Tuning the inner radio: The mental control of musical imagery in everyday environments

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Abstract:

How easily can people tune their inner radio? Musical imagery—hearing music in your mind—is common but little is known about people's ability to control their musical imagery in daily life. A recent model distinguishes between *initiation* (starting musical imagery) vs. *management* (modifying, stopping, or sustaining musical imagery) as facets of control, and the present research examined people's ability to use these two forms of control in daily life. For seven days, students (29 music students, 29 non-music students) were signaled 10 times daily and asked to initiate musical imagery and to perform manipulations on initiated and ongoing imagery (e.g., increasing the tempo, changing the vocalist's gender). When asked, people reported exerting control over the initiation and management of their musical imagery most of the time. As expected, music students reported controlling their musical imagery more often and more easily. This work suggests that people's control over their musical imagery is stronger and more flexible than prior work implies.

Keywords: experience sampling | imagery | mental control | musical expertise | musical imagery

Article:

Sometimes the stream of consciousness is loud. Musical imagery—hearing music in your mind that isn't simultaneously playing in the environment—is ubiquitous. Most people report experiencing musical imagery sometimes (Bailes, 2007, 2015; Cotter, Christensen, & Silvia, 2018), yet little is known about the inner radio in people's natural environments. Recent research has emphasized *earworms*—involuntary, repetitive episodes of musical imagery that is a type of *involuntary musical imagery* (Williams, 2015)—but this emphasis raises an interesting question: How well can people exert control over their musical imagery?

In recent work, Cotter et al. (2018) proposed two distinct forms of mental control of everyday musical imagery: *initiation* and *management. Initiation*—the involuntariness meant by most involuntary musical imagery work—describes whether the imagery was started intentionally. *Management* refers to control that occurs after the imagery has begun (e.g., changing the song, ending the experience, sustaining it in the face of distraction). The same

episode of musical imagery can thus be voluntarily initiated while lacking control in management, or vice versa (cf. Seli, Risko, Smilek, & Schacter, 2016).

The basic science of auditory imagery has shown that people can control aspects of their imagery. Auditory imagery tasks require people to initiate an image, and people can initiate images of single tones (Farah & Smith, 1983), chords (Hubbard & Stoeckig, 1988), musical scales (Janata & Paroo, 2006), tonal hierarchies (Vuvan & Schmuckler, 2011), and simple melodies (Herholz, Lappe, Knief, & Pantev, 2008) with reasonable accuracy. Likewise, people can manipulate and manage these images, from sustaining images of musical passages (Halpern & Zatorre, 1999) and monitoring images to evaluate their similarity to notation (Bailes, Bishop, Stevens, & Dean, 2012) to performing simple manipulations (e.g., changing pitches of imagined tones; Gelding, Thompson, & Johnson, 2015) and complex transformations (e.g., transposing images into different keys; Foster, Halpern, & Zatorre, 2013). A self-report instrument, the Bucknell Auditory Imagery Scale (BAIS; Halpern, 2015), has a "Control" subscale assessing the management of auditory images; higher scores predict better performance on musical imagery tasks (Gelding et al., 2015). (The BAIS does not use *management* to describe its control subscale, but the manipulations it captures reflect how management is used here.) Collectively, this literature shows that people can both initiate and manage their musical imagery in controlled lab settings.

A natural next step is to explore the ability to control imagery experiences outside the lab. Auditory imagery experiments typically use single tones, chords, or melodic lines, but musical imagery in everyday life is rarely so simple—it contains vivid representations of the melody, lyrics, and timbre of a song (Bailes, 2007), often extended across long passages. Because lab-based work is generally assessing voluntary, controlled instances of imagery, it's unclear how well these findings apply to people's frequent involuntary musical imagery experiences. Thus, musical imagery experiences in controlled lab settings don't necessarily resemble musical imagery in real-world environments.

Past experience-sampling method (ESM) studies show that people don't often start their imagery deliberately (Cotter et al., 2018), and survey work suggests that involuntary musical imagery is common (Liikkanen, 2008, 2011). It is thus important to distinguish between the control people *typically* exert and the control they *can* exert when motivated to do so. Research examining everyday musical imagery, while not explicitly investigating control, shows that people can at times control musical imagery. For instance, people will change their musical imagery to a new song (Williamson, Liikkanen, Jakubowski, & Stewart, 2014) or stop the experience altogether (Beaman & Williams, 2010, 2013).

Musicians describe many instances of purposeful musical imagery in their daily environments. Performers often report relying on mental rehearsal of their repertoire (Fine, Wise, Goldemberg, & Bravo, 2015). Many of these reports allude to intentionally initiated and managed musical imagery (e.g., mentally running through a song moments before an audition; Bowes, 2009) and reveal that musical imagery can be used to achieve technical (Bailes, 2009) and stylistic goals (Holmes, 2005). Moreover, these mental rehearsal techniques improve performance (Bernardi, De Buglio, Trimarchi, Chielli, & Bricolo, 2013; Rubin-Rabson, 1941).

Composers also report using musical imagery when developing their compositions (Agnew, 1922; Hamburger, 1952). Within their minds, composers are free to manipulate and adjust fragments of their work for notation in the final piece of music (Bailes, 2009; Bailes & Bishop, 2012; Mountain, 2001). Additionally, musical imagery frees composers from physical constraints (e.g., someone who can't play the violin can imagine one playing) and allows them to "hear" their composition in its entirety rather than through playing isolated instrumental parts (Cowell, 1926).

The major open question, however, is how well can people control the musical imagery they experience in everyday life? The present research examined people's ability to control different qualities of musical imagery in everyday environments and the relative difficulty of controlling these different qualities. During one week of experience-sampling, participants were asked to initiate and manage their musical imagery. We also examined how musical expertise predicts the ability to control musical imagery and the difficulty of doing so. Musical experts hear musical imagery more often in everyday life (Beaty et al., 2013; Cotter & Silvia, 2017), perform better on lab-based musical imagery tasks (Bishop, Bailes, & Dean, 2013a, 2013b; Herholz et al., 2008; Weir, Williamson, & Müllensiefen, 2015), and have somewhat higher general auditory imagery ability (Zatorre, Halpern, & Bouffard, 2010). Because musical imagery is important to musical training, we expect that people with greater musical expertise will have better control of their musical imagery.

Method

Participants

Participants were 76 adults (37 music students; 39 non-music students) who received $20 cash. Music students were majoring or minoring in music (19 Music Education, 2 Music Performance, 3 Jazz Studies, 1 Composition, 6 General Music Majors, 3 General Music Minors, and 3 Education/Performance double-majors). All programs had a music performance requirement. We excluded 18 participants who completed under five daily surveys, a minimum for experience sampling (Bolger & Laurenceau, 2013). Our final sample was 58 people (*M* age = 19.45, *SD* = 1.45), with 29 music students (14 female, 12 male, 3 unreported) and 29 non-music students (24 female, 4 male, 1 unreported).

Measures

Goldsmiths Musical Sophistication Inventory (GMSI). The GMSI (Müllensiefen, Gingras, Musil, & Stewart, 2014) is a five-factor measure of musical expertise—Active Engagement, Perceptual Abilities, Singing Abilities, Emotions, and Musical Training. This study used the *General Sophistication* score (18 items), which contains items from each of these five factors. Items are rated from 1 (*Completely Disagree*) to 7 (*Completely Agree*), and scores are computed as item sums.

Experience sampling survey. When signaled, people completed a brief survey about their inner experience (see Table 1). People were first asked if they were hearing music in their head. People who were experiencing musical imagery were asked to perform four manipulations of their

musical imagery: increasing the tempo, changing the key, changing the primary instrument (if the music was instrumental) or gender of the vocalist (if the music had a vocal track), and changing to a different song. People reported whether they could complete each change (*Yes* or *No*) and, if able to perform the manipulation, how difficult it was to execute the manipulation on a seven-point scale (*Not at all difficult* to *Very difficult*). People rated whether they were able to make each manipulation one-at-a-time and the difficulty of each manipulation immediately after completing the manipulation. People were not asked to revert to their original image prior to making subsequent manipulations.

Table 1. Experience sampling survey.

Dimension	Item	Response scale
Frequency	*Hearing Musical Imagery*: Right now, are you hearing music in your head?	*Yes* or *No*
Initiation	*Start on Purpose*: I made the music in my mind start playing on purpose.	1 (*Strongly Disagree*) to 7 (*Strongly Agree*)
	Initiate Ability: Think of a song you have heard recently. Are you able to start playing this song in your head?	*Yes* or *No*
	Initiate Difficulty: How difficult was it to start playing this song?	1 (*Not difficult at all*) to 7 (*Very difficult*)
Management	*Speed Ability*: Try to increase the tempo (speed) of the music in your head. Are you able to do this?	*Yes* or *No*
	Speed Difficulty: How difficult was it to increase the tempo of the music?	1 (*Not difficult at all*) to 7 (*Very difficult*)
	Key Ability: Try to change the key of the music in your head. Are you able to do this?	*Yes* or *No*
	Key Difficulty: How difficult was it to change the key of the music?	1 (*Not difficult at all*) to 7 (*Very difficult*)
	Is the music in your head primarily vocal or instrumental?	*Vocal* or *Instrumental*
	Vocal Ability: Try to change the gender of the vocalist. Are you able to do this?	*Yes* or *No*
	Vocal Difficulty: How difficult was it to change the gender of the voice?	1 (*Not difficult at all*) to 7 (*Very difficult*)
	Instrument Ability: Try to change the primary instrument to a different instrument. Are you able to do this?	*Yes* or *No*
	Instrument Difficulty: How difficult was it to change the instrument?	1 (*Not difficult at all*) to 7 (*Very difficult*)
	Change Song Ability: Try to change the music in your head so that you are hearing a different song. Are you able to do this?	*Yes* or *No*
	Change Song Difficulty: How difficult was it to change to a different song?	1 (*Not difficult at all*) to 7 (*Very difficult*)

These manipulations were selected to assess several ways that musical imagery can be managed. Past laboratory work has examined representations of tempo (Jakubowski, Farrugia, & Stewart, 2016), the range of tempos people can imagine (Halpern, 1992), the ability to imagine music in different keys (Foster et al., 2013), and the ability to imagine music played by different instruments and their timbres (Crowder & Pitt, 1992). Additionally, people report trying to imagine different songs to dislodge their earworms (Beaman & Williams, 2010; Williamson & Jilka, 2014). The manipulations in the present study, while not identical to those used in

laboratory research, are conceptually related to these aspects of musical imagery. We anticipated that the manipulations would vary in difficulty, so examining different aspects of musical imagery allowed us to explore potential difficulty differences. Because this was our first attempt to assess the manipulation of musical imagery in daily life, we held some changes constant (e.g., asking participants only to increase the tempo instead of to increase or decrease it) and did not dig into some finer-grained aspects of control (e.g., asking participants only to change the key, not to change it in a certain direction or distance). Such issues are fertile topics for future research.

People who were not experiencing musical imagery when signaled were asked if they could initiate musical imagery (*Yes* or *No*). If they could, people were asked to rate the difficulty of initiation (via a seven-point *Not at all difficult* to *Very difficult* scale) and to perform the manipulations described earlier to their musical imagery. People who could not initiate musical imagery were asked filler questions about their thoughts so that the ESM survey was always of a similar length. Consistent with standard practices in ESM research, each survey included additional items about participants' current environment and moods. We did not analyze these items because they were not relevant to our predictions, but we note them here for readers who might wish to reanalyze the data to test other hypotheses.

Procedure

Participants were recruited at a table on campus. After learning about the study, participants provided informed consent and completed a practice ESM survey on MetricWire, an application downloaded to their smartphones. Research assistants ensured that all participants understood the study's music terms (e.g., key, tempo). Finally, participants completed demographics and the GMSI on MetricWire.

The data were collected over 7 consecutive days. MetricWire signaled participants 10 times each day between 8 a.m. and midnight at quasi-random times at least 90 minutes apart. Participants were instructed to turn off their volume or ignore notifications when completing a survey would be inappropriate or unsafe. As an incentive, participants who completed at least 45 surveys were entered in a raffle for one of three $40 prizes—26% of participants qualified. People with low response rates after 2 days were contacted via email to address technical malfunctions. All participants received a mid-week email to check for any issues. After 7 days, participants were thanked, told whether they qualified for the raffle, and asked to uninstall MetricWire.

Results

Descriptive statistics

Internal consistency was good for the GMSI *General Sophistication* score (18 items; $\alpha = .88$). Not surprisingly, music students scored much higher on the GMSI ($M = 100.48$, $SD = 9.78$, range = 71–116) than non-music students ($M = 77.69$, $SD = 17.78$, range = 42–111).

Participants completed a total of 1,409 ESM surveys. Each person completed the survey 24.29 times, on average ($SD = 14.31$, range = 5–64). The ESM data have two levels: the within-person

level (containing repeated responses to the ESM survey) and the between-person level (containing expertise scores and pooled ESM scores). Table 2 displays the within-person and between-person descriptive statistics. Unless noted otherwise, the text emphasizes the within-person effects, consistent with the focus of ESM research on within-person processes (Bolger & Laurenceau, 2013).

Table 2. Descriptive statistics.

	Full sample				Music students				Non-music students			
	Within		Between		Within		Between		Within		Between	
	M (SD)	Range	*M (SD)*	Range	*M (SD)*	Range	*M (SD)*	Range	*M (SD)*	Range	*M (SD)*	Range
Hearing Musical Imagery	.52 (.50)	0, 1	.52 (.21)	.13, 1.00	.55 (.50)	0, 1	.57 (.20)	.13, 1.00	.49 (.50)	0, 1	.48 (.21)	.13, 1.00
Start on Purpose	2.42 (1.94)	1, 7	2.42 (1.15)	1.00, 5.50	2.27 (2.02)	1, 7	2.39 (1.32)	1.00, 5.50	2.55 (1.86)	1, 7	2.45 (.95)	1.00, 5.31
Initiate: Ability	.61 (.49)	0, 1	.66 (.32)	.00, 1.00	.73 (.45)	0, 1	.79 (.27)	.00, 1.00	.52 (.50)	0, 1	.53 (.32)	.03, 1.00
Initiate: Difficulty	2.05 (1.58)	1, 7	2.20 (1.23)	1.00, 6.50	1.55 (1.16)	1, 6	1.68 (.84)	1.00, 4.00	2.57 (1.77)	1, 7	2.71 (1.33)	1.00, 6.50
Speed: Ability	.71 (.45)	0, 1	.67 (.31)	.00, 1.00	.82 (.39)	0, 1	.82 (.21)	.33, 1.00	.61 (.52)	0, 1	.52 (.33)	.00, 1.00
Speed: Difficulty	1.97 (1.45)	1, 7	2.37 (1.35)	1.00, 7.00	1.50 (1.08)	1, 7	1.80 (1.05)	1.00, 4.50	2.57 (1.63)	1, 7	3.02 (1.36)	1.13, 7.00
Key: Ability	.47 (.50)	0, 1	.46 (.37)	.00, 1.00	.51 (.50)	0, 1	.56 (.37)	.00, 1.00	.44 (.50)	0, 1	.37 (.33)	.00, 1.00
Key: Difficulty	2.37 (1.65)	1, 7	2.97 (1.44)	1.00, 6.00	1.85 (1.46)	1, 7	2.45 (1.19)	1.00, 5.00	2.95 (1.65)	1, 7	3.51 (1.48)	1.00, 6.00
Vocalist: Ability	.63 (.48)	0, 1	.62 (.31)	.00, 1.00	.73 (.45)	0, 1	.73 (.28)	.00, 1.00	.56 (.50)	0, 1	.57 (.31)	.00, 1.00
Vocalist: Difficulty	2.56 (1.70)	1, 7	2.83 (1.46)	1.00, 7.00	1.96 (2.19)	1, 7	2.19 (1.06)	1.00, 4.57	3.08 (1.74)	1, 7	3.49 (1.53)	1.00, 7.00
Instrument: Ability	.61 (.49)	0, 1	.55 (.37)	.00, 1.00	.70 (.46)	0, 1	.71 (.31)	.00, 1.00	.45 (.25)	0, 1	.37 (.36)	.00, 1.00
Instrument: Difficulty	2.11 (1.61)	1, 7	2.56 (1.62)	1.00, 7.00	1.62 (1.17)	1, 6	2.05 (1.25)	1.00, 5.50	3.57 (1.85)	1, 7	3.38 (1.81)	1.00, 7.00
Change Song: Ability	.72 (.45)	0, 1	.70 (.29)	.00, 1.00	.78 (.42)	0, 1	.79 (.25)	.17, 1.00	.67 (.47)	0, 1	.62 (.31)	.00, 1.00
Change Song: Difficulty	1.95 (1.42)	1, 7	2.25 (1.21)	1.00, 6.00	1.46 (.98)	1, 6	1.77 (1.02)	1.00, 6.00	2.49 (1.63)	1, 7	2.76 (1.18)	1.00, 6.00

Note. "Within" and "Between" refer to descriptive statistics at the within-person level and between-person level, respectively.

The multilevel models were estimated in Mplus 8 using maximum-likelihood with robust standard errors and fixed effects. Both the GMSI and music student status were used to predict frequency of musical imagery and all mental control indices. When possible, outcomes were modeled using multivariate multilevel models to control for their potential overlap and family-wise error. The five management ability items were analyzed concurrently (i.e., as a multivariate model), and the five management difficulty items were analyzed concurrently. Due to survey branching, analyses for the three initiation items were conducted separately. The findings for both musical expertise measures were very similar, so we report results only for music student status in text unless otherwise noted (see Table 3 for all results).

How often did people experience musical imagery?

Of the 1,409 ESM surveys, 730 (51.81%) captured musical imagery episodes. The intraclass correlation (ICC)—an estimate of the proportion of variance at the between-person level—for experiencing musical imagery was .11 (see Figure 1 for all ICCs), so experiencing musical

imagery at any given survey is more strongly influenced by within-person factors that change throughout the day rather than stable between-person differences, such as musical expertise.

Table 3. How musical expertise predicts mental control ability and difficulty.

Outcome	GMSI general sophistication		Music student	
	β(SE)	95% CI	β(SE)	95% CI
Hearing Musical Imagery	.32* (.14)	[.05, .59]	.23 (.15)	[−.07, .53]
Start on Purpose	−.12 (.14)	[−.38, .15]	−.07 (.16)	[−.37, .24]
Initiate: Ability	.29* (.15)	[.00, .57]	.45*** (.13)	[.21, .70]
Initiate: Difficulty	−.32** (.12)	[−.56, −.07]	−.56*** (.13)	[−.80, −.31]
Speed: Ability	.41*** (.12)	[.17, .64]	.48*** (.11)	[.28, .69]
Speed: Difficulty	−.35** (.12)	[−.58, −.12]	−.51*** (.10)	[−.72, −.31]
Key: Ability	.35** (.11)	[.13, .57]	.26* (.13)	[.00, .52]
Key: Difficulty	−.45*** (.13)	[−.69, −.21]	−.44*** (.12)	[−.68, −.25]
Vocalist: Ability	.40** (.13)	[.14, .66]	.46*** (.12)	[.22, .70]
Vocalist: Difficulty	−.40*** (.12)	[−.64, −.21]	−.47*** (.11)	[−.68, −.25]
Instrument: Ability	.65*** (.10)	[.45, .84]	.51*** (.13)	[.26, .76]
Instrument: Difficulty	−.31* (.14)	[−.60, −.03]	−.53*** (.13)	[−.78, −.28]
Change Song: Ability	.29* (.12)	[.06, .53]	.30* (.13)	[.05, .55]
Change Song: Difficulty	−.50*** (.10)	[−.69, −.30]	−.52*** (.11)	[−.73, −.31]

Note. * $p < .05$, ** $p < .01$, *** $p < .001$. "Music student" variable was coded 0 = non-music student, 1 = music student.

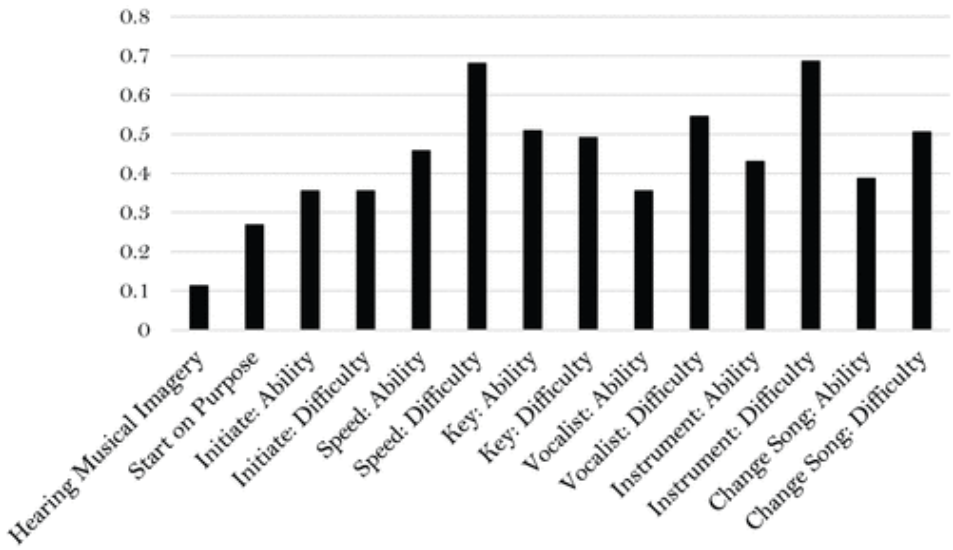

Figure 1. ICCs for the experience-sampling items.

People with more musical sophistication, measured by the GMSI, experienced musical imagery more frequently, β = .32, p = .021, 95% CI (.05, .59). When comparing music (55.03%) to non-music students (49.16%); however, the difference was not significant, β = .23, p = .125, 95% CI (−.07, .53).

Can people initiate musical imagery?

We measured initiation of musical imagery in two ways: whether people already experiencing musical imagery when signaled started it on purpose, and whether people could initiate musical imagery when asked. Consistent with past work, our first method indicated that people infrequently initiated their musical imagery episodes ($M = 2.42$, $SD = 1.94$)—approximately 17% of episodes were voluntarily initiated (indicated by responding above the scale midpoint). Music student status, $\beta = -.07$, $p = .676$, 95% CI (−.37, .24), did not predict this measure of initiation.

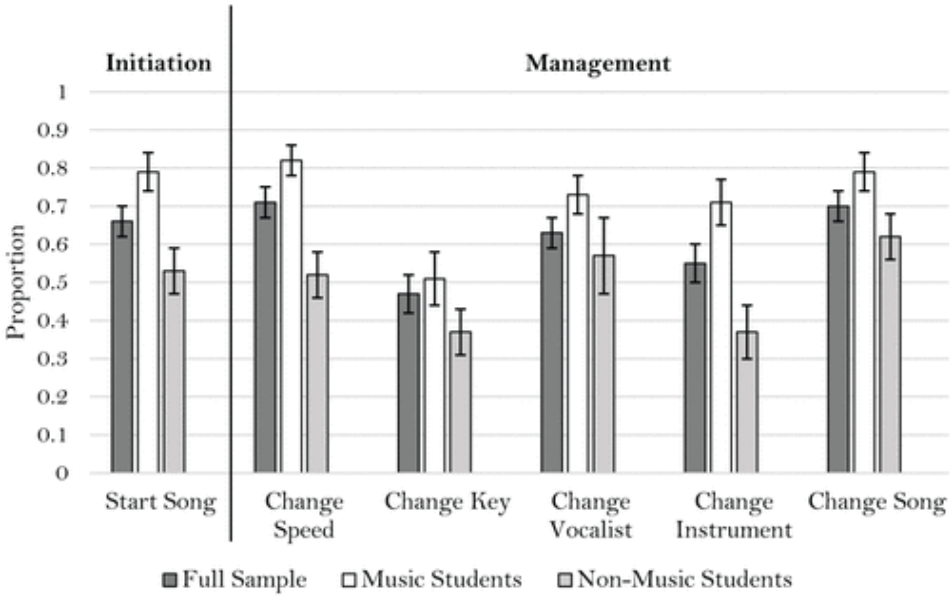

Figure 2. Ability to manipulate musical imagery (between-person).
Note. Errors bars indicate +/− 1 *SE*. All differences between music and non-music students were statistically significant.

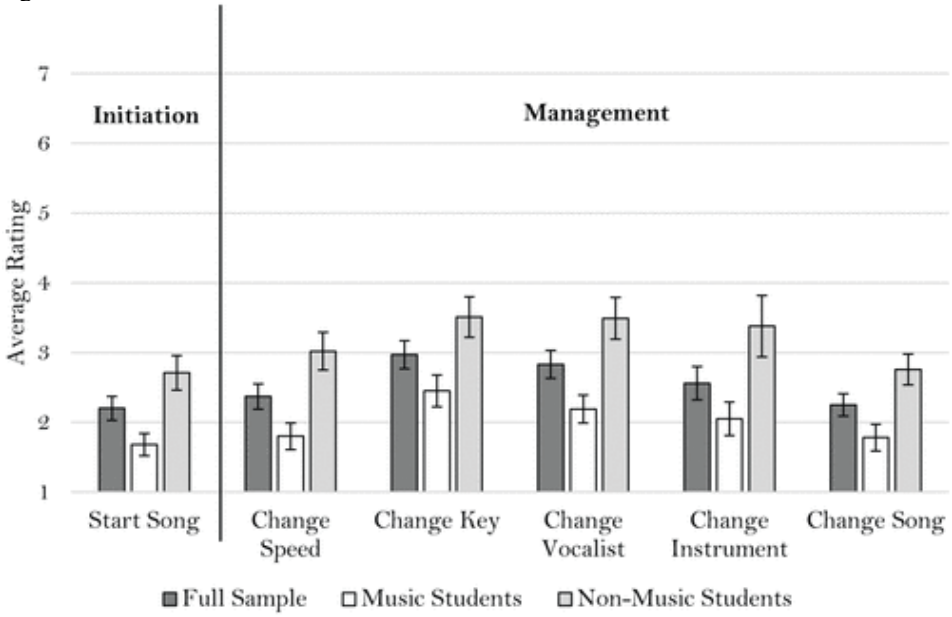

Figure 3. Difficulty of manipulating musical imagery (between-person).
Note. Error bars indicate +/− 1 *SE*. All differences between music and non-music students were statistically significant.

Our second measure of initiation addresses whether people can initiate musical imagery when asked. Overall, people could initiate musical imagery for 60.59% of the surveys—music students were able to do this in a higher percentage of surveys (72.89%) than non-music students (51.66%), $\beta = .45$, $p < .001$, 95% CI (.21, .70); see Figure 2 for all manipulations. Participants also rated how difficult it was to initiate this imagery. Music students, $\beta = -.56$, $p < .001$, 95% CI (−.80, −.31), rated this manipulation as less difficult than did non-music students (see Figure 3 for all manipulations).

Can people manipulate musical imagery?

We also assessed people's ability to manipulate the content of their musical imagery in five ways—altering the tempo, key, vocalist's gender, primary instrument, and entire song—and the difficulty of making these manipulations. All five manipulations followed a similar pattern—people were generally able to perform these manipulations, but music students could more frequently perform the manipulations and found them to be easier than did non-music students.

Overall, people were most frequently able to change the song they were imagining (72.21%) and increase the tempo (70.98%). People were able to change the gender of the vocalist (62.88%) and primary instrument (60.96%) most of the time but less frequently than changing the tempo or entire song. The only manipulation that people failed to do most of the time was changing the music's key (47.17%). Music student status most strongly predicted the ability to change the primary instrument in the song, $\beta = .51$, $p < .001$, 95% CI (.26, .76). It was a weaker predictor of increasing the tempo, $\beta = .48$, $p < .001$, 95% CI (.28, .69), changing the gender of the vocalist, $\beta = .46$, $p < .001$, 95% CI (.22, .70), altering the key, $\beta = .26$, $p = .047$, 95% CI (.00, .52), and changing to a different song, $\beta = .30$, $p = .017$, 95% CI (.05, .55).

Overall, people who could complete the manipulations did not find them to be that difficult (*M*s = 1.46 to 2.56 on the seven-point scale). Changing the gender of a vocalist was perceived to be the hardest ($M = 2.56$), whereas changing to a new song was thought to be easiest ($M = 1.46$). Music students rated all manipulations as easier (*Ms* = 1.95 to 2.56) than did non-music students ($M = 2.49$ to 3.57), and the differences were statistically significant in each case (βs = −.56 to −.44; see Table 3).

Discussion

This study explored how often and how easily people could control their musical imagery in everyday life. We found that people can exercise two types of mental control: they can start experiencing musical imagery at will (*initiation*), and they can change the existing imagery (*management*). Both musical experts and novices could initiate and manage musical imagery experiences when asked to do so, including complex transformations of a song (e.g., shifting its key or the vocalist's gender), but music students, not surprisingly, could control their musical imagery more often and more easily.

Beyond these two general factors of control, these findings revealed interesting differences between musical imagery manipulations. The easiest manipulations were initiating musical

imagery, increasing an image's tempo, and changing the song imagined. The hardest manipulations were changing the image's key or primary instrument. One reason for this pattern may be prior experiences with performing these manipulations. For example, people report actively changing imagined songs experienced as earworms in everyday life (Williamson & Jilka, 2014; Williamson et al., 2014). Ability to complete these manipulations may also be related to the salience of these features in musical imagery (Bailes, 2007, 2015). The more difficult manipulations may represent dimensions that are less salient in musical imagery or that people rarely try to alter in their daily lives. These explanations are preliminary, however, and future work should evaluate why some musical imagery features are easier to manipulate.

These findings naturally have implications for how musicians use musical imagery. The mental rehearsal and composition literatures don't usually describe these processes as controlled forms of musical imagery but do tacitly suggest that many of musical imagery's applications are intentional (Bowes, 2009; Holmes, 2005). Much like the lab-based auditory imagery literature, studies of mental rehearsal ask musicians to use specific imagery techniques, such as musical, visual, or kinesthetic imagery, to rehearse unfamiliar music for subsequent performance (Bernardi, Schories, Jabusch, Colombo, & Altenmüller, 2013; Bernardi, de Bruglio, et al., 2013; Bishop et al., 2013a; Cahn, 2008; Highben & Palmer, 2004). Collectively, these studies suggest that musicians can use imagery in those contexts, but they do not always evaluate whether these images are actively controlled. Future research should explore how controlled imagery techniques affect performance and composition quality, especially in naturalistic settings and with musicians' own music (e.g., pieces being rehearsed, original compositions) to go beyond experimental environments.

These findings also clarify the experiences of non-musicians. Colloquially, "earworms" are repetitive, uncontrollable episodes of musical imagery. Although earworm-like experiences certainly occur, our findings show that people are not completely at the mercy of their musical imagery and can often change it if they wish. But past research has not examined the full extent of people's control over musical imagery in daily life contexts because it simply hasn't asked. Few involuntary musical imagery studies, for example, have assessed whether the imagery experience was in fact involuntary—participants instead report only experiences that conform to involuntary musical imagery descriptions or the term "earworms" (Floridou, Williamson, Stewart, & Müllensiefen, 2015; Williamson et al., 2011). As a result, musical imagery research hasn't observed the substantial control even musical novices report having over their inner soundtracks.

This study yields a rich view of reported mental control in everyday musical imagery, but we should note that it relies on self-reported experiences. Nevertheless, despite happening in the field and using self-reports, our findings fit with lab-based auditory imagery work using behavioral measures: people are relatively good at controlling their inner musical experiences when instructed (Foster et al., 2013; Gelding et al., 2015). Additionally, past experience-sampling work shows that self-reports are more accurate when they are collected close to when an experience happens (Schwarz, 2012). It is conceivable that music students believe that they should be able to perform the manipulations, causing higher self-reported ability. But in past research, musical experts show better ability to complete similar imagery tasks in a lab setting (Bishop et al., 2013a; Herholz et al., 2008; Weir et al., 2015). Using self-reports instead of

behavioral measures reflects a trade-off inherent in ecological assessment methods, which trade the ability to explore concepts in people's idiosyncratic, real-world environments for the control of lab-based methods. It is also possible, that in some instances, the ESM probe disrupted people's involuntary imagery and necessitated its voluntary re-creation. Past research has found, however, that musical imagery often occurs alongside other tasks (e.g., while working, interacting, or listening to music; Bailes, 2007), so it seems unlikely that completing the ESM surveys typically disrupted people's imagery.

Past experience-sampling studies that observed musical imagery experiences found low rates of initiation and management (Cotter et al., 2018). If people can control their musical imagery, why don't they do it more often? This intriguing issue awaits future research, but we suspect that valence is important. People usually enjoy their musical imagery (Cotter et al., 2018; Floridou & Müllensiefen, 2015; Halpern & Bartlett, 2011). If musical imagery is typically pleasing, people probably aren't motivated to turn down the volume on the musical stream of consciousness.

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References

Agnew, M. (1922). The auditory imagery of great composers. Psychological Monographs, 31(1), 279–287.

Bailes, F. A. (2007). The prevalence and nature of imagined music in the everyday lives of music students. Psychology of Music, 35, 555–570.

Bailes, F. A. (2009). Translating the musical image: Case studies of expert musicians. In Chan, A., Noble, A. (Eds.), Sounds in translation: Intersections of music, technology and society (pp. 41–59). Canberra, Australia: ANU E-Press.

Bailes, F. A. (2015). Music in mind? An experience sampling study of what and when, towards an understanding of why. Psychomusicology, 25(1), 58–68.

Bailes, F., Bishop, L. (2012). Musical imagery in the creative process. In Collins, D. (Ed.), The act of musical composition: Studies in the creative process (pp. 53–78). New York: Routledge.

Bailes, F., Bishop, L., Stevens, C. J., Dean, R. T. (2012). Mental imagery for musical changes in loudness. Frontiers in Psychology, 3, 1–9.

Beaman, C. P., Williams, T. I. (2010). Earworms ("stuck song syndrome"): Towards a natural history of intrusive thoughts. British Journal of Psychology, 101, 637–653.

Beaman, C. P., Williams, T. I. (2013). Individual differences in mental control predict involuntary musical imagery. Musicae Scientiae, 17(4), 398–409.

Beaty, R. E., Burgin, C. J., Nusbaum, E. C., Kwapil, T. R., Hodges, D. A., Silvia, P. J. (2013). Music to the inner ears: Exploring individual differences in musical imagery. Consciousness and Cognition, 22, 1163–1173.

Bernardi, N. F., De Buglio, M., Trimarchi, P. D., Chielli, A., Bricolo, E. (2013). Mental practice promotes motor anticipation: Evidence from skilled music performance. Frontiers in Human Neuroscience, 7, 1–14.

Bernardi, N. F., Schories, A., Jabusch, H. C., Colombo, B., Altenmüller, E. (2013). Mental practice in musical memorization: An ecological-empirical study. Music Perception, 30(3), 275–290.

Bishop, L., Bailes, F., Dean, R. T. (2013a). Musical expertise and the ability to imagine loudness. PLoS ONE, 8(2), 1–12.

Bishop, L., Bailes, F., Dean, R. T. (2013b). Musical imagery and the planning of dynamics and articulation during performance. Music Perception, 31(2), 97–117.

Bolger, N., Laurenceau, J. P. (2013). Intensive longitudinal methods: An introduction to diary and experience sampling research. New York: Guilford.

Bowes, P. L. (2009). An exploratory study of the use of imagery by vocal professionals: Application of a sport psychology framework (Unpublished dissertation, UMI No. 3420534). University of South Florida, Tampa, FL.

Cahn, D. (2008). The effects of varying ratios of physical and mental practice, and task difficulty on performance of a tonal pattern. Psychology of Music, 36(2), 179–191.

Cotter, K. N., Christensen, A. P., Silvia, P. J. (2018). Understanding inner music: A dimensional approach to musical imagery. Psychology of Aesthetics, Creativity, and the Arts. doi:10.1037/aca0000195

Cotter, K. N., Silvia, P. J. (2017). Measuring mental music: Comparing retrospective and experience sampling methods for assessing musical imagery. Psychology of Aesthetics, Creativity, and the Arts, 11, 335–343.

Cowell, H. (1926). The process of musical creation. American Journal of Psychology, 37(2), 233–236.

Crowder, R. G., Pitt, M. A. (1992). Research of memory/imagery for musical timbre. In Reisberg, D. (Ed.), Auditory imagery (pp. 29–44). New York: Psychology Press.

Farah, M. J., Smith, A. F. (1983). Perceptual interference and facilitation with auditory imagery. Perception & Psychophysics, 33(5), 475–478.

Fine, P. A., Wise, K. J., Goldemberg, R., Bravo, A. (2015). Performing musicians' understanding of the terms "mental practice" and "score analysis." Psychomusicology, 25(1), 69–82.

Floridou, G. A., Müllensiefen, D. (2015). Environmental and mental conditions predicting the experience of involuntary musical imagery: An experience sampling method study. Consciousness and Cognition, 33, 472–486.

Floridou, G. A., Williamson, V. J., Stewart, L., Müllensiefen, D. (2015). The Involuntary Musical Imagery Scale (IMIS). Psychomusicology, 25(1), 28–36.

Foster, N. E. V., Halpern, A. R., Zatorre, R. J. (2013). Common parietal activation in musical mental transformations across pitch and time. NeuroImage, 75, 27–35.

Gelding, R. W., Thompson, W. F., Johnson, B. W. (2015). The pitch imagery arrow task: Effects of musical training, vividness, and mental control. PLoS ONE, 10(3), 1–20.

Halpern, A. R. (1992). Musical aspects of auditory imagery. In Reisberg, D. (Ed.), Auditory imagery (pp. 1–28). New York: Psychology Press.

Halpern, A. R. (2015). Differences in auditory imagery self-report predict neural and behavioral outcomes. Psychomusicology, 25(1), 37–47.

Halpern, A. R., Bartlett, J. C. (2011). The persistence of musical memories: A descriptive study of earworms. Music Perception, 28(4), 425–432.

Halpern, A. R., Zatorre, R. J. (1999). When that tune runs through your head: A PET investigation of auditory imagery for familiar melodies. Cerebral Cortex, 9(7), 697–704.

Hamburger, M. (1952). Beethoven: Letters and journals and conversations. New York: Pantheon.

Herholz, S. C., Lappe, C., Knief, A., Pantev, C. (2008). Neural basis of music imagery and the effect of musical expertise. European Journal of Neuroscience, 28, 2352–2360.

Highben, Z., Palmer, C. (2004). Effects of auditory and motor mental practice in memorized piano performance. Bulletin of the Council for Research in Music Education, 159, 58–65.

Holmes, P. (2005). Imagination in practice: A study of the integrated roles of interpretation, imagery and technique in the learning and memorisation processes of two experienced solo performers. British Journal of Music Education, 22(3), 217–235.

Hubbard, T. L., Stoeckig, K. (1988). Musical imagery: Generation of tones and chords. Journal of Experimental Psychology: Learning, Memory, and Cognition, 14(4), 656–667.

Jakubowski, K., Farrugia, N., Stewart, L. (2016). Probing imagined tempo for music: Effects of motor engagement and musical experience. Psychology of Music, 44(6), 1274–1288.

Janata, P., Paroo, K. (2006). Acuity of auditory images in pitch and time. Perception & Psychophysics, 68(5), 829–844.

Liikkanen, L. A. (2008). Music in every mind: Commonality of involuntary musical imagery. Paper presented at the 10th International Conference on Music Perception and Cognition, Sapporo, Japan.

Liikkanen, L. A. (2011). Musical activities predispose to involuntary musical imagery. Psychology of Music, 40(2), 236–256.

Mountain, R. (2001). Composers and imagery: Myths and realities. In Godøy, R. I., Jørgensen, H. (Eds.), Musical imagery (pp. 271–288). New York: Routledge.

Müllensiefen, D., Gingras, B., Musil, J., Stewart, L. (2014). The musicality of non-musicians: An index for assessing musical sophistication in the general population. PLoS ONE, 9(2), 1–23.

Rubin-Rabson, G. (1941). Studies in the psychology of memorizing piano music. VI: A comparison of two forms of mental rehearsal and keyboard overlearning. Journal of Educational Psychology, 32(8), 593–602.

Schwarz, N. (2012). Why researchers should think “real-time”: A cognitive rationale. In Mehl, M. R., Conner, T. S. (Eds.), Handbook of research methods for studying daily life (pp. 22–42). New York: Guilford.

Seli, P., Risko, E. F., Smilek, D., Schacter, D. L. (2016). Mind-wandering with and without intention. Trends in Cognitive Sciences, 20, 605–617.

Vuvan, D. T., Schmuckler, M. A. (2011). Tonal hierarchy representations in auditory imagery. Memory and Cognition, 39, 477–490.

Weir, G., Williamson, V. J., Müllensiefen, D. (2015). Increased involuntary musical mental activity is not associated with more accurate voluntary musical imagery. Psychomusicology, 25(1), 48–57.

Williams, T. I. (2015). The classification of involuntary musical imagery: The case for earworms. Psychomusicology, 25(1), 5–13.

Williamson, V. J., Jilka, S. R. (2014). Experiencing earworms: An interview study of involuntary musical imagery. Psychology of Music, 42(5), 653–670.

Williamson, V. J., Jilka, S. R., Fry, J., Finkel, S., Müllensiefen, D., Stewart, L. (2011). How do "earworms" start? Classifying the everyday circumstances of involuntary musical imagery. Psychology of Music, 40(3), 259–284.

Williamson, V. J., Liikkanen, L. A., Jakubowski, K., Stewart, L. (2014). Sticky tunes: How do people react to involuntary musical imagery? Plos ONE, 9(1), 1–9.

Zatorre, R. J., Halpern, A. R., Bouffard, M. (2010). Mental reversal of imagined melodies: A role for the posterior parietal cortex. Journal of Cognitive Neuroscience, 22, 775–789.