Examining Rate Priming on Information Processing

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Abstract

The current study investigated the effect of a musical prime on an individual's reading rate, reading comprehension, and processing speed. This research further examined if there is a correlation between reading speed and reading comprehension. Music and language primes have been shown to affect processing speed, such that when participants were exposed to a slow prime, language production slows down, and vice versa for fast primes (Jungers, Hupp, & Dickerson, 2016). This effect of priming has been observed in other cognitive capacities such as decision-making (Buelow, Hupp, Porter & Coleman, 2018), suggesting that the rate of prime could change processing speed across domains. The current study sought to further support this theory by testing processing speed in motor movements and reading rate. These domains were measured when participants completed the Purdue Pegboard Task and The Nelson Denny Reading Test after being exposed to 3 minutes of a classical music prime. The musical prime was manipulated to have either a slow or fast tempo. It was observed that there is a positive correlation between reading rate and reading comprehension, but that the rate of prime did not affect processing speed, reading rate, or reading comprehension.

Article

On the typical college campus today, students can frequently be seen listening to their favorite music with a pair of headphones. They may be walking to class or walking to their dorm, but do they ever think about how this can affect their processing of information? According to previous research, when a person is exposed to a fast prime, they tend to have faster cognitive functions, and the opposite when exposed to a slow prime (Buelow, Hupp, Porter, & Coleman, 2018; Jungers & Hupp, 2009; Jungers, Hupp, & Dickerson, 2016). A prime is a stimulus such as music or speech that a participant is exposed to before an experiment or task. When applied to music, it is expected that participants exposed to fast music will process information faster, and those exposed to slow music will process information slower. This leads to the question of whether college students can better comprehend a textbook or lecture if they listen to fast music

Effect of Rate Priming on Cognition

Previous research has shown an effect of rate priming on different cognitive domains such as language production, processing speed, and decision-making. Specifically, researchers found that participants produce speech differently based on the speed of a prime (Jungers et al., 2016). In the study, there were two separate experiments: one with a speech prime and the other with a music prime. In the first experiment, participants looked at a picture being described slowly (60 beats per minute) or fast (120 beats per minute). Next, the participants would be shown another picture, and told to describe it. When exposed to a fast language prime, participants spoke faster than when exposed to the slow prime.

In the second experiment, Jungers et al. (2016) performed the same procedure with familiar musical melodies as primes. Participants were shown the title of the song while listening to it at a slow (60 BPM) or fast (120 BPM) pace. After each song, participants were shown a picture, and told to describe the picture. Once again, when exposed to the fast prime, participants spoke faster than when exposed to the slow prime. These findings were replicated using unfamiliar musical melodies (Jungers & Hupp, 2018). This research showed that both music and language primes affected how fast participants described the pictures, specifically that participants spoke faster when exposed to a fast prime than when exposed to a slow prime. This could suggest that there is a common temporal processing mechanism between music and language, or even domain generality of temporal processing.

In a recent study, researchers measured how speech rate affected performance on a decision-making task (Buelow et al., 2018). Participants listened to a story recorded at a slow pace (145 seconds long) or fast pace (98 seconds long), and the control group did not listen to a story. Participants then completed the Hungry Donkey Task (HDT), which is an adaptation of the Iowa Gambling Task (IGT), to measure risky decision-making. The researchers found that when participants were exposed to a slow language prime, they took longer and made more advantageous decisions on the HDT than those in the fast-prime group, thus showing that slow language primes lead to slower cognitive functions, such as decision making.

In addition to language production and decision-making, processing speed is also affected by the rate of primes. A study conducted by Ilie and Thompson (2011) looked at the relationship between music and processing speed. Their first experiment looked at how exposure to music affected emotion, processing speed, and creativity. They manipulated the music to have different pitches (high or low), rates (fast or slow), and intensities (loud or soft). To measure processing speed, they had participants complete a routine task, which consisted of identifying wingdings (i.e., arrow or teardrop) from a one-page document, after being exposed to 7 minutes of the manipulated classical piece. Ilie and Thompson (2011) found that those who were exposed to the slow music before the routine task took longer on this task than those exposed to the fast music. However, the rate of prime was confounded with their other variables: emotion and arousal. The current study expands on the effects of rate of prime by investigating if the rate of music prime extends to other measures of processing speed, such as those involving the cognitive domains for reading, and to isolate the effect of rate of prime from other confounds.

Reading Rate and Comprehension

For some, reading comes easily, allowing them to process the information faster, but for others, it can be tough, so they process information much slower (LaBerge & Samuels, 1974). Skilled readers have better word recognition, which involves fewer attentional resources (Jenkins, Fuchs, van de Broek, Espin, & Deno 2003). Attentional resources can then be dedicated to better comprehension of a text. In contrast, less skilled readers attend more to word recognition, leading to poor comprehension (Jenkins et al. 2003). In several studies, researchers have investigated how reading rate can affect comprehension, and some have indicated that there is a correlation between natural reading speed and the comprehension of a text. Similar results were found in previous research measuring reading rate and reading comprehension in sixth and seventh graders (Hale, Skinner, Wilhoit, Ciancio, & Morrow 2012). Skilled readers exert less effort into reading and read faster than less skilled readers, who tend to read slower and less often because it requires more effort (Hale et al., 2012).

Breznitz, DeMarco, Shammi, and Hakerem (2001) looked at how reading speed affects adults' comprehension of a text by manipulating how fast they read. Participants started with 17 passages from the Test of English as a Foreign Language (TOEFL), which they read at their own speed. When each passage was done, there was a comprehension question. The test was conducted electronically, allowing reading time to be calculated. After the self-paced portion was completed, researchers calculated an individual's fast-paced reading speed based off of the passages they comprehended particularly well. To manipulate the fast-paced speed, researchers based the new speed on the individuals' average reading rate on the self-paced portion of the assessment. To force the fast pace on the reading passages, words would disappear individually from the beginning of the passage until it was completed, and then the comprehension question would appear. Breznitz et al. (2001) found that when participants' reading rate was manipulated to be 12% faster, their comprehension scores could increase up to 21.8%.

One possible explanation is that faster reading speed allows the working memory (WM) to be used more efficiently (Breznitz & Share, 1992). WM is a form of memory that is used when completing demanding tasks, allowing pieces of information to be stored temporarily (Baddeley & Hitch, 1974), and has been found to be an important predictor of reading comprehension (Seigneuric, Ehrlich, Oakhill & Yuill, 2000). WM has a limited amount of resources used to maintain information (Baddeley & Hitch, 1974), which could suggest that Breznitz and Share's (1992) theory is on the right track. Because WM is only able to hold a limited amount of information, reading faster may allow subjects to remember more in that short period of time, as they are taking in information at a faster rate. If reading speed can be manipulated by a rate prime, it may be able to influence how much information participants can remember.

Music's Effects on Cognition

Background music has been shown to influence processing; music affects concurrent processing in certain areas of cognition (Bottroli, Rosi, Russo, Vecchi, & Cavallini, 2014). Background music can have both positive and negative effects on cognition, depending on the task. For example, fast music can lead a participant to take less time on a processing speed task (Bottiroli, Rosi, Russo, Vecchi, & Cavallini, 2014; Ilie & Thompson, 2011). Additionally, it has been found that background music can have a positive effect on the Symbol Digit Modalities Test (SDMT), a processing speed task, when compared to no music and white noise groups (Bottiroli et al., 2014). Participants' declarative memory (semantic and episodic) and processing speed were assessed with concurrent background music (Mozart or Mahler), white noise, or neither. Participants in the Mahler background music condition showed higher scores on both the semantic and episodic memory tasks; those in the background music condition with Mozart had higher scores on the SDMT than those in the white noise and no music groups (Bottiroli et al., 2014). Researchers state that music that puts participants in an alert mood and state (i.e., fast music) can produce better scores on processing speed tasks (Bottiroli et al., 2014).

The effect of background music on reading speed has also been investigated. When listening to concurrent background music, reading speed can imitate the speed of the music playing. Kallinen (2002) had participants silently read a news article on their smart-device (such as a phone, or small tablet) while listening to music. Researchers measured how long it took participants to read the article; participants in a slow music group took much longer to read the article than participants in the fast group.

These studies mostly investigated the effect of background music on different tasks, but lacked investigation of the effects of music primes (i.e., music played before continuing onto a different task). However, music primes have been shown to affect processing speed (Ilie & Thompson 2011), language production (Jungers & Hupp, 2009; Jungers et al., 2016), and emotional processing (Ilie & Thompson, 2011). The current study is investigating generality of the effect by observing if a music prime affects processing speed, reading speed, and reading comprehension. Exploring how music primes affect subsequent processing will aid in the understanding of temporal processing more generally.

Current Study

The current study presents the question: how does the speed of a musical prime affect subsequent processing speed, speed of reading, and reading comprehension? First, the Nelson Denny Reading Test (NDRT; Brown, Fishco, & Hanna, 1929) was used to measure reading comprehension and reading speed. Second, the Purdue Pegboard Task (PPT; Tiffin, 1968) measured general processing speed. The PPT involves putting pegs into a large board with two parallel rows of holes, and has been successfully used to measure processing speed across a variety of studies (Marczinski et al, 2012).

It is predicted that those who are exposed to a slow musical prime would process information more slowly and be slower on the PPT and NDRT tasks, compared those who are exposed to a fast musical prime. For reading comprehension, it is predicted that those who are exposed to the fast musical prime will have a higher comprehension score since they may process the information faster, compared to those exposed to the slow music prime.

Method

Participants

This study's final analysis included 96 college-age participants from a regional campus of a large midwestern university. They were enrolled in introductory psychology courses and received course credit for participating in this study. There were 47 males and 49 females with a mean age of 19.28 years (SD = 2.17). There was an approximately equal number of participants across rate priming conditions: slow n = 30, fast n = 32, control n = 34. The participants were predominately white (76.04%), but also included African-Americans (15.63%), and multi-racial people (4.17%). Additional participants were not included in the data analysis because they had serious mental or medical conditions (n = 2), English was not their first language (n = 11), or they had untreated vision, hearing, or attention impairments (n = 12). Two participants were excluded due to incomplete testing. Participants who appeared to be aware of the experimental manipulation were also excluded from the analyses (n = 8); this was determined by their response to the question, "What was the purpose of this study" on the demographics sheet.

Procedure and Measures

This research was approved by the university's Institutional Review Board. Students volunteered through an online system that allowed them to sign up for research studies. Once they were in the lab, the participants gave informed consent electronically, and were tested individually. Participants were then randomly assigned to one of three groups: fast prime (music at 120 BPM), slow prime (music at 60 BPM), and control group (no musical prime). Participants in the two experimental groups were exposed to 3 minutes of music, (Serenade No. 4 in D Major 'Colloredo', K. 203: VI Andante by Wolfgang Amadeus Mozart), on the computer through headphones at either a fast or slow pace. The control group went directly into the first task. The music selection was manipulated through Audacity to have either a fast or slow pace, while still having the same pitch, tone, and volume. It was an instrumental classical piece without lyrics to ensure the prime remained non-linguistic, similar to the Ilie and Thompson (2011) study. After the musical prime, participants completed the NDRT to measure reading speed and comprehension and the PPT to measure processing speed. Task order was counterbalanced; half of the participants completed the NDRT first, and the other half completed the PPT first.

The NDRT (Brown et al., 1929) measures vocabulary, reading rate, and reading comprehension. For the purpose of this study, only the reading rate and reading comprehension portion of the test was used in the most recent forms, G and H. The NDRT is completed with a provided answer sheet, reading booklet, and pencil. The comprehension portion consists of 7 reading passages and 38 multiple choice questions, with 5 answer choices each. The first passage of the test contains over 600 words, which allows the researcher to measure reading speed; the rest of the passages are no longer than 3 paragraphs, or 200 to 300 words. The test is limited to 20 minutes, and the first minute is used to measure reading rate. Participants start reading the passage, and when a minute passes, the experimenter says, "Time." At this point, the participant records what line they have reached, and then continues reading. Comprehension is scored based on the number of questions answered correctly: the number of questions correct out of 38, multiplied by two to be consistent with typical scoring procedures (Brown et al., 1929).

The second task is the PPT (Tiffin, 1968) used to measure processing speed. It is a board that has two parallel rows with 25 holes each. Pegs are placed in the top of the board in four divots, or bowl-like shapes. First, participants are instructed to use their right hand to put as many pegs in the board on the corresponding side in a 30-second time period. Participants must keep their other hand to the side as they place pegs in the board. The participant then does the same with the left hand, followed by both hands (entering pegs in holes adjacent to each other at the same time). The raw score is based on the number of pegs put in the board. A high score represents faster processing speed (Lafayette Instrument Company, 2015).

When the PPT and NDRT were finished, the participant completed a paper and pencil demographics form that measured basic demographic information as well as information regarding general visual, auditory, and attentional health. This form also asked the participants what they thought the purpose of the study was. Then the participant was debriefed, and they received participation credit and a piece of candy.

Results

Each participant had three scores: PPT, NDRT rate, and NDRT comprehension. The score on the PPT is the total number of pegs placed on the board added across left, right, and both hand trials. A higher score indicates faster processing speed. The score for the NDRT reading rate is based off of the line of the reading passage reached at the end of the first minute. A higher score indicates faster reading rate. The comprehension portion of the NDRT is based off of the number of questions answered correctly (out of 38) multiplied by two, in order to maintain scoring consistency with previous research. A higher score indicates a higher level of reading comprehension.

A series of one-way ANOVAs were conducted to analyze the effect of musical rate prime on the PPT and NDRT across the three Music Prime Conditions (control, slow, and fast), as well as analyze the effect of reading rate on the number of questions answered correctly. In addition, a correlation between reading rate and comprehension was calculated for all participants, and one sample t-tests were conducted to determine similarity with normative data.

Purdue Pegboard Score

One sample t-tests were conducted on each subset of scores (preferred hand, non-preferred hand, and both hands) to determine if there was a statistically significant difference between the PPT scores from this study's participants and normative data (as reported in Lafayette Instrument Company, 2015). Students scored significantly worse than normative data for all subsets. For preferred hands, students scored (M = 14.250, SD = 1.875) compared to (M = 16.13), t (95) = -9.824, p = < .05. For non-preferred hands, students scored (M = 13.364, SD = 1.597) compared to (M = 15.59), t (95) = -13.655, p = < .05. For both hands, students scored (M = 11.552, SD = 1.710) compared to (M = 13.18), t (95) = -9.28, p = < .05.

There was no effect of music prime on the total PPT score, F (2, 96) = .234, p = .792, preferred hand PPT score, F (2, 96) = .601, p = .550, non-preferred hand PPT score, F (2, 96) = .283, p = .755, or both hands PPT score, F (2, 96) = .090, p = .914. Refer to Table 1 for means and standard deviations across conditions. This pattern of results was identical only for those who received the PPT directly after the music prime (e.g., PPT as the first task). These results indicate that the rate of musical prime has no effect on processing speed.

(Table 1 Below)

Reading Rate

The participants' average reading rate (i.e., line number) was worse when compared to the normative data for the NDRT. Students read significantly slower (M = 224.74, SD = 65.86) compared to normative data (M = 238.31, Brown et al., 1993), t (95) = -2.00, p = .048. There was also no effect of music prime on the NDRT reading rate score, F (2, 96) = .261, p = .771. Refer to Table 2 for means and standard deviations across music conditions. This pattern was identical only for those who received the NDRT directly after the music prime. These results show that rate of musical prime does not influence reading rate. (Table 2 on next page)

Comprehension Score

The participants' average comprehension score was better on the NDRT, (M = 52.77, SD = 13.92) when compared to normative data (M = 48.50, Brown et al., 1993), t (95) = 3.007, p = .003.

Table 1

Purdue Pegboard Score Subsets Across Music Conditions

	Total Score		*Preferred Hand Score*		*Non-Preferred Hand Score*		*Both Hands Score*	
Music Condition	Mean Score	Standard Deviation	Mean Score	Standard Deviation	Mean Score	Standard Deviation	Mean Score	Standard Deviation
Slow (*n* = 30)	38.9	4.08	*14.2*	2.01	*13.23*	1.48	*11.47*	1.96
Fast (*n* = 32)	39.59	4.49	*14.53*	1.92	*13.53*	1.57	*11.53*	1.61
Control (*n* = 34)	39	4.48	*14.03*	1.73	*12.32*	1.75	*11.65*	1.61

Table 2
Reading Scores across Music Conditions on the Nelson Denny Reading Test

Music Condition	Mean Score	Standard Deviation
Slow (*n* = 30)	226.53	68.32
Fast (*n* = 32)	218.03	56.11
Control (*n* = 34)	229.47	65.86

There was no effect of music prime on the NDRT comprehension score, F (2, 96) = .213, p = .808. See *Table 2* for means and standard deviations across music conditions. This pattern of results was identical only for those who received the NDRT directly after the music prime. These results indicate that rate of musical prime does not influence reading comprehension. *(Table 2 above)*

Reading Rate and Comprehension

A Pearson Correlation was run to analyze the relationship between reading rate and comprehension scores on the NDRT. There was a positive correlation between Reading Rate and Comprehension, r = .567, p < .001, indicating that a faster reading rate corresponds with better scores on the comprehension NDRT.

Discussion

The aim of the current study was to see if music rate priming had an effect on processing speed and reading. This study also investigated if reading rate was related to reading comprehension. The results of this study show that the music prime had no effect on processing speed, reading rate, or reading comprehension. This finding could suggest that there is no domain general temporal processing mechanism. However, these results replicate previous findings that reading rate and comprehension are positively correlated.

The music prime did not affect the scores on the Purdue Pegboard Task (PPT), which can have multiple explanations. First, there may not have been a strong enough prime. Ilie and Thompson (2011) investigated how the speed (fast or slow), pitch (high or low), and intensity (loud or soft) of music affected processing speed and creativity, and found that slow music leads to slow processing speed on the routine task. Meanwhile, the current study only manipulated the speed of the music and kept intensities and pitch constant. However, Ilie and Thompson's prime was stronger because it was confounded with other factors such as emotion, so it is possible that rate was not a contributing factor in their study. Further, Ilie and Thompson (2011) measured emotion, and found when participants listen to something more upbeat or happy, it leads to arousal, leading to a participant to have a better score on a processing speed task (Bottiroli et al., 2014). Their prime was also seven minutes in length (instead of three minutes), which contributes to the strength of their prime. It is believed that the lack of prime strength could have been the problem in the current study because other research (e.g., Jungers & Hupp, 2009; Jungers et al., 2016; Kallinen, 2002) has found an effect of music primes. However, the music in the other studies was played concurrently with the task, was confounded with emotion, and was longer, leading to stronger effects of the music rate. Future research should assess emotion to see if it's effects on arousal also influence processing or reading speed rather than the rate of music itself.

Table 3
Comprehension Score across Music Conditions on the Nelson Denny Reading Test

Music Condition	Mean Score	Standard Deviation
Slow (*n* = 30)	52.73	11.39
Fast (*n* = 32)	51.63	15.83
Control (*n* = 34)	53.88	14.34

Another possible explanation for the lack of priming effects on processing speed could be that the PPT is not an appropriate measure of general processing speed. The PPT was originally used as a motor speed task, and later started being used as a processing speed task for a small handful of studies. Although the PPT is generally used for motor dexterity measurement, there is a positive correlation between motor dexterity and processing speed, suggesting that the PPT would have initially been a good measure of processing speed (Ebaid, Crewther, MacCalman, Brown, & Crewther, 2017). However, the effect of music primes may be specific to other types of non-motor processing tasks. Future research should use a different measurement for processing speed and assess other types of processing.

Future research should also investigate how music primes affect oral reading (out-loud) compared to silent reading (in the mind), due to the different methods for measuring accuracy and comprehension (Van de Boer, Van Bergen, & De Jong, 2014). With oral-based reading, comprehension is assessed using oral reading rate and accuracy (Tranin, Hiebert, & Wilson, 2015). Meanwhile, silent reading does not measure reading accuracy, allowing for less concentration on the pronunciation of the words (Schimmel & Ness, 2017), and less work on simultaneous demanding tasks. This saves more cognitive resources for comprehension of a text (Hale, Hawkins, Schmitt, & Martin, 2011; Schimmel & Ness, 2017). When reading silently, studies show that reading speed is faster and recall of the text is better, when compared to reading orally (Schimmel & Ness, 2017). Previous research has also shown that music primes affect language production (Jungers & Hupp, 2009; Jungers et al., 2016), suggesting music primes may affect oral reading differently to silent reading. Future research should also assess for reading difficulties and disabilities through self-assessment on the demographics sheet.

These results support previous research that a faster reading rate is correlated with better reading comprehension, but do not support research that music primes affect processing speed. Based on these results, listening to music before completing a task may not have a negative effect on the task. This information can be used for future research investigating the reading process and how music primes affect reading. Though this research did not find what was expected, it contributes to previous research on music primes by demonstrating the scope where music rate primes may not have an effect, and can influence future research on music primes. Although priming is a largely studied phenomenon, there is still much to be explored in the effects of music priming on cognition.

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