HIGH SCHOOL EDITION
Journal of Student Research

A Comparison of the Effect of Major- Versus Minor-Keyed Music on Short-Term Cognitive Performance

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ABSTRACT

Music cognition is an interdisciplinary field that combines music theory with cognitive science to maximize the brain's potential. Several variables like tempo and instrumentation have been researched in music's effect on cognition, but many, such as key, remain. This pilot study sought to initiate an effort towards: (a) examining the hypothesis that there is a difference between major- and minor-keyed music's effect on cognitive performance, (b) utilizing a single-subject design to account for music cognition's individual differences. Three participants listened to an instrumental excerpt in major key, minor key, and silence while completing elementary arithmetic tests as a metric of cognitive performance. The number of correct responses determined the participant's cognitive performance for that session. Each participant's responses were individually examined through a visual analysis. Two participants supported the hypothesis, favoring the major key; one performed best with the silent condition and demonstrated no distinction between the major and minor key. These results suggest individual differences are a key contributor to music's effect on cognitive performance. Future studies should incorporate single-subject designs to account for these differences. Until future research is done to confirm major-minor's relative efficacy, individuals should continue studying the music (or lack of music) that confines to the variables already proven to increase cognition.

Introduction

There are theories of the mind and theories of music. Taken together, they represent one of the most promising and quickest evolving fields of psychology: music cognition. This interdisciplinary field combines music theory with cognitive science to maximize the brain's potential. Listening to music is observed to improve cognitive functioning in working memory (Fairfield, Mammarella, & Cesare, 2007), attention (McConnel & Shore, 2011), and productivity (White, 2007), among others. With research relating happiness to improved productivity, music's function has evolved from emotional arousal (Saarikallio, 2012) to cognitive performance (Schäfer, Sedlmeier, Städtler, & Huron, 2013). According to Schäfer et al., there are four dimensions for why one listens to music: social, emotional, cognitive, and arousal functions. Look no further than the rise of Lo-Fi, music strategically designed for studying, and the fall of the Mozart Effect, a refuted theory that listening to Mozart improves spatial-reasoning (Rauscher, Shaw, & Ky, 1993, 1995); students, academics, and the music industry clamor for the musical formula to best increase cognitive performance. If such a formula does exist, music cognition is still far from discovering it. Several variables like tempo and instrumentation have been researched in music's effect on cognition, but many more remain. More variables, such as major-minor key, must be researched to unlock music's cognitive potential.

Literature Review

Mood and Cognitive Performance

Studies investigating enhanced task performance have reached a consensus: there is a relation between mood and cognitive performance. Mood, the persisting emotions associated with cognitive states, is factored by a positive or negative balance throughout past research. In a 1986 study, researchers induced a happy, sad, or neutral mood in college students before presenting them with anagram tasks to measure cognitive performance. After observing that the "happy" participants were the most persistent and successful, researchers attributed positive mood to improved productivity (Kavanagh, 1986). In a later study assessing this relationship, researchers introduced a new variable: self-efficacy. 139 participants of varying self-efficacy underwent cognitive tasks adhering to Kavanagh's (1986) study design. The results indicated that individuals in a positive mood are more likely to anticipate success, increasing their intrinsic motivation, and thus, their likelihood to succeed (Niemiec & Lachowicz-Tabaczek, 2015).

Motivation and cognitive performance are linked via the Activation Theory, or Yerkes-Dodson Law. Originally proposed in 1908 by Robert Yerkes and John Dodson, the law asserts that performance and arousal (degree of physiological activation) have an inverted U-shaped relation (Fig.1). Individuals have an optimal level of arousal for optimal task performance. However, over- or under-arousal reduces performance (Yerkes & Dodson, 1908). The threshold of optimal arousal depends on the individual and varies on the complexity and familiarity of the task. Past studies generalize ideal performance to moderate arousal levels with difficult tasks performed best at lower levels, and simple tasks performed best at higher level (Endler, Reg, & Butz, 2012; Jackson & Dongen, 2011).

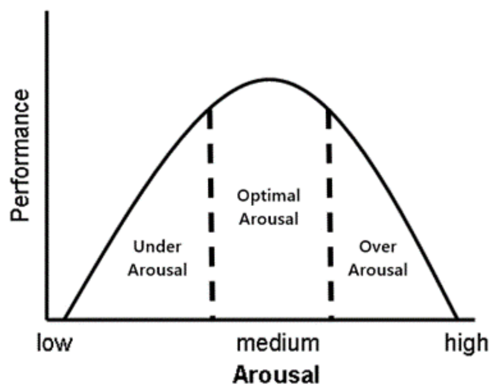

Figure 1. Model of Optimal Arousal According to the Yerkes-Dodson Law (Yerkes & Dodson, 1908)

In 1993, the first empirical evidence was found for music enhancing shot-term cognitive performance, specifically spatial task performance, dubbed the "Mozart Effect" (Rauscher et al., 1993). College student participants listened to 15 minutes of Mozart's Sonata for Two Pianos in D Major, K.448, before completing the spatial tasks portion of the Stanford-Binet Intelligence Test. The results were statistically significant with an increase of 8-9 IQ points; the increase did not occur when the participants sat in silence or were probed with non-musical stimuli (Rauscher et al., 1993). Although the general public welcomed the Mozart Effect (Beauvais, 2015), the scientific community shared concerns over the author's reasoning. Rauscher et al. (1993) attributed the increased cognitive performance to biological factors through the Trion Model of the cerebral cortex (Leng & Shaw, 1991). Their assumption that Mozart primes the same cortical firing patterns as special reasoning received heavy criticism for its lack of empirical evidence in neuropsychology (Schellenberg and Weiss, 2013). Most attempts to replicate the study resulted in failure (e.g., Chambris, 1999); in successful replications, the effect was real but short-lasting (Hetland, 2000), alluding to an alternative explanation for this phenomenon.

Amid refutations of the Mozart Effect, Nantais and Shellenberg (1999) proposed the Arousal and Mood Hypothesis (AMH). This perspective abides by the same reasoning as Kavanaugh's (1986) study on mood and productivity: a pleasant stimulus improves mood which, in turn, improves cognitive performance. In this context, music is the pleasant stimulus. While the Trion Model is limited to Mozart and spatial-temporal abilities, AMH has been observed in a variety of compositions and cognitive tasks (e.g., Ivanov & Geake, 2003; Rideout, Dougherty, & Wernert, 1998; Hallam, Price, & Katsarou, 2002), in which participants listening to music outperformed the silent condition. Regardless of composer, the music must evoke a pleasant mood. In one instance, participants either listened to a "sad" composition (notably in minor) or a "happy" composition (notably in major) before taking two subtests from the Wechsler Adult Intelligence Scale. Participants reliably scored the highest after listening to the "happy" composition. Schellenberg (2005) concluded people perform best listening to music they individually find enjoyable. In sum, increased cognitive performance is a product of arousal, mood, and preference.

AMH has become the leading theory of music cognition (Goltz and Sadakata, 2021). The current study will also subscribe to AMH, as it offers the foundation for this paper: individual preferences inspired the single-subject design; mood inspired the inquiry into major-minor (MM) differences. MM's pre-researched effect on mood offers several implications when paired with AMH.

Major-Minor Keyed Music on Mood and Cognitive Performance

Most musical compositions have a tonic scale: a major or minor key that its pitches will revolve around. Even a layperson can often distinguish major from minor due to the emotions each key evokes (Kolchinsky, Dhande, Park, & Ahn, 2017). Minor scales are associated with somber, negative emotions while major scales are to passionate, positive emotions (Harnish, 2020). German composer, Christian Friedrich Daniel Schubart, first recorded tonic associations in 1785. For example, Schubart describes F Major as "complaisance and calm" while F minor as "deep depression". Although Schubart's reasoning is currently regarded as outdated (e.g., Staubli, 2021; Parncutt, 2013), the fundamental logic still applies: sharps and flats evoke emotions. This results in two theories on MM key associations: sociocultural learnt association (Kolchinsky et al., 2017) and "Sound Symbolism" (Cook, 2006). Cook theorized that MM's emotional connotations reflect the pitch of human speech. Under this reasoning, David Huron (2008) analyzed 9,788 compositions of the Western European classical tradition. Instrumental themes in minor keys reflected the prosodic cues of depressed speech patterns. The results found minor music's "sadness" tended towards smaller melodic intervals, agreeing with the hearing intervals discovered in the minor compositions of Classical and Romantic Composers (Staubli, 2021). As dictated in Cook's 2006 study on human perception, major chords are seen as "happy and bright" while minor chords are "dark and sad", just as Schubart observed centuries prior.

Despite these historical implications on mood, the role of MM keyed music on cognitive enhancement is largely unexplored. An undergraduate's pilot study offers the most direct comparison of major- versus minor-keyed music on cognition (Sayer, 2018). The study utilized a group design and reading tests to measure participants' long-term declarative memory; it did not apply to short-term cognitive performance or task engagement. While minor-keyed music trended towards improved memory retention, it did not meet statistical significance. MM, while promising, remains an uninvestigated variable.

Previously Studied Variables

In contrast, there are several variables that are heavily researched in the music cognition field. The presence of lyrics, for example, are observed to impair cognitive performance (Baldwin, Levy, Oliver, 2020), along with other high-arousal variables such as a loud volume. Saarikallio measured the emotional arousal of 61 teenage participants while listening to a 15-minute musical excerpt of varying volumes: the louder the intensity, the larger the emotional arousal. Recall that, like the Yerkes-Dodson Law, an excess of musical engagement distracts the listener from their task

(Levitin, 2006); thus, a moderate volume is ideal. Likewise, tempo yields the best cognitive performance at a moderate pace. Singaporean researchers factored major-minor keys along with tempo as variables in music-induced arousal. “Major-slow” compositions evoked the lowest arousal and most relaxation and satisfaction in participants (Tay, R., & Ng, B. C., 2019).

According to the AMH, genre is mediated by individual preferences (Schellenberg and Hallam, 2005). However, in general, experiments favor the classical genre to explore cognitive performance. A 1999 study, (Chalmers, Olson, & Zurkowski), utilized soft, classical music to improve behavior and relaxation in elementary school students. Results discovered classical music led to a 7% decrease in students’ volume and 65% decrease in behavioral corrections. Improvements were attributed to classical music’s reduction of emotional arousal: limiting stress and improving concentration (Chalmers et al., 1999). A study of academically struggling fourth graders supplied similar findings for the positive influence of classical music on productivity and emotional wellbeing (White, 2007). Even prior to the discovery of the Mozart Effect, researchers found students focus best with classical music at 60 beats per minute (BPM) (Giles, 1991). Soft, instrumental music of “largo” tempo (60 BPM) meets the optimal threshold for cognitive performance.

Individual Differences

Akin to the prior relation of mood on cognition, music-induced arousal can either enhance performance by improving mood, or hinder performance as a cognitive distraction (Levitin, 2006). Lyrics, loud volumes, quick tempos, and punctuated rhythms all increase listener engagement by evoking high-arousal responses. In multiple studies (e.g. Dolegui, 2013; Hallam, et al., 2002), these high intensity variables were tested by measuring music’s impact on cognitive performance via arithmetic-based tasks. Concentration worsened when listening to high intensity compositions; softer tones, like the classical genre, improved it (Chalmers et al., 1999). Therefore, in tandem with the Yerkes-Dodson Law, the most effective music arouses enough emotion to improve mood, but not enough to divert the listener’s attention. Likewise, the level of optimal music-induced arousal depended on the individual.

For instance, musical ability factors into arousal. Blood and Zatorre (2001) observed musicians’ amygdalae, the brain’s arousal system, while listening to classical compositions; musicians were targeted for their amplified emotional responses to music. Patson and Tippet (2011) even found that task engagement, specifically reading, while listening to music was worse in individuals with a musical background, likely due to their stronger arousal. Individuals also have more intense and positive emotional responses to familiar music (Ali & Peynircioğlu, 2010). Across all the characteristics measured by Goltz and Sadakat’s (2021) study music listening, one unequivocal consensus was reached: some individuals cognitively benefited from music; some did not. This explains the mixed results from current experimental studies (e.g., Hallam et al., 2002), whose group averages do not account for individual differences.

Research Gap

Past research agrees that music improves mood which improves cognitive performance. Major keys have historically improved mood more than minor keys. MM has been investigated cognitively (Cook, 2006; Sayer, 2018), but never by a single-subject design, nor narrowed to task engagement. The present study aims to initiate an effort towards: (a) examining the hypothesis that there is a difference between major- and minor-keyed music’s effect on cognitive performance, (b) utilizing a single-subject design to account for music cognition’s individual differences.

To meet these objectives and further explore music as a cognitive tool, this paper asks: do major-minor keys have a disparate influence on short-term cognitive performance?

Methods

Design

Music's cognitive effect is highly individualized; this is a reoccurring obstacle for those attempting to average data in group designs. Prior studies employing a true experimental or quasi experimental design acknowledge the heavy presence of outliers in their data, attributing the variance of individual results to differences in musical preferences or arithmetic ability (Dolegui, 2013; Hallam et al., 2002). A single-subject experimental design offers a new approach for this topic's history of confounding variables: it only measures individual improvement. Single-subject designs are not case studies; case studies observe the behavior of a subject while single-subject designs utilize independent and dependent variables, just like a typical dependent design. Although these designs are predominately used in Applied Behavior Analysis, Montague and Dietz (2009) recommended them for cognitive studies in which individual results would be lost in group averages. Even without group design, results can still examine a causal-effect relation in the form of a single-subject experimental design known as an alternating treatments design (ATD). In ATD, a subject is exposed to two or more rapidly alternating conditions at random, thus reducing the practice effect that troubled previous within-subjects designs (Dolegui, 2013) whilst accounting for individual differences. Subjects act as their own control group during control sessions; consequently, only individual improvement is measured. ATD is traditionally used by Applied Behavior Analysis to compare a subject's behavior over a baseline, treatment, and withdrawal phase. When applied to cognitive science, researchers recommend its use in a single stage (Sindelar, Rosenberg, Wilson, 1985). Regardless of field, ATD was proposed by Barlow and Hayes (1979) to compare the influence of two or more variables in a single subject; for the current study, these variables were major key and minor key. Considering the anticipated variety of music preferences, cognitive ability, and receptiveness, an ATD was selected.

This study is a single-subject ATD with one independent variable, key, split into two levels of manipulation: major and minor. The dependent variable is the level of cognitive performance defined by the number of correctly answered arithmetic questions during each condition when compared to a baseline of silence. Illegible or blank responses were disregarded. Participants were exposed to all conditions in a randomized order: the Major condition, the Minor condition, and the Silent (Control) condition.

Participants

Three undergraduates, ranging in age from 19 to 22 years, from the University of California Los Angeles voluntarily participated in this study. Prior to the study, participants provided information about their (a) gender; (b) current major; (c) prior musical background; and (d) study preferences (Table 1). The demographic questionnaire (Appendix D) did not determine eligibility; rather, it highlighted any confounding variables from the participants' background to be examined alongside their results, a procedure recommended and implemented by Tay and Ng (2019). The small sample size (n = 3) adheres to the 1 to 10 participant average of prior single-subject designs (Price, 2012). Participants will be referred to as Amy (Subject A), Beth (Subject B), and Claire (Subject C).

Table 1. General Demographics, Pre-Study Questionnaire.

Pseudonym	Gender	Age	Current Major	Study Preference
Amy[a]	F	19	Music	Music, with lyrics
Beth	F	21	Psychology	Silence
Claire	F	22	Neuroscience	Music, no lyrics

[a]Indicates a self-reported musical background ≥ 2 years.

Materials

The study used fifteen different arithmetic tests of matching difficulty to measure cognitive performance (Appendix A) akin to those created and tested by Dolegui (2013). All tests were completed on paper. All problems fell within each participant's level of competence: elementary addition, subtraction, multiplication, and division. Unlike complex cognitive tasks prioritizing leaning and thus long-term performance, simple arithmetic engages previously learned material adhering to the short-term benefits specified in this study (Dolegui, 2013; Hallam et al., 2002).

The music for this study was selected for Giles' (1991) criteria as 'mood calming' to evoke the optimal low arousal of a slow but pleasant composition. Frédéric Chopin's (1840) Nocturne in G minor, Op. 37, No.1 met these requirements with a tempo of 67 BPM and a relative obscurity to reduce any familiarity bias from participants (Ali & Peynircioğlu, 2010). Once selected, the composition was recorded with a solo piano in strict adherence to Chopin's (1840) notation. The subsequent audio was then transposed from minor to its parallel major using the software Audacity® Version 2.4.1. This resulted in two sixty second excerpts (Fig. 2): G Minor for the Minor condition and G Major for the Major condition.

Figure 2. Original and Transposed Nocturne in G Minor, Op. 37, No.1 (Chopin, 1840)

Procedure

This study adopted an ATD conducted in a single phase with three conditions, one of which is a no-treatment control condition. This allows MM to be compared simultaneously alongside a control of silence. In the Minor condition, the participant completed an arithmetic test while listening to a composition in a minor key. In the Major condition, the participant completed a similar arithmetic test while listening to the same composition in its parallel major key. In the control condition, the participant completed a similar arithmetic test in silence. All three participants were exposed to each condition five times to meet the design standard for providing solid evidence (Wolery, Gast, & Haymond, 2010). The conditions alternated at random to control for the carryover and practice effects. The experiments were conducted individually utilizing 15 arithmetic tests. Each session involved one arithmetic test over a 60-second interval with a two-minute break between each test, per the recommendation of past literature (Barlow et al., 2008; Kazdin, 2011). The break was intended to control for multiple treatment inference, an internal validity threat in ATD designs.

All sessions were conducted individually in the same empty classroom without external distractions. To reduce bias, subjects were not told which condition they were listening to, nor the study's narrowed focus of task engagement, at any point in the experiment.

All sessions were completed in the same sitting to (a) respect participants' time, (b) simulate the fatigue of dull tasks from the back-to-back sessions. All excerpts were played from the same portable wireless speaker at a low, but audible volume. Subjects were instructed to complete as many questions as accurately as possible within the allotted 60 seconds to test cognitive performance.

At the end of the experiment, each subject was briefed on all aspects of the study, including which excerpt was in the major key and which was in the minor key. Subjects were also informed which condition best increased their own cognitive performance; although single-subject designs are not generalizable, participants can directly benefit from their individual findings.

Approach to Analysis

There are several analytical techniques to interpret ATD data (Manolov, Onghena, 2017). However, only one analytic technique best applies to this study's single-phase design: visual analysis. Visual analysis is the traditional technique in ATD. Barlow et al. (2008) encourages its use in evaluating research questions with independent and dependent variables, like MM on cognitive performance. The analysis interprets trends, levels, overlap, and data patterns on a subject's graph. Holcombe et al. (1994) prioritizes level and trend to evaluate the effectiveness of a treatment. Alternatively, Barlow et al. (2008) asserts that nonoverlap of lines indicates a difference between conditions. This study will consider both perspectives and mean differences (Table 2), but directly conform to Barlow et al.'s criteria. Accordingly, to support the hypothesis, the lines for the Major and Minor conditions cannot overlap.

Results

Table 2. Individual Means

Pseudonym	Silent (M)	Major (M)	Minor (M)	MM (MD)
Amy	40.6 [a]	35.6	37.8	2.2
Beth	26.8	36.3 [a]	27.8	8.6
Claire	19.6	23.8 [a]	18	5.6

Note. (M) = mean. MM (MD) = mean difference between the Major Condition and the Minor Condition.
[a]Indicates the condition each subject performed best with.

Figures 3–5 represent each participant's cognitive performance across the fifteen sessions. A visual inspection of the figures verifies the aggregated statistics and individual means presented in Table 2. Subject-specific findings must be interpreted in this section because ATD trends are otherwise incomprehensible without context and implications. Discussion of differences in general responses to the music (MM) conditions versus the silent (control) condition will be deferred until the next section.

For visual convenience, each single-subject graph (Figs. 3-5) will be addressed individually with its corresponding subject. The y-axis reflects the number of correct arithmetic responses per minute ($_{CR/m}$). The score for each session is marked with the employed condition: a square represents performance listening to the major key, a triangle represents performance listening to the minor key, and a grey circle represents performance listening to silence, the control condition. Cognitive performance is visualized by a line connecting markers for each condition. A dashed horizontal line tracks the subject's enhancement during the silent condition to subtly compare music, regardless of key, to the control; the focus should be any difference between keys. Both MM conditions are distinguished by solid lines to compare their respective trends and thus prioritize the study's inquiry: do major-minor keys have a disparate influence on short-term cognitive performance?

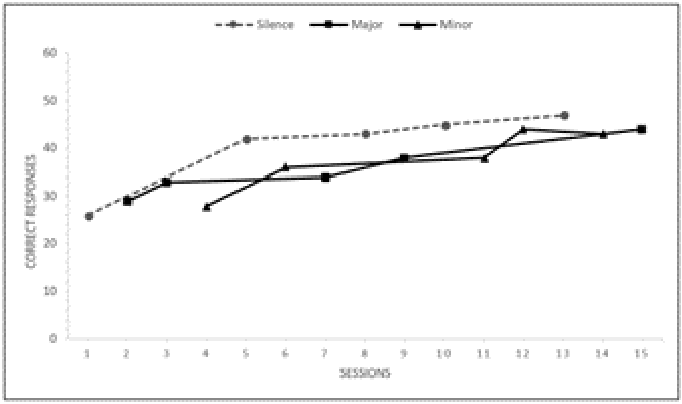

Figure 3. Subject A, Amy

From both a visual and statistical inspection of Fig.3, Amy's cognitive performance appeared independent of treatment. All conditions adhered to a gradual incline upwards trend averaging 43.2 $_{CR/m}$ in the final five sessions. This is a 36.7% increase from the first five sessions (31.6 $_{CR/m}$). Additionally, the inclined trajectory of all scores from session five onward suggests her progress reflects improvement from practice and not a response to any condition. Amy began with the highest accuracy and maintained the score with relatively low variation across all fifteen sessions. Performance during the silent condition (40.6) was near consistently higher than either music condition (Major: 35.6 and Minor: 37.8); music impaired Amy's cognitive performance. A visual inspection of the major and minor overlap indicated no reliable difference between the two conditions. Moreover, their mean difference was 2.2, the smallest observed across subjects. The Major condition and Minor condition overlapped four times; therefore, Amy's results reject the hypothesis.

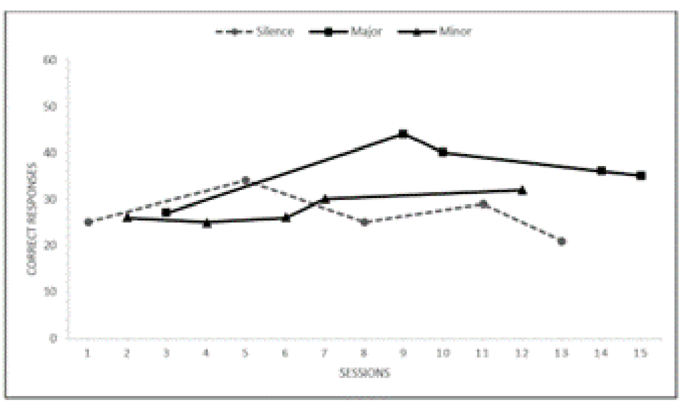

Figure 4. Subject B, Beth

Unlike Amy, Beth exhibited the most robust discrimination of major and minor between the three participants. She performed nearly identical at the start of each condition, averaging around 26 $_{CR/m}$ in the first three sessions (Fig.4). This pattern subsided by the second session of each condition: performance under major and silence increased while minor dwindled. Beth settled at an average 27.8 $_{CR/m}$ for minor with an irrelevant upward trend in the final two sessions. Beth's control level declined below the minor key at session 7. Beth's responses improved with the Major condition by the second session and stabilized at an average 36.4 $_{CR/m}$, even as her scores for Silence decrease to 21 correct responses by the final session and a total average of 26.8 $_{CR/m}$. The Major line stayed above the Minor and Silence lines for the remainder of Beth's sessions. These gains yielded a distinct 8.6 $_{CR/m}$ difference between MM means, with major-keyed music being the most effective for Beth's cognitive performance (Table 2). The fact that no overlap was found between the Major and Minor conditions strongly suggests major had a greater effect than minor on her arithmetic scores. Beth’s results support the hypothesis.

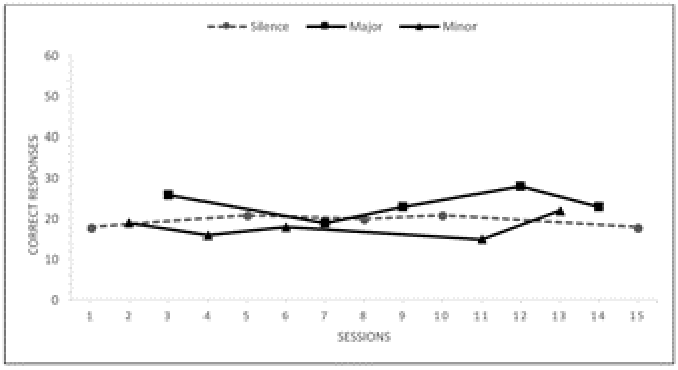

Figure 5. Subject C, Claire

The final participant, Claire, began with low arithmetic performance and demonstrated little variability over the course of fifteen sessions (Fig.5). Her overall progression was marked by a 6% increase, a lowered range in comparison to the previous two participants. However, this did not reduce the significance of Claire’s data; recall that all data in an ATD design are only applied in the context of the subject’s ability (Wolery et al., 2010). Claire’s graph, on a smaller scale, was reminiscent of Beth’s trends (Fig 4). For example, her major level was similarly elevated above the other two conditions at a mean of 23.8 $_{CR/m}$ across the experiment. In the context of Claire’s narrowed range, her performance during Major saw a distinct increase of 47.4%. between the 7th and 12th sessions. The decline from Major’s final data point (23 $_{CR/m}$) still fell within the top of her range (19-28 $_{CR/m}$), and therefore supports that major-keyed music improved Claire’s performance. The control, Silence, saw the least variation and maintained an average 19.6 $_{CR/m}$. The Silent line trended above the Minor line; Claire performed the worst listening to minor-keyed music and the best listening to major-keyed music (Table 2). A mean difference of 5.8 $_{CR/m}$ separates the Major and Minor conditions. Considering the lack of overlapping data between MM, her results support the hypothesis.

Discussion

The present study sought to distinguish the influences of MM on short-term cognitive performance. It was hypothesized that if a subject performed differently listening to a song in major than in minor, then a song’s key is a factor in music’s capability for cognitive performance. The music conditions, MM, were compared against each other and against the control condition, silence.

This study’s secondary objective was to demonstrate the use of single-subject designs for future researchers’ consideration. As several differences were observed between individuals and outcomes, this objective was met.

In two out of three cases, the hypothesis was supported. Beth and Claire performed better listening to the major key than the minor key. Both demonstrated a differential response between the Major and Minor conditions, supporting the hypothesis. As for Amy, the Silent condition was associated with the highest cognitive performance. She demonstrated the most overlap between the music conditions, suggesting MM had no influence on her cognitive performance and thus refuted the hypothesis.

Amy is the only subject who performed best in silence and the only subject with a background in music. Because Amy is a music major, there is a possibility her musicianship amplified her response to the point of distraction as proposed by prior research (Blood & Zatorre, 2001), worsening her performance during both music conditions. Her performance in both conditions followed near identical trends with heavy overlap. Rather than dismiss MM as a variable in music’s cognitive performance, Amy’s data points to a broader debate: music versus silence. The current study

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found that some individuals may respond differently to musical conditions based on their general preference for silence or music (Fig. 3-5). Only Amy demonstrated no difference of response between Major and Minor Conditions; she was also the only subject that performed best listening to silence. Beth and Claire demonstrated the opposite: they performed better listening to music in major than in silence and had differential responses between the Major and Minor Conditions.

Implications

The discrepancy between Amy's graph to the other two participants may offer an explanation why prior studies have struggled with evaluating which factors contribute to music's cognitive performance (Dolugui, 2013). Certain individuals are cognitively enhanced by music (e.g., Beth and Claire), while others are impaired by it (e.g., Amy), as consistent with the results of existing literature (e.g., Hallam et al., 2002). Under this theory, only those helped by music are affected by musical factors. Those who perform best in silence would exhibit an indifferent response to factors like key, as is portrayed by Major and Minor overlap in Figure 3.

Determining whether music or silence best increase cognitive performance may differ on an individual basis. Yet, prior studies have largely utilized group designs without consideration of their participants innate preference for music or silence (e.g., Dolegui, 2013; Hallam et. al., 2002; Schellenberg et al., 2007). Consequently, subjects' responses are too individualized to support or refute a hypothesis; this issue has received repeated attention in the current literature on music cognition. Refer to Future Directions for further elaboration.

Findings also implied that, for some individuals, music may increase engagement over time, as opposed to silence. This study did not measure task engagement directly; instead, it fell under the domain of cognitive functioning. The quantity of accurately answered arithmetic questions was this study's metric for engagement. All sessions were completed in succession with one another to allow fatigue to set in and decrease engagement. A decreasing trend line only occurred in one graph (Fig. 4) and for only one condition: silence. Beth's scores with silence worsened as her scores with minor improved; the lines cross at session 7, which could reflect a loss in motivation. The simultaneous score improvements across both MM conditions with time alludes to music's role in cognitive arousal and supports AMH. This finding agrees with White (2007) and McConnel and Shore (2011) who linked music to improved productivity and concentration.

In both cases where subjects responded differently to each key, there was a distinct preference for the Major condition (Fig. 4-5). Intriguingly, Claire's Silent line was elevated above her Minor line, indicating she performed the worst while listening to music in minor key. Such findings imply minor negatively influenced Claire's cognitive performance; notably, the major key improved it. This offers support for AHM: while minor key is associated with negative emotions, major key is linked to positive emotions (Huron, 2008) and improved mood. Furthermore, a positive mood correlates with improved productivity (Kavanaugh, 1987). Consistent with Claire's trends, major key may improve productivity while minor key worsens it.

Limitations and Future Directions

The present study investigated an understudied factor of music cognition. However, accompanying the study's exploratory nature, some limitations must be considered. First, all findings are constrained by the limited number of participants (n = 3). This is a caveat of any single-subject design. Consequently, results are not generalizable and cannot be applied to individuals, cognitive tasks, or situations other than the one's tested in the current study. Due to the small sample size, it is difficult to evaluate the influence of demographic factors, such as musical background and musical preference, on subjects' responses. Therefore, to determine if music reliably improves cognitive performance, subsequent research should investigate the factors that can predict whether an individual is cognitively enhanced or cognitively impaired when listening to music. Only then, by targeting a population with a preference for studying music, can group designs conclusively determine whether MM keyed music is a variable. Until then, the use of single-subject experimental designs to counter any individual differences should be strongly encouraged. Music cognition is not reserved to the scholarly community; individuals can perform their own single-subject ATDs to find which MM key suits their personal preferences. Although such a self-study would be heavy with researcher and response bias, just being aware of one's music preferences while studying can inform future listening. If music is highly individualized, then it is an individual responsibility to understand how music affects their personal cognition.

Observation of cognitive performance was limited to the short-term. For the two subjects who exhibited a positive response to music, any enhancement was assumed to expire once the 60 second excerpt stopped playing. Although the existence of a carry-over effect defies literature, which confines cognitive benefits to the short-term, it still posed a risk, however minimized, due to the brevity of the session. Any replication of this study is strongly advised to increase the number of sessions and tests per session. More datapoints could strengthen the patterns in the single-subject plots and increase effect sizes. Furthermore, more tests in a session might amplify the subject's fatigue, which may be the pivotal reason that scores decline with silence but are invigorated by music (e.g., Fig.4). A study with a longer time frame would also cement the line trends and demonstrate with confidence which condition is the most effective; ideally, all three lines should stabilize with time regardless of the practice effect.

Finally, future research should explore a variety of cognitive tasks rather than the current study's arithmetic metric. This study's findings are limited to cognitive performance regarding engagement of simple and repetitive tasks. However, cognitive performance extends to executive functions in memory, learning, reasoning, etc. Measuring major-minor keys influence over a multitude of tasks, such as the reading comprehension explored by Hallam et al. (2002), is necessary to determine the extent music applies to. More research must be done to reach certainty on any of the aforementioned topics.

Conclusion

Visual inspection revealed significant differences for two subjects. In both cases, performance listening to major key exceeded performance listening to minor key and silence. Taken together, these results support that MM key is a factor in music's cognitive performance for some individuals. However, the presence of the other subjects' overlapping data and their limited generalization signify that a difference between major-minor influences is not a definitive conclusion; it may differ between individuals. Future research is necessary to determine the difference and efficacy between MM on short-term cognitive performance. Above all, individual differences must always be considered.

Music may enhance the cognitive ability of some individuals, but understanding which factors contribute to this enhancement is fundamental to the music cognition field. While variables such as tempo, instruments, and volume are well researched, there are many others, like MM, that require further evaluation than one study can provide. Identifying which variables contribute to music's cognitive performance can better inform educators' use of music in the classroom (White, 2007). Students seeking the ideal studying music for cognitive performance should factor in these variables; in the context of this study, choosing a song in major key versus a song in minor key could be the difference between improvement and impairment. But until future research is done to definitively confirm major-minor's relative efficacy, individuals should continue studying to the music (or lack of music) that confines to the variables proven to increase cognition: soft, moderately paced, instrumental music, regardless of key.

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