyre, 2007; Rummer, Schweppe, & Schwede, 2016).

Attempts to comprehend metacognitive modulation of thought have typically evoked dual-process theories, which posit the existence of two qualitatively distinct types of thinking: Types 1 and 2 processes (Evans & Stanovich, 2013a,b). Type 1 processes are autonomous and undemanding of working memory (a concept used in ways that links to notions of executive and attentional control) and tend to be fast, nonconscious, intuitive, and associative. On the other hand, Type 2 processes rely on working memory (including executive and attentional control) and are focused on cognitive decoupling and mental simulation, critical for hypothetical thinking. Type 2 processes also tend to be slow, conscious, analytic, and deliberative. Type 2 processes can be activated if the monitoring system—as part of the metacognitive architecture—judges that a task is difficult (e.g., Bjork, Dunlosky, & Kornell, 2013; see also Thompson, 2010). Mehta et al. (2012) argue that the presence of noise creates processing disfluency and supports a processing shift inducing higher construal levels and more abstract thinking that is presumably linked to more diffuse associative processing of the type that is known to arise in creative insight. For example, in the case of CRATs, diffuse associative processing could cause spreading semantic activation within a network of associates yielding convergent activation on the word that the three seemingly unrelated words have in common, thereby yielding the solution (see Bowden & Beeman, 1998; Shen et al., 2017).

That background sound can *improve* performance on creative tasks contrasts with a large literature relating to distraction of human cognition through exposure to noise (for reviews, see Beaman, 2005; Hughes & Jones, 2003). The task typically used to illustrate the vulnerability of cognition to disruption by the mere presence of to-be-ignored background sound is short-term visual–verbal serial recall (Colle & Welsh, 1976; Jones & Macken, 1993; Salamé & Baddeley, 1982). This task involves the visual presentation of verbal items (e.g., seven or eight letters or digits) with the requirement to recall these items according to the serial order in which they were presented. Initial work suggested that this disruption arose because the sound was composed of speech. However, the semantic properties of speech were found to be impotent in their capacity to disrupt serial recall: speech presented in a language understood by the participant produces no more disruption than that produced in a language incomprehensible to the participant (Jones, Miles, & Page, 1990). Thus, semantic properties of the to-be-ignored background sound were irrelevant to the level of disruption caused. Similarly, the notion that the disruption by background sound arose due to a confusion between phonemes derived from the visual items (via their covert articulation) that gain direct (spoken items) and indirect (visual items) access into a phonological store (Salamé & Baddeley, 1982) was undermined by findings that serial recall was shown to be susceptible to disruption by the presence of background music without lyrics, and therefore phonemes (Klatte, Kilcher, & Hellbrück, 1995; Klatte, Lachmann, Schlittmeier, & Hellbrück, 2010; Nittono, 1997; Salamé & Baddeley, 1989; Schlittmeier, Hellbrück, & Klatte, 2008), and by the presence of sequences of tones, provided they change from one successive tone to the next (Divin, Coyle, & James, 2001; Elliott, 2002; Jones & Macken, 1993).

The key empirical referent for this so-called "irrelevant sound effect" is the *changing-state effect*. This concerns the finding that a changing sequence of sounds, regardless of whether the changes occur on a speech carrier (e.g., a sequence of different verbal tokens) or a nonspeech carrier (e.g., a sequence of tones of different frequency), disrupts serial recall to a far greater extent than a nonchanging or steady-state sound (e.g., a repeated token or tone; Jones & Macken, 1993; Jones, Madden, & Miles, 1992). According to the *interference-by-process* approach (e.g., Jones & Tremblay, 2000), the pre-attentive processing of the order of changes within sound impairs the deliberate serial rehearsal process that supports the ordered recall of to-be-remembered items.

Given that the solving of CRATs appears to be underpinned by verbal processes such as subvocal rehearsal (Ball & Stevens, 2009) in addition to executive processes (Chein & Weisberg, 2014) and spreading activation in associative networks (Smith et al., 2013), we expect CRATs to be susceptible to disruption by the presence of to-be-ignored background music. Our rationale behind suggesting that verbal processing of CRATs will be susceptible to changing-state distraction is supported by the findings that impairment of CRAT performance through concurrent articulatory suppression is observed within this procedure, whereas facilitation of CRAT performance occurs via encouraging verbalisation through the "think aloud" technique (Ball & Stevens, 2009). Thus, the availability of speech (inner speech or external speech) is necessary for efficient CRAT problem solving performance. In the context of serial recall, the skill of speech (or rather speech planning) is co-opted because it provides an effective medium for retaining visual–verbal items due to its inherent sequentiality, continuity, and prosodic and co-articulatory nature. Inner speech therefore enables the grafting of serial order constraints onto the presented list; the act of covertly co-articulating to-be-remembered items generates sequential information and constraints that do not occur within the list itself. However, this motoric based serial rehearsal process is subject to interference from the automatic, pre-attentive processing of the serial order of changes in a background auditory sequence (such as music).

In our recent work, it is becoming clearer that tasks that may not necessarily involve serial rehearsal, but that do involve the use of inner speech for effective task performance (e.g., face recognition; Marsh et al., 2018) are also vulnerable to the changing-state effect. Of course, speech (inner or outer) involves planning of sequential motor acts, which may render it vulnerable to disruption via changing-state speech in many settings. In the context of CRATs, inner (and outer) speech clearly supports effective performance (Ball & Stevens, 2009). It may even be that participants use serial rehearsal to test out novel solutions.

We do not claim that CRAT performance is underpinned *entirely* by verbal maintenance processes. Rather, it is clear that spreading semantic activation processes (Smith et al., 2013), and executive processes that are involved in generating response candidates and inhibiting misleading/incorrect solutions (Storm & Angello, 2010) are also central to the production of responses. That said, it is often not clear which component of a multicomponent task is associated with CRAT performance. For example, the finding of an association between Working Memory Capacity measures and CRAT performance (Chein & Weisberg, 2014) could be due to the role of attentional/cognitive control (which may involve executive control processes such as inhibition) or the requirement to retain serial order information: Working Memory Capacity tasks involve combining the short-term storage of visual/verbal items with a concurrent processing task. Therefore, we hold that subvocal maintenance processes involving inner speech can underpin solution of CRATs and that this process is susceptible to disruption via processing of a changing-state auditory sequence. The aim of the series of three experiments that we present here was to investigate the impact of to-be-ignored background sound (i.e., music with foreign, [unfamiliar] lyrics; instrumental music; and music with familiar lyrics) on tasks believed to measure creativity, that is, CRATs.

1 | EXPERIMENT 1

The aim of Experiment 1 was to establish if music with unfamiliar lyrics facilitates creativity as measured via performance with CRATs through engendering processing disfluency (Mehta et al., 2012), or impairs creativity, possibly due to the disruption of verbal processes such as subvocal rehearsal (Ball & Stevens, 2009) due to its changing-state characteristics. To investigate these two competing accounts and opposing predictions, we contrasted performance in a quiet condition to a condition with to-be-ignored background music with clearly discernible lyrics in a foreign language that were unfamiliar to the participants (i.e., the musical excerpt contained Spanish lyrics presented to native English speakers; thus, the lyrics were both *unfamiliar* and *meaningless* to the participants, who were unable to process their semantic content). As such, any observed disruption could not be viewed as being attributable to interference between the semantic properties of the to-be-ignored sound and the semantic processes underpinning the solving of CRATs (see Marsh et al., 2008, 2009). If unfamiliar music engenders processing disfluency (cf. Mehta et al., 2012), then one should observe better performance when music, as compared with quiet, accompanies problem solving. However, if verbal processes underpinning CRAT performance are susceptible to disruption via changing-state irrelevant sound—as the interference-by-process account would assume (Jones & Tremblay, 2000)—then performance should be poorer in the presence of music as compared with quiet.

1.1 | Method

1.1.1 | Participants

Thirty adults (15 female and 15 male) from the University of Central Lancashire participated in the experiment (*M* = 22 years, *SD* = 2.78, age range 19 to 30 years old). The participants were recruited via an opportunity sample. Participants received course credit or the standard department payment rate in exchange for 30 min of participation time. All participants spoke English as their first language and reported normal (or corrected-to-normal) vision and hearing. The experiment received Ethical Clearance from the University of Central Lancashire.

1.1.2 | Design and materials

The design was a fully within-participants 2 × 2 design with Sound (Quiet vs. Spanish Music) and CRAT Difficulty (Easy vs. Difficult) as the factors. A set of 38 CRATs were selected from the problems developed by Bowden and Jung-Beeman (1998) using the program "Match" (Van Casteren & Davis, 2007). Match automates the selection of several groups of smaller stimuli sets from a larger pool ensuring the groups are matched on multiple dimensions. Here, the sets of CRATs were matched on solution accuracy and solution time data provided by Bowden and Jung-Beeman (1998). Each CRAT consisted of the presentation of three single words, with the participant having to find a word that combines with each of the three presented words to make a common word or phrase. For example, if participants are presented with the words *stick/maker/point*, then the word that links with each of these is the word *match* to create the phrases or words *matchstick*, *match maker*, and *match point*. Therefore, the answer or target in this instance would be the word "match."

The 38 selected CRATs were divided into a set of 20 easy CRATs (Easy CRATs' solution rates: *M* = 68.9%, *SD* = 16.2, Easy CRATs' solution times: *M* = 8.23 s, *SD* = 2.61) and 18 difficult CRATs (Difficult CRATs' solution rates: *M* = 26.6%, *SD* = 14.3, Difficult CRATs' solution times: M = 12.1 s, SD = 3.07). Each difficulty set was then further divided into two equal matched sets (Set A solution rates: M = 49.4%, SD = 26.1, solution times: M = 9.98 s, SD = 3.6 vs. Set B solution rates: M = 48%, SD = 27, solution times: M = 10.1 s, SD = 3.3) as indexed by normative data on solution rate and solution time data for 30-s presentation time provided by Bowden and Jung-Beeman (1998). It is typical to divide CRAT sets into easy and difficult (Ball & Stevens, 2009). Difficult, but not easy, problems can benefit from overt verbalisation, whereas preventing subvocalisation via requiring participants to suppress articulation while problem solving can hinder performance with both easy and difficult problems (Ball & Stevens, 2009). Although not a primary goal of the study, we nevertheless considered it important to investigate the potential differential susceptibility to distraction of easy and difficult problems. The experiment was fully counterbalanced such that each CRAT set appeared within each sound condition.

1.1.3 | Procedure

Participants read an information sheet and completed a consent form prior to taking part in the experiment. Participants were given instructions for the CRATs that explained the need to find one target word per problem, that, when combined with the three presented words (either before or after the presented words), created a common word or phrase. Prior to the test problems, participants were asked to tackle five practice problems to ensure familiarity with the task. These practice problems were also selected from Bowden and Jung-Beeman (1998). Participants were allocated 30 s per CRAT item. All three problem words were presented simultaneously along the same horizontal plane.

The music was played via Sennheiser HD-202 headphones at approximately 65–70 dB(A). The music was a 30-s segment of a Spanish translation of a 1990s UK chart pop song played via E-Prime Software that contained clearly discernable lyrics and accompanying instruments. The music contains appreciable acoustic variation and satisfied the criterion for being a changing-state stimulus. In the sound condition, this music segment accompanied each CRAT problem, starting with the onset of the problem and ending once the participant indicated they had solved the CRAT by pressing the spacebar. After participants pressed the spacebar, a textbox appeared wherein participants typed their answer. Participants were asked to complete the CRATs while ignoring the background sound. They were also reassured that they would not be asked anything about the background sound. Participants were fully debriefed at the end of the task and thanked for their participation. During debriefing, participants were presented with the auditory stimuli they were exposed to during the experiment and asked if they were familiar with the song or had heard it before in experiment; none replied that they were or had.

1.2 | Results

The data for each of the three experiments can be found via the following link: https://osf.io/j6hwd/. The basic data pattern for the present experiment indicated that CRAT solution rates were higher in the quiet condition in comparison with the music condition. Furthermore, a greater number of easy CRATs were solved in comparison with difficult CRATs. To examine the data further, a 2 (Sound: Quiet vs. Spanish Music) × 2 (CRAT Difficulty: Easy vs. Difficult) within-participants analysis of variance (ANOVA) was conducted on mean solution rates (i.e., proportion correct). An alpha level of $p < 0.05$ was adopted for all statistical tests. There was a significant main effect of Sound, $F(1, 29) = 9.91$, $MSE = 0.01$, $p = 0.004$, $\eta_p^2 = 0.25$. Significantly more CRATs were solved in the quiet condition (M = 0.43, SE = 0.04) in comparison with the Spanish music condition (M = 0.36, SE = 0.05). There was a main effect of CRAT Difficulty, $F(1, 29) = 63.36$, $MSE = 0.02$, $p < 0.001$, $\eta_p^2 = 0.67$, with significantly higher solution rates for the easy CRATs (M = 0.49, SE = 0.04) in comparison with the difficult CRATs (M = 0.29, SE = 0.05). There was no significant Sound × CRAT Difficulty interaction, $F(1, 29) = 1.36$, $MSE = 0.02$, $p = 0.25$, $\eta_p^2 = 0.05$.

1.3 | Discussion

The aim of Experiment 1 was to compare CRAT performance in a quiet condition to performance when ignoring background music with unfamiliar foreign lyrics. Significantly more CRATs were solved in the quiet condition relative to the background music condition. As anticipated, there was a significant difference in solution rates for the easy versus the difficult CRATs. Furthermore, there was no significant interaction between Sound and CRAT Difficulty for solution rates. That Sound impaired CRAT performance regardless of problem difficulty coheres with the findings of Ball and Stevens (2009), who demonstrated that articulatory suppression similarly impaired performance with easy and difficult tasks. However, the results are inconsistent with the general view that music enhances creativity, and dispute the prediction that background noise enhances creativity due to the promotion of processing disfluency and subsequent encouragement of abstract thought (Mehta et al., 2012). That CRAT performance was disrupted by the presence of a stimulus that conveyed no meaning to the participants precludes a semantic interference-by-process explanation of the results (cf. Marsh et al., 2008, 2009). However, the results are consistent with previous findings, which demonstrate background sounds that are meaningless to participants, can impair performance of tasks that require verbal working memory components such as serial recall, providing they possess appreciable changing-state properties (e.g., Jones et al., 1990): an acoustic interference-by-process (Jones & Tremblay, 2000).

2 | EXPERIMENT 2

Experiment 1 identified that music with foreign (unfamiliar) lyrics had a detrimental effect on the solution rates of CRATs in comparison with a quiet condition. At first glance, this finding is at odds with the notion that creative performance can be enhanced in the presence of background sound, through encouraging processing disfluency and promoting the abstract thought believed to be required to solve CRATs.

However, Mehta et al. (2012) obtained facilitatory effects on CRAT performance with ambient sound comprising "multi-talker noise in a cafeteria, roadside traffic, and distant construction noise to create a soundtrack of constantly varying background noise" (p. 786), whereas the current study used Spanish music with a clearly discernible voice (although in a language foreign to the participant, thereby conveying unfamiliar lyrics). We note that the presence of a clearly discernible voice could be a key difference between our study and that of Mehta et al. (2012) in driving the direction of the effect of background sound on creative performance. One possibility is that the presence of discernible speech in Experiment 1 could somehow prevent participants from achieving the disfluent processing state that could facilitate CRAT performance through abstract thought.

To address this aforementioned issue, Experiment 2 compared a quiet background with music without speech (lyrics) to investigate whether the presence of speech in some way impedes disfluent processing and thus prevents any supposed benefits of such disfluent processing on CRAT performance. In terms of the contrasting view that background sound can impair creative processing through impairing verbal working memory, music without lyrics should impair CRAT performance similarly to Spanish music with a discernible voice. In support of this view, numerous studies in the context of serial-verbal short-term memory (Klatte et al., 1995; Klatte et al., 2010; Nittono, 1997; Salamé & Baddeley, 1989; Schlittmeier et al., 2008) have shown that the presence of speech is not a prerequisite to produce disruption of verbal working memory. Thus, on the interference-by-process account, music without lyrics (speech) would also be expected to disrupt the creative processes necessary for solving CRATs and Experiment 2 sought to determine whether this was indeed the case.

2.1 | Method

2.1.1 | Participants

Eighteen adults (12 female and six male) from the University of Central Lancashire aged between 19 and 45 years old participated in the experiment (*M* = 25 years, *SD* = 9.31). The participants were recruited via an opportunity sample and received course credit, or the standard department payment rate in exchange for 30 min of participation. All participants spoke English as their first language and reported normal (or corrected-to-normal) vision and normal hearing. The experiment received Ethical Clearance from the University of Central Lancashire.

2.1.2 | Design and materials

The design and materials were identical to those outlined in Experiment 1 above, with the exception of a manipulation to one of the levels of the within-participant factors, Sound, which had two levels: Quiet vs. Music without Lyrics. The sound used within Experiment 2 was therefore the same as that used in Experiment 1, but without the lyrical content.

2.1.3 | Procedure

Each participant read an information sheet and signed a consent form prior to beginning the experiment. The procedure remained identical to that reported in Experiment 1 outlined above. All participants were fully debriefed at the end of the experiment. As with Experiment 1, at debriefing, participants were presented with the auditory stimuli they were exposed to during the experiment and asked if they were familiar with the song or had heard it before the experiment. None of the participants reported familiarity with the song, nor hearing it previously.

2.2 | Results

The pattern of results in the present experiment replicated that found in Experiment 1. CRAT solutions were higher in the quiet condition in comparison with the music condition. Furthermore, a greater number of easy CRATs were solved in comparison with difficult CRATs. A 2 (Sound: Quiet vs. Music without Lyrics) × 2 (CRAT Difficulty: Easy vs. Difficult) within-participants ANOVA was conducted on the dependent variable of mean solution rate. An alpha level of $p < 0.05$ was adopted for all statistical tests. There was a significant main effect of Sound, $F(1, 17) = 8.60$, $MSE = 0.02$, $p = 0.009$, $\eta_p^2 = 0.34$. Significantly more CRATs were solved in the Quiet condition ($M = 0.39$, $SE = 0.04$) in comparison with the Music without Lyrics condition ($M = 0.29$, $SE = 0.03$). There was a main effect of CRAT Difficulty, $F(1, 17) = 61.05$, $MSE = 0.03$, $p < 0.001$, $\eta_p^2 = 0.78$, with significantly higher solution rates for the easy CRATs ($M = 0.48$, $SE = 0.05$) in comparison with the difficult CRATs ($M = 0.19$, $SE = 0.03$). There was no significant Sound × CRAT Difficulty interaction, $F(1, 17) = 2.51$, $MSE = 0.02$, $p = 0.13$, $\eta_p^2 = 0.13$.

2.3 | Discussion

The aim of Experiment 2 was to compare CRAT performance in a quiet condition versus performance with to-be-ignored background music without lyrics. This was to investigate whether the presence of speech in Experiment 1 produced disruption of CRAT performance, and if this effect would hold for music without any speech content (in other words, music without lyrics). Experiment 2 supported the findings of Experiment 1 in that significantly more CRATs were solved in the quiet condition in comparison with the music without lyrics condition. Consistent with Experiment 1, there was a significant difference in solution rates for the easy versus the difficult CRATs. Furthermore, there was no significant interaction between Sound and CRAT Difficulty for solution rates.

The results are again inconsistent with the general view that music enhances creativity, and instead we demonstrate a deficit to CRAT performance in the presence of to-be-ignored background music with unfamiliar lyrics (Experiment 1) as well as in the absence of lyrics (Experiment 2). Moreover, the results oppose the view that background noise leads to processing disfluency, which in turn promotes creativity by engendering increased abstract thought (Mehta et al., 2012). The results run counter to the idea that the failure to find facilitation of CRAT performance via background music was due to the presence of speech in Experiment 1. Here, we demonstrate in Experiment 2 that music without lyrics (i.e., in the absence of any speech content) still failed to produce a facilitation in creativity and in fact resulted in a decrement in creativity in comparison with a quiet condition.

Taken together, the findings of Experiments 1 and 2 support the notion that verbal working memory is necessary for CRAT performance (Ball & Stevens, 2009), and that this is susceptible to disruption by the presence of to-be-ignored background sound, regardless of whether this background sound is speech or nonspeech based (e.g., Jones & Macken, 1993).

3 | EXPERIMENT 3

As we have discussed in our introduction, both the interference-by-process view (Jones & Tremblay, 2000) and the processing disfluency view (Mehta et al., 2012) eschew the role of mood and arousal in mediating the effect of background sound on creative task performance. However, there is a compelling literature showing that increased mood and arousal that derives from listening to music may affect cognitive task performance. For example, Thompson et al. (2001) demonstrated a benefit to subsequent visuo-spatial task performance from prior listening to music as compared with exposure to quiet that was entirely dependent on the change in mood and arousal that the music produced. Furthermore, Ritter and Ferguson (2017) reported that music presented 15 s prior to, and concurrently with, the performance of a task that involved creative verbal cognition facilitated performance on that task. However, this facilitatory effect occurred only for “happy” music that engendered positive affect and increased arousal. The relationship between happy music and increased arousal is usually attributed to the music's higher tempo (Vieillard et al., 2008). Moreover, music that is rated as being “liked” is typically “happy” music (Husain, Thompson, & Schellenberg, 2002). Therefore, it remains possible that given the pleasure that individuals usually derive from music, the music one choses to listen to might typically induce a positive mood and increased arousal, thereby yielding a positive impact on task performance (Thompson et al., 2001), particularly for tasks that involve creativity (Ritter & Ferguson, 2017). Indeed, previous research has established that positive mood can improve performance on RATs (Rowe, Hirsh, & Anderson, 2007). In both Experiments 1 and 2, our use of arbitrary music with foreign or “unfamiliar” lyrics, and music with the absence of lyrics, could have induced a neutral or even negative mood state in participants, which might have hindered the emergence of creative insight.

To investigate any potential mediating impact of mood on CRAT performance in Experiment 3, participants tackled CRAT problems in the presence of music with positive lyrics and fast tempo (approximately 160 beats per minute), which we considered should increase positive affect and arousal. Indeed, research has identified that happy music typically has a tempo of around 150 beats per minute; thus, our musical condition exceeds this figure (Khalfa, Roy, Rainville, Dalla Bella, & Peretz, 2008). Furthermore, “happy” music is known to increase arousal (e.g., Salimpoor, Benovoy, Longo, Cooperstock, & Zatorre, 2009). To identify support for the assertion that music with a fast tempo is perceived as “happy,” we measured mood states at two different time points (i.e., before and after each background sound condition) using the Profile of Mood States (PoMS) questionnaire (McNair, 1971). In Experiment 3, we also acquired data relating to participants' musical preferences (i.e., whether they liked or disliked the presented background sound) and their study habits (i.e., whether they tend to study with music or without background music). These data were intended to be peripheral to the main findings, but they nevertheless had the capacity to provide an indication of whether the impact of mood on CRAT performance is influenced by either musical preference or study habits.

We also note that in explaining the findings arising in Experiments 1 and 2, yet another possibility is that the promotion of creativity through processing disfluency in the presence of background noise (Mehta et al., 2012) is a specific effect that is limited to the presence of relatively “steady-state” sound, unlike the background music used in our conditions, which clearly satisfied the criteria for “changing-state” sound. Therefore, in Experiment 3, we included a “library noise” condition, which resembled that used by Mehta and colleagues (Mehta et al., 2012). We contrasted this library noise condition with a music condition (i.e., popular music with familiar lyrics) and with a quiet condition.

In terms of the outcomes of Experiment 3, if the mood and arousal account (Ritter & Ferguson, 2017; Thompson et al., 2001) is correct, then we expected to observe an increase in CRAT performance in the background music condition compared with the quiet and library noise conditions, assuming that the music condition reliably increases mood and arousal compared with the library noise condition. We note here that studies exploring the mood and arousal effect usually present music prior to, rather than concurrently with, the cognitive task of interest and typically study the effects of these music stimuli on visuo-spatial performance such as mental rotation (Thompson et al., 2001). However, effects of music on creative task performance that are reportedly mediated through mood and arousal have also been shown when music is presented concurrently with the target task in the context of a verbally-based creative task (Ritter & Ferguson, 2017). Moreover, participants within mood and arousal studies are free to attend to the music, rather than instructed to ignore the background sound, as is the case with studies of the irrelevant sound effect (Jones & Macken, 1993). We make the assumption, however, that changes to mood and arousal induced by the presentation of music occurs regardless of whether participants are free to attend the music or requested to ignore it and explore this proposition.

The processing disfluency account (Mehta et al., 2012) would predict that both library noise and music conditions should increase CRAT performance, whereas the modified processing disfluency account only predicts a positive effect of background library noise on CRAT performance. Finally, the interference-by-process view (e.g., Jones & Tremblay, 2000) predicts that CRAT performance should be reduced in the music condition relative to the library noise and quiet conditions because the music condition comprises a changing-state auditory stimulus, whereas the library noise condition constitutes a steady-state stimulus.

3.1 | Method

3.1.1 | Participants

Thirty-six adults (23 female and 13 male) from the University of Central Lancashire aged between 19 and 56 years old participated in the experiment (M = 24 years, SD = 8.36). The participants were recruited via an opportunity sample. Participants received course credit, or the standard department payment rate in exchange for 30 min of participation. All participants spoke English as their first language and reported normal (or corrected-to-normal) vision and hearing.

3.1.2 | Design

In relation to the assessment of CRAT performance, the design was a 3 (Sound: Quiet vs. Music vs. Library Noise) × 2 (CRAT Difficulty: Easy vs. Difficult) × 2 (Study Habit: Music vs. No Music) mixed design. For the purpose of mood evaluation, the following within-participants design was used to determine mood changes using the PoMs questionnaire: 3 (Sound: Quiet vs. Music vs. Library Noise) × 2 (Time: Before vs. After) × 6 (Mood State: Tension vs. Depression vs. Anger vs. Confusion vs. Fatigue vs. Vigour). The music chosen for the background sound was a popular 2013 mid-tempo soul and neo-soul song that contained positive lyrics and had an upbeat melody. The library noise consisted of distant (nonintelligible) speech, photocopier noise, typing, and rustling of papers.

3.1.3 | Materials

Before undertaking the CRATs, participants were asked: "Do you ordinarily study in the presence of background music?" and responded yes or no. The PoMS questionnaire is designed to measure fluctuating feelings and affective states (for further details, see McNair, 1971). The questionnaire measures six different aspects of mood state: tension, depression, anger, confusion, fatigue, and vigour. According to instructions of administration, the six mood states can be combined in the following way to produce a Total Mood Disturbance (TMD) score: tension + depression + anger + confusion + fatigue − vigour. However, for the purposes of this design, we were interested in the specific mood profile, and therefore, the six specific profile scores were used rather than a general TMD measure (McNair, 1971).

Using the norming data on solution rate and solution time for 30-s presentation time, an additional set of 19 CRAT problems (10 easy and nine difficult) matching accuracy and solution times to Sets A and B was selected using the program "Match" (Van Casteren & Davis, 2007) to create Set C (solution accuracy M = 47.9%, SD = 25.7, solution times: M = 9.6 s, SD = 3.3). The experiment was fully counterbalanced such that each CRAT set appeared within each sound condition. After undertaking the CRATs, participants were asked: "Did you like the music?" and responded yes or no.

3.2 | Results

Like Experiments 1 and 2, the dependent variable was the mean solution rate for the CRAT problems. As mentioned in the foregoing, Experiment 3 included a number of further dependent variables. These were responses to the PoMS questionnaires administered before and after the completion of each set of CRATs. The PoMS contains measures of six mood states: tension, depression, anger, confusion, fatigue, and vigour. There was also a brief questionnaire related to musical preference (whether participants liked the music played during the music condition) and study habits (whether they regularly listened to music when studying). Twenty-nine participants responded that they liked the music and seven responded that they disliked the music, indicating that the vast majority of participants found the music appealing. Furthermore, 18 participants responded that they ordinarily studied in the presence of music, whereas 18 preferred to study without the presence of music. Participants were assigned to Music vs. No Music for Study Habit, accordingly. An alpha level of p < 0.05 was adopted for all statistical tests used.

3.2.1 | Solution rates

The descriptive data for solution rates (see Figure 1) suggested that CRATs were more likely to be solved in the quiet and library noise conditions, in comparison with the music condition. However, there appeared to be no difference in the number of CRATs solved between the quiet and library noise conditions. Easy CRATs also seemed to be solved more readily than difficult CRATs. To examine these apparent effects further, a 3 (Sound: Quiet vs. Music vs. Library Noise) × 2 (CRAT Difficulty: Easy vs. Difficult) × 2 (Study Habit: Music vs. No Music) mixed ANOVA was conducted on the solution rate data. There was a significant main effect of Sound on solution rates, $F(2, 68) = 7.08$, $MSE = 0.07$, $p = 0.002$, $\eta_p^2 = 0.12$. Pairwise comparisons revealed that significantly more CRATs were solved in the Quiet condition (M = 0.34, SE = 0.05) in comparison with the Music condition (M = 0.30, SE = 0.04, p = 0.002). There were also significantly more CRATs solved in the Library Noise condition (M = 0.37, SE = 0.04,

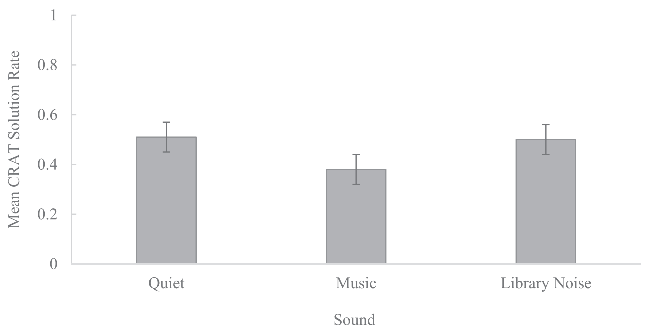

FIGURE 1 Compound Remote Associate Task (CRAT) solution rates in the three sound conditions of Experiment 3. Error bars represent the standard error of the mean

p = 0.003) in comparison with the Music condition. However, there was no significant difference between the mean number of CRATs solved in the Quiet and Library Noise conditions (p = 0.70).

As expected, there was a significant main effect of CRAT difficulty on solution rates, $F(1, 34)$ = 218.13.75, MSE = 0.02, p < 0.001, η_p^2 = 0.87, with significantly more easy CRATs solved (M = 0.48, SE = 0.04) than difficult CRATs (M = 0.19, SE = 0.04). There was also no significant main effect of Study Habit on CRAT solution times, $F(1, 32)$ = 0.01, MSE = 0.26, p = 0.93, η_p^2 = 0.000. Participants who specified that they preferred to study without music (M = 0.34, SE = 0.05) did not solve significantly more CRATs than those who specified that they preferred to study with music (M = 0.34, SE = 0.05). The remaining interactions and three-way interactions all failed to reach significance (all ps > 0.05).

3.2.2 | PoMs questionnaire

To ascertain any changes in mood before and after completing the CRATs in each sound condition, a PoMS questionnaire was administered to participants at two different points (before and after completing the CRATs in each of the three sound conditions). Therefore, each participant completed the PoMS questionnaire a total of six times. A 3 (Sound: Quiet vs. Music vs. Library Noise) × 2 (Time: Before vs. After) × 6 (Mood State: Tension vs. Depression vs. Anger vs. Confusion vs. Fatigue vs. Vigour) within-participants ANOVA was conducted on the mood state scores. The ANOVA revealed that there was no significant main effect of Sound, $F(2, 70)$ = 1.66, MSE = 0.20, p = 0.20, η_p^2 = 0.05, with no significant difference in the mean mood state score in the Quiet (M = 5.89, SE = 0.54), Music (M = 5.65, SE = 0.58), and Library Noise (M = 6.10, SE = 0.54) conditions. There was a main effect of Time, $F(1, 35)$ = 6.10, MSE = 9.98, p = 0.02, η_p^2 = 0.15, with mean mood state scores significantly higher Before (M = 6.10, SE = 0.58) in comparison with After (M = 5.66, SE = 0.49) completing the CRATs. There was a significant main effect of Mood, $F(5, 175)$ = 28.17, MSE = 80.60, p < 0.001, η_p^2 = 0.45. Pairwise comparisons indicated that there were significant differences between all mood states with the exception of tension (M = 5.05, SE = 0.67) versus fatigue (M = 5.13, SE = 0.78), depression (M = 2.86, SE = 0.87) versus anger (M = 5.13, SE = 0.78), anger versus fatigue, and fatigue versus vigour (M = 11.96, SE = 0.91; all ps > 0.05). There was no significant Sound × Time interaction, $F(2, 70)$ = 2.43, MSE = 11.88, p = 0.10, η_p^2 = 0.07, Sound × Mood interaction, $F(10, 350)$ = 1.42, MSE = 8.25, p = 0.10, η_p^2 = 0.07, or Time × Mood interaction, $F(5, 175)$ = 0.48, MSE = 5.18, p = 0.79, η_p^2 = 0.01.

As expected, there was a significant three-way Sound × Time × Mood interaction, $F(10, 350)$ = 3.50, MSE = 5.846, p < 0.001, η_p^2 = 0.09. Pairwise comparisons indicated the source of this significant interaction. For the Quiet condition, there was no significant change in any of the mood states after completing the CRATs (all ps > 0.05). However, for the Music condition, there was a significant change in mood for four out of the six mood states. There was a significant decrease in tension (M = 5.36, SE = 0.82 vs. M = 4.00, SE = 0.69, p = 0.01), anger (M = 4.08, SE = 1.04 vs. M = 2.72, SE = 0.69, p = 0.049), confusion (M = 6.92, SE = 0.75 vs. M = 5.69, SE = 0.59, p = 0.02), and fatigue (M = 4.81, SE = 0.87 vs. M = 3.72, SE = 0.80, p = 0.03). There was no significant change in depression (M = 3.25, SE = 1.23 vs. M = 2.61, SE = 0.98, p = 0.33) or vigour (M = 11.86, SE = 0.97 vs. M = 12.72, SE = 1.13, p = 0.22). For the Library Noise condition, there was no significant change in five of the six mood states (all ps > 0.05). However, there was a significant decrease in vigour (M = 12.67, SE = 1.08 vs. M = 10.67, SE = 0.94, p < 0.001).

These findings indicate that the significant changes in mood states before and after completing CRATs occurred within the Music condition and not in the Quiet or Library Noise condition, thus indicating that music altered a number of mood states, and as measured by the PoMS, provided a general increase in positive mood. Since previous research (Rowe et al., 2007) has shown that positive mood can improve performance on RATs, the present observation that music increased mood but decreased CRAT performance suggests that a mood-based explanation of the detrimental effect of music on creative insight seems implausible.

3.2.3 | PoMs and solution rates

In the previous section, the PoMS scores and CRAT solution rates were examined independently. However, it is useful to consider the possible impact of mood as a mediating influence on the relationship between to-be-ignored background sound and CRAT performance. Unfortunately, the current dataset is unsuitable for mediation analysis (i.e., to ascertain mood as a possible direct or indirect mediator in the relationship between background sound and CRAT performance) given the implementation of Sound as a within-participants factor rather than a between-participants factor. However, an analysis of covariance was performed to examine CRAT solution rates when mood score was included as a covariate. Here, we focused on the relationship between the quiet and music conditions, given our particular interest in the disruption caused by to-be-ignored background music.

In order to establish the mood score for entry as a covariate, the “before” score for each of the six mood score dimensions (tension, depression, anger, confusion, fatigue, and vigour) was subtracted from the “after” score to provide a “mood change” score for each of the six profile of mood state dimensions listed above. This resulted in a mood state dimension change score for both the music and quiet conditions, for each mood state (tension, depression, anger, confusion, anger, and vigour). The change score for the music condition was subtracted from the change score for the quiet condition, to provide a single change score for each of the six mood states. A 2 × 2 analysis of covariance was conducted (Sound: Quiet vs. Music) × 2 (CRAT Difficulty: Easy vs. Difficult) on solution rates, with tension, depression, anger, confusion, fatigue, and vigour each entered as a covariate. The findings revealed that all covariates failed to reach significance (all ps > 0.05), indicating that each of the six mood state measures failed to have a significant impact on CRAT solution rates, either directly or in interaction with the Sound and CRAT Difficulty factors.

3.3 | Discussion

Experiment 3 demonstrated that popular music with familiar lyrics disrupted CRAT performance (in terms of solution rates) in comparison with a quiet condition or library noise condition. However, there was no significant difference in CRAT performance between the quiet and library noise conditions. Mehta et al. (2012) previously demonstrated a beneficial effect to creativity with what could be termed "steady-state sound." Although these findings demonstrate that a steady-state sound such as library noise does not result in a relative enhancement to creativity, we also find that the decrement was not significant, particularly in comparison with the background music with familiar lyrics.

Furthermore, the findings imply that music with familiar lyrics resulted in a decrement in CRAT performance, despite an apparent overall positive increase in mood as identified by six mood states recognised in the PoMS. Given that previous research has identified that positive mood can lead to an improvement in RAT scores (Rowe et al., 2007), the findings here demonstrate that the decrement in performance in the music condition does not appear to be driven by mood. Indeed, these findings further support the notion that CRAT performance relies on verbal working memory, and that this is susceptible to disruption by nonsteady-state sound, with or without the presence of speech.

4 | GENERAL DISCUSSION

In a series of three experiments, we investigated the impact of background music (with varying semantic properties) on creativity, as measured by performance on CRATs. In Experiment 1, background music with foreign (and therefore "unfamiliar") lyrics resulted in a significant decrement to CRAT performance; significantly fewer CRATs were solved in the music with foreign lyrics condition in comparison with the quiet condition. This finding was replicated in Experiment 2 with the implementation of background instrumental music in comparison with a quiet condition. In Experiment 3, familiar music was found to impair CRAT performance regardless of whether the music induced a positive mood or whether those participants typically studied in the presence of music. Moreover, disruption occurred despite the fact that the music was liked by the participants, which coheres with the findings of Perham and Vizard (2010) and Perham and Currie (2014), who showed equivalent disruption by liked and disliked background music in the context of serial recall and reading comprehension, respectively.

Prior to discussing the implications of Experiments 1 to 3 for the theoretical accounts entertained, we undertook a Bayesian meta-analysis of the collective findings. Bayes factors were calculated to quantify the evidence for two hypotheses: the hypothesis from the processing disfluency account (cf. Mehta et al., 2012) that CRAT performance would be better in the music conditions relative to the quiet conditions (H1), and the hypothesis from the auditory distraction account (Jones & Tremblay, 2000) that CRAT performance would be better in the quiet conditions relative to the music condition (H2).

To calculate Bayes factors, one must specify the plausibility of effect sizes given one's theory. For both H1 and H2, we model the sort of effect size considered plausible on the results of Mehta et al. (2012), who reported that hearing a moderate level of noise resulted in participants solving a significantly greater proportion of RATs ($M = 0.73$) than participants in the quiet control condition ($M = 0.56$). These results provide an approximate effect size that could be expected for a noise manipulation (such as music) on measures of creativity, from 0.73 to 0.56 = 0.17. Following Dienes' (2011, 2014) guidelines, the experimental hypotheses in the current analyses were modelled using a half-normal distribution with a mode of 0 and a standard deviation of 0.17. Bayes factors <0.33 are interpreted as moderate evidence for the null hypothesis and Bayes factors >3 as moderate evidence for the experimental hypotheses. Bayes factors around 1 are conventionally considered inconclusive (Dienes, 2011, 2014). Bayes factors were calculated using Dienes and McLatchie's (2018) calculator (results following each experiment are reported on each row of Table 1).

Individually, there was strong evidence across all three studies for H0 relative to H1, indicating that playing music did not enhance creativity as measured by CRAT performance (see Table 1). In contrast, there was moderate to strong evidence from all three studies for H2 relative to H0, suggesting that music decreased creativity to approximately the same extent one might have expected it to have increased (again refer to Table 1).

The experiment-level analyses were followed up with a fixed-effects meta-analysis using Dienes' (2008) calculator (see Goh, Hall, & Rosenthal, 2016, for an overview of the benefits of including internal meta-analyses within studies). The meta-analytic posterior distribution (M = −0.06, SD = 0.01; 95% CI [−0.08, −0.03]) provides the best estimate of the population parameter and its uncertainty in light of all three studies. The meta-analysis suggests that music reduces creativity as measured using the CRAT. Bayes factors were calculated on the meta-analytic data to test H1 and H2 and revealed that the overall body of evidence provided substantial support for H2, that the presence of music diminishes rather than enhances creativity, $B_{H2/H1(0,\ 0.17)} = 3.36 \times 10^4$, thereby supporting the interference-by-

TABLE 1 Bayes factors testing the effect of Music versus Quiet conditions from Experiments 1 to 3

Effect	Study	$B_{H1/H0}$: Music increases creativity	$B_{H2/H0}$: Music decreases creativity	$B_{H2/H1}$
CRAT performance	Experiment 1	0.04	21.89	547.25
	Experiment 2	0.08	11.58	144.75
	Experiment 3	0.04	3.31	82.75

Note. *H1* = Music > Quiet, *H2* = Quiet > Music, *H0* = Quiet = Music. Alternative hypotheses specified using a half-normal distribution with a mode of zero and a standard deviation of 0.17 (Mehta et al., 2012; Experiment 1). CRAT: Compound Remote Associate Task.

process account (Jones & Tremblay, 2000) over the processing disfluency account (Mehta et al., 2012).

Taken together, the findings from Experiments 1 to 3, supported by our Bayesian meta-analysis, contradict the popular opinion that background music enhances creativity. Instead, they demonstrate that background music, with or without familiar semantic content (i.e., lyrics), or in the absence of speech, disrupts performance on CRATs, which represent a class of highly researched verbal problem solving tasks that are often solved creatively through insight-based processes. Furthermore, the findings of Experiments 1 to 3 undermine the processing disfluency account (Mehta et al., 2012), which predicts superior performance in the presence of moderate intensity background noise in comparison with quiet. We note that a reprieve for the account might be offered if one were to assume that music (at least pleasant music) impairs creativity via inducing processing fluency (Mehta et al., 2012, p. 796). However, it is not immediately obvious why, on the processing disfluency account, noise and music should differ in relation to the processing fluency that they hypothetically engender.

We contend that the deficit in CRAT performance in the presence of background music appears altogether more consistent with the interference-by-process framework (e.g., Marsh et al., 2009) than with the processing disfluency account (Mehta et al., 2012). According to the interference-by-process approach, the disruption of CRAT performance is attributable to the *changing-state effect*, which refers to the finding that a changing sequence of sound (regardless of whether the changes occur on a speech or nonspeech carrier), disrupts serial recall to a far greater extent than a nonchanging or steady-state sound (e.g., a repeated token or tone; Jones & Macken, 1993; Jones et al., 1992). The pre-attentive perception of changes between elements in the sound, as a by-product of acoustic-based perceptual organisation processes (Bregman, 1990), gives rise to irrelevant order cues. These cues compete with the process responsible for subvocally maintaining the to-be-remembered items in sequence. In support of this suggestion, we have recently found that changing-state letters (c, t, g, u) produce more disruption to CRAT performance than steady-state letters (c, c, c, c; Marsh, Threadgold, Barker, & Ball, 2017). Music, of course, is a changing-state, rather than a steady-state, sound. Therefore, the findings presented here, which attest to the disruption to verbal insight problem solving as measured through CRAT performance, are entirely consistent with findings that have revealed a disruption to serial recall by changing-state sounds that include music (e.g., Perham & Vizard, 2010). Furthermore, the findings imply that the presence or absence of semantic content (i.e., lyrics)—and indeed the familiarity of the lyrics (e.g., lyrics in foreign and unfamiliar language)—does not alter the disruptive influence of background music. Moreover, that background music successfully increased mood and arousal in Experiment 3, but led to poorer, rather than better, CRAT performance compared with the quiet control and library noise condition undermines the mood and arousal account (Ritter & Ferguson, 2017; Schellenberg et al., 2007).

One explanation for why background music impairs CRAT performance in the same way as it impairs serial recall (e.g., Salamé & Baddeley, 1989) relates to the processes of verbal working memory and their importance for insight problem solving. Indeed, Ball and Stevens (2009) identified a strong verbal component to the solving of insight-based CRATs, in that implementing a "think aloud" process during problem solving reliably enhanced solution rates. If verbal working memory is important for CRAT performance, and any nonsteady-state background sound (such as music) is disruptive to the creative and analytic processes necessary to solve CRATs, a decrement to CRAT performance would be expected. This, therefore, suggests that it is not the type of semantic content within the to-be-ignored background per se that is disruptive to insight problem solving, but rather the presence of changing-state sound and its impact on verbal working memory processes (such as rehearsal) underpinning the solving of CRATs. It might be, for example, that participants rehearse various target solutions, before obtaining an appropriate solution word. For example, for the problem "house," "pear," and "family," it might be the case that "tree-house" and "pear-tree" are rehearsed, whereas participants test out the viability of another generated word, including the solution, "family-tree." That solution words can either serve as a prefix or a suffix to problem words may reinforce the rehearsal strategy because order processing is necessary to obtain an appropriate solution ("tree-pear" being an appropriate combination of the problem and solution word but in the reverse order). However, because semantic associative processes are likely to be involved in CRAT solving (Smith et al., 2013), it would be reasonable to predict that meaningful background speech in a participant's mother tongue, as compared with meaningless background speech (speech in a language foreign to the participant), could produce additional disruption to CRAT solving, superimposed on the changing-state effect, as a consequence of a semantic interference-by-process. The general notion is that disruption over and above the changing-state effect can occur when there is a conflict between semantic processing of the sound and semantic processing in the focal task (Jones et al., 2012; Marsh et al., 2009). For example, in the context of mental arithmetic, Perham, Marsh, Clarkson, Lawrence, and Sörqvist (2016) argued that the additional disruption due to an ascending sequence of number distracters as compared with a random sequence was produced due to an additional priming process that was superimposed upon the interference-by-process that underpinned the changing-state effect.

One challenge that stems from the finding that background music impairs CRAT solving relates to determining the generalisability of the observed effect beyond CRATs alone. CRATs are but one example of a verbal insight problem solving task, albeit a popular and widely used example that is believed to provide an effective test of creativity (e.g., Bowden & Jung-Beeman, 1998; Mednick, 1962). However, many other types of verbal and non-verbal insight problem solving tasks exist (e.g., see Gilhooly, Fioratou, & Henretty, 2010). An important consideration is to what extent do the explanations presented here in terms of interference-by-process and working memory generalise to further insight problem solving tasks in both the verbal and visual domain?

In relation to this latter question, preliminary evidence from Ball, Marsh, Litchfield, Cook, and Booth (2015) suggests that non-verbal (i.e., visuo-spatial) insight problem solving may in fact be facilitated, rather than hampered by background sound. Participants solved "classic" non-verbal insight problems (such as the pigs-in-pens problem; see Schooler, Ohlsson, & Brooks, 1993) more accurately, and faster, when background sound was presented (in a form that involved repeated, canonical counting of the digit sequence 1 to 7) compared with a quiet background. According to Ball et al. (2015), these results can be interpreted in terms of background sound impairing inner speech, thereby permitting the operation of nonreportable, "special processes" (e.g., problem restructuring) that are critical for enabling successful solutions to emerge in classic insight-based problem solving tasks involving predominantly visuo-spatial components. It is our conjecture that background music would have a similar positive effect to this, yet it would be the *changing-state properties* of the to-be-ignored background music, rather than the music per se, that would underpin an apparent enhancement in creativity. In sum, boundary effects are likely to be evident in terms of the following: (a) the relationship between background music and creativity; (b) the negative consequences of background music on verbal insight problem solving tasks as demonstrated here with CRATs; and (c) the positive consequences on visuo-spatial insight problem solving tasks (e.g., Ball et al., 2015).

One further point of consideration is that Mehta et al. (2012) found facilitatory effects of background sound for a number of different tasks that are thought to tap creativity. Although we found no evidence for the processing disfluency account (Mehta et al., 2012) in the context of our current study, it is possible that other tasks, or their component processes, are more sensitive to the potential engendering of processing disfluency—and thus enhancement of cognition—via the presence of background noise. Arriving at a CRAT solution may involve multiple processes that include a delicate balance between top-down processes (e.g., rehearsal and executive control, such as inhibition in the case of excluding incorrect response candidates) and bottom-up processes, such as spreading activation in associative, semantic networks that provide the candidate responses (cf. Benedek et al., 2016). Because it is likely that the balance between these top-down and bottom-up processes may differ substantially between different insight problems, different susceptibility to distraction by background sound is likely across different types of problem solving tasks solved via a process of insight. In this way, it is possible that any advantage to creative problem solving promoted by processing disfluency due to the presence of background noise may be dependent upon the particular strategy and processes used to solve a CRAT. It is reasonable to suggest that such strategies and processes could differ on a problem-by-problem basis.

Although we argue that our results can be explained in terms of the interference-by-process account (Jones & Tremblay, 2000), it is important to note that there are two competing explanations for a deficit in CRAT performance with background noise, which both stem from well-established theories of creativity. One such explanation derives from the "broad attentional scope" (BAS) view of creativity (Zabelina, O'Leary, Pornpattananangkul, Nusslock, & Beaman, 2015), whereas the other derives from the "focused attentional scope" (FAS) perspective (Gilhooly, Fioratou, Anthony, & Wynn, 2007). The BAS view supposes that background sound may reduce the overall amount of attention that one can apply to the problem solving task, resulting in a *diffuse attentional state* that can facilitate insight problem solving (Jarosz, Colflesh, & Wiley, 2012). In comparison, the FAS view proposes that if background sound reduces overall attention, then insight problem solving will be impaired. This FAS view is consistent with theories of distraction that assume the presence of background sound captures attention away from the focal task (Cowan, 1995) or reduces the overall amount of attention applied to the focal task (Neath, 2000), thus impairing observed performance. Across three experiments, we demonstrate a deficit to CRAT performance with distraction via to-be-ignored background music. Such a deficit to creativity is consistent with the importance of FAS in verbal insight problem solving such as with CRATs.

One might assume that the findings reported here suggest that a disruption to FAS is generated by to-be-ignored background music, and that this is disruptive to the analytic and associative processes necessary to solve insight problems. However, there are two key problems with this assumption. First, there was nothing inherent within the presented background sound that was likely to capture attention and thus disrupt the attention directed towards the task at hand. Moreover, the notion that the overall amount of attention that could be applied to the focal task is reduced in the presence of background sound is inconsistent with the literature showing that only tasks that require verbal rehearsal are susceptible to distraction (Beaman & Jones, 1997; Jones & Macken, 1993). Second, if background sound impaired a focused attentional state necessary to solve insight problem solving tasks, then one would expect disruption, not facilitation, on tasks that require visuo-spatial insight problem solving, similar to that found with verbal insight problem solving. However, evidence from Ball et al. (2015) and the findings presented here suggest a dissociation in the facilitatory and disruptive effects of to-be-ignored background sound on verbal and visuo-spatial insight problems, respectively.

To conclude, the findings here challenge the popular view that music enhances creativity, and instead demonstrate that music, regardless of the presence of semantic content (no lyrics, familiar lyrics, or unfamiliar lyrics), consistently disrupts creative performance in insight problem solving as measured by CRATs.

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