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An Experience-Sampling Study to Investigate the Role of Familiarity in Involuntary Musical Imagery Induction

Rebecca Lancashire

Department of Music, University of Hull, United Kingdom
R.E.Lancashire@2014.hull.ac.uk, rebecca.lancashire@mail.com

ABSTRACT

Despite its prevalence in Western society, little is known about why certain songs get stuck in our heads or the intrinsic musical features which contribute to their potential as involuntary musical imagery (INMI). This paper considers the use of Experience-Sampling Methods to explore the role of familiarity in inducing INMI. Eighteen participants of varying musical expertise were provided with four prescribed musical stimuli, three of which had been selected for their low INMI potential according to the melodic analysis software FANTASTIC (Müllensiefen, 2009), and requested to listen to each piece a minimum of once per day for a seven-day period. Over the following week, participants continued with their listening but were also signaled randomly three times per day to fill out an experience-sampling form (ESF), which contained open-ended questions and scaled items relating to both listening and imagery experiences.
Participants reported imagining the prescribed stimuli for 11% of all recorded episodes. A significant link was also found between musical experience and INMI occurrence and focus. The results indicate that musical training can make a listener more susceptible to INMI induction, even when the intrinsic features of the piece are not conducive to leading to INMI. This paper will contribute to existing research on the extra-musical factors which may lead to or trigger INMI episodes, and through a more detailed analysis of the intra-musical features which evoked INMI episodes in these participants it may be possible to develop a more comprehensive method of assessing the INMI potential of a piece analytically.

I. INTRODUCTION

Music is a ubiquitous experience that prevails even in silence. Musical experiences can persist introspectively, without the need for an external stimulus. The 'inner hearing' of a mental representation of music is known as musical imagery (Bailes, 2002). Musicians may use voluntary musical imagery (VMI) to aid with performance preparation or composition. However, musical imagery may also occur spontaneously, which is often referred to as an "earworm" (a direct translation of the German word *Ohrwurm*), in which we involuntarily revive the auditory image of a piece in the absence of an external source (Bailes, 2007; Brown, 2006; Sacks, 2007), which may then go on to repeat outside of conscious control (Beaman and Williams, 2010). Involuntary musical imagery (INMI), which is sometimes referred to as "stuck song syndrome" (Levitin, 2006), is especially prevalent within Western society, with 33.2% of a recent survey indicating that they experienced INMI daily, whilst 89% reported experiencing the phenomenon at least once a week (Liikkanen, 2012b).

Recent scientific literature has refrained from the use of the term "earworm", considering it an insufficient description of the phenomenon, and potentially even 'misleading' (Liikkanen, 2012b). Accordingly, for the purpose of this report I shall refer to the phenomenon only as INMI. Despite being considered an integral part of our musical mind, there is a dearth of empirical knowledge on the subject. As Bailes (2002) suggests, this may be due to the private and internal nature of the phenomenon, which has led to significant methodological problems, and as such, psychological methods of examining the phenomenon are necessarily restricted to indirect research techniques making INMI experiences onerous to substantiate.

An expanding body of literature has begun to examine the traits that predispose an individual toward experiencing INMI (Beaman and Williams, 2013; Beaty et al., 2013; Floridou, Williamson and Müllensiefen, 2012; Müllensiefen, Jones, Jilka, Stewart and Williamson, 2014), and the circumstances under which INMI is most likely to occur (Floridou and Müllensiefen, 2015; Hemming, 2009; Liikkanen, 2012a; Williamson et al., 2012). Through grounded theory analysis, Williamson et al. (2012) composed a list of eight dominant themes that describe the circumstances of INMI episodes: Recent, Repeated, Association, Recollection, Anticipation, Affective state, Dreams and Mind wandering. These eight themes were then further grouped into four abstract categories, with musical exposure ("recent" and "repeated") being considered the most prevalent trigger for INMI.

It has been shown that the brain has a tendency to loop the latest tune processed, and therefore it is the most recently acquired or activated memory of music that is most likely to be experienced as INMI (Bailes, 2007; Kvavilashvili and Mandler. 2004). This implies a strong recency effect for INMI. Incidentally, self-report studies have revealed that recent exposure to a tune is generally the most regularly reported cause of INMI experiences in diary and questionnaire studies (Bailes, 2015; Floridou and Müllensiefen, 2015; Hemming, 2009; Jakubowski, Farrugia, Halpern, Sankarpandi and Stewart, 2015; Williamson et al., 2012). However, researchers do state that other factors are also likely to be of significance.

Repeated exposure is also a significant factor in influencing INMI, with Bailes (2002) going as far as to say that 'familiarity with the music is key to imagery definition'. Beaman and Williams (2010) found that all reported earworms came from music that had been previously familiar to the participants, and it is generally understood that the greater the individual's familiarity with the music, the greater the likelihood of it stabilizing in the mind as a mental representation. The more we are exposed to a stimulus, the stronger our memory for it will be, and as such, musical imagery is thought to reflect high

familiarity with the music (Clynes and Walker, 1986). It is also unusual to experience entirely novel music as INMI, denoting the important link between INMI and familiarity.

Despite the commonality of INMI, the question of which certain songs get stuck in our heads is still not well understood. This is due in part to the fact that there are an array of both extra- and intra-musical factors which contribute to a song's INMI potential, and very few studies have explored the latter. Anecdotal evidence indicates that musical works differ in their intrinsic ability to induce INMI, yet we are still lacking a comprehensive method to assess the INMI potential of a piece analytically. Recent research has however begun to identify the musical features which tend to be recurrent in the majority of INMI pieces (Jakubowski et al., 2016). The most commonly found characteristics were simple, repetitive patterns, small melodic intervals and longer note durations. These characteristics are also fundamental in creating melodies that are easy to sing, even for non-musicians. Subsequently, these findings led Williamson and Müllensiefen (2012) to propose that 'INMI episodes are essentially your brain singing'.

Margulis (2013) suggests that when music is familiar to you, it encapsulates expectations of how the piece will progress and develop. This may explain why INMI candidates also tend to contain a certain amount of predictability. However, not all music we are exposed to conforms to conventional and familiar patterns of style, form and harmonic structure. It remains to be seen whether music that should not be considered conducive to emerging as INMI due to its unpredictable and unfamiliar nature could potentially by induced in listeners if they were exposed to such music regularly.

The primary aim of the present study was to explore the role that familiarity plays in the potential of a piece to emerge as INMI, and whether familiarity and regular exposure can negate the intrinsic features of the music to produce INMI. A preliminary investigation was used to determine the features of pieces with high INMI potential, through use of the melodic analysis software FANTASTIC (Feature ANalysis Technology Accessing STatistics [in a Corpus]; Müllensiefen, 2009). Based on the findings from this preliminary analysis, four pieces were selected as musical stimuli for this study. Three of these pieces scored very low on their INMI potential when analysed computationally, and the current model is said to have an 80% success rate on predicting whether a tune has the latent potential to be INMI. Through exposing participants to these three unfamiliar musical stimuli, along with an additionally unfamiliar baseline piece, over a period of seven days, we can begin to examine through use of experience-sampling methods whether it is possible to induce INMI episodes of these pieces despite their apparently incongruous intra-musical characteristics.

II. METHOD

A. Design

To investigate these research questions, a mixed methods design was employed. Experience-sampling methods (ESM) combined the approaches of observational field study with self-report diary. The method allows individuals to record thoughts and feelings extemporaneously in a real naturalistic environment, through self-report forms with open-ended and scaled items. The method is direct, allowing respondents to provide an immediate response, rather than a retrospective report, without parting them from their current location and activity. The contiguity of sampling experience in real time prevents the distortions involved when asking people to report retrospectively.

B. Participants

Eighteen participants were recruited through response to an email advertisement for the study which was sent out to several British universities. The study consisted of five men and thirteen women, aged from 18 to 72 (M = 29.06 years; SD = 13.55). It is likely that the gender imbalance observed may be attributed to general trends which reflect significant differences between men and women in their willingness to participate in ESM studies. Previous research indicates that women are more likely to volunteer, and also display greater response rates to signals, than men (Hektner, Schmidt and Csikszentmihalyi, 2007). Two-thirds of the sample also reported prior exposure to musical training to some extent, which may reflect their willingness to participate, as the study was advertised as ideal for music enthusiasts who engage in daily listening. Participants were grouped according to their responses to a selection of questions taken from the Goldsmith's Musical Sophistication Index (GMSI; 2014). The group of 'musicians' were primarily experts in the field (n = 6; five females, one male; mean age = 28; SD = 8.29), those with some 'musical experience' were either hobbyists or had a history of musical training earlier in life (n = 6; four females, two males; mean age = 32.67; SD = 20.51), and the 'non-musicians' had no experience of formal musical training (n = 6; four females, two males; mean age = 26.5; SD = 10.46).

C. Materials

Participation in the study required the use of a mobile telephone, which participants were instructed to carry with them at all times. Ideally the telephone was set to silent-vibrate mode, or a single-tone notification. The message read 'Please complete form' and also included an identification stamp to facilitate easier tracking of contact times.

Experiencing sampling forms were sent to participants along with a consent form, demographic questionnaire and listening diary, which they were asked to complete and return. Participants were also provided with an information sheet about the study. This sheet also contained the definition of INMI: 'The experience whereby a (usually) short section of music comes into the mind, unintentionally, without effort, and then tends to repeat without conscious control (i.e. "tune on the brain")' so as to help participants identify this phenomenon when it occurred.

1) The stimuli. Four short pieces of piano music were used in this study, all of which were composed in the twentieth century: Philip Glass's *Etude* No. 3; Scriabin's *Poeme-Nocturne*, Op. 61; the first of Arnold Schoenberg's Three Piano Pieces, Op. 11; and Luciano Berio's Rounds, for piano solo. All four pieces were unfamiliar to the participants at the onset of the study. The Glass was chosen as a baseline with which to compare participants' responses to the other three stimuli, due to its sense of stasis and repetitive nature. The Scriabin is less conventional, and despite relying on traditional sonata principles, draws heavily on chromaticism and the mystic chord.

The Schoenberg marks an important milestone in the evolution of the composer's compositional style as one of his first free atonal works, however, conventional features of form, melody, rhythm and texture are maintained. The Berio also adheres to a typical ternary form structure, but the textural and rhythmic features are much more complex. Although the piece is atonal, there is a discernible pitch centre in the work.

2) The Experience Sampling Form (ESF). The ESF consisted of three primary sections and is closely based on that used by Bailes (2002), comprising both open-ended and closed questions, as well as Likert rating scales, which were designed to be analysed in conjunction with each other. The form was designed to take no more than a few minutes to complete to minimise disruption to daily activities. Respondents were requested to note both the time they were contacted and the time they completed the form in order to monitor any discrepancies and so that data could be discounted if the response was delayed. Part A of the form gathered information about the participant's location and current activities. Part B concerned the hearing of real music, whilst Part C inquired about any imagery experienced. In both Part B and Part C respondents were asked to rate, on a scale of 1–7, their levels of concentration on the music, the importance of the music to the moment and whether they would have preferred to hear alternative music or no music. Free descriptive responses were also invited to highlight any other important or noticeable features of the music. Participants were also questioned as to whether they had recently heard the music they were imagining, and invited to provide a potential reason for the episode. Likert scales were also used to assess the vividness (scale of 1–7) of various musical dimensions.

D. Procedure

The study was conducted in two stages over a two-week period, with each stage lasting seven days. Prior to the start of the study, participants were provided with a WAV file of each of the musical stimuli, along with a listening diary and a demographic questionnaire. On day one, participants were requested to listen to each of the musical stimuli whilst completing their demographic questionnaire, which had a section for participants to record their preference and liking for the pieces, as well as comment on whether any of the music was familiar to them. Over the rest of stage one participants were instructed to listen to each of the pieces a minimum of once per day. Listening did not have to be focused and did not need to occur all in one session, or in the order the tracks were presented. The listening diary allowed participants to track how many times they listened to each piece on each day.

In preparation for stage two of the study, which commenced immediately following stage one, participants were provided with an electronic copy of the ESF, allowing them to print as needed or fill it out electronically from a mobile device. The information sheet presented to all interested participants had outlined the procedure of the study, including the potential contact hours of the study, during which time phones should be switched on and set to silent-vibrate mode. Call times were between 9am and 9pm each day, for seven consecutive days. One call would be made within every four-hour block. Calls were made in quick succession to each participant (starting with a different participant each time). Participants were called within 90 seconds of each other to allow for an examination of a cross-section of data at any particular time episode. Participants were requested to complete a form as soon as they received the signal, or at the next convenient moment if this was not possible.

III. RESULTS AND DATA ANALYSIS

Compliance rate for the study was high (99%), with a total of 374 completed ESFs, called "episodes", being recorded. For analysis of general trends and emerging patterns, all completed forms were used with any unanswered questions being discounted in the analyses. For more detailed analyses, any ESFs completed more than 30 minutes later than the time of the signal (13%) were discounted, leaving a collection of 325 responses (86% of all possible returns). Of these 325 responses, imagery episodes were isolated, and a particular focus assigned to those relating to the prescribed stimuli.

As experience was semi-randomly sampled throughout the week, it was possible to calculate the amount of time spent in each musical state. These results are a general measure of the overall prevalence of INMI experiences in general, and for the prescribed stimuli, during a seven-day period. Participants reported hearing music in 33% of episodes, and imagining music in 26% of episodes, which leaves 41% of episodes in which music was neither heard nor imagined. Results are shown in Figure 1, where a distinction has been indicated between INMI relating to the prescribed stimuli (11%), and those episodes in which participants experienced INMI of other, unrelated music (15%).

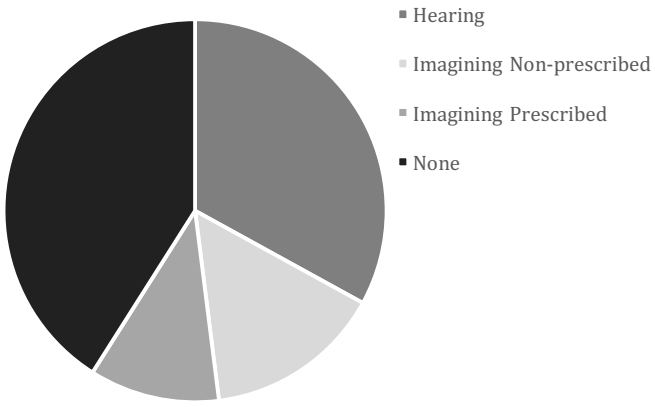

Figure 1. Distribution of musical episodes (N = 374)

Within this global measure of the prevalence of INMI, there was great individual variation. The participant who experienced the least INMI did so for 11% of the time, while another participant reported imagining music as much as 44% of the time. Previous studies have provided evidence to support an association between musical imagery and musical experience, and therefore it was to be expected that those participants categorized as 'musicians' reported more imagery episodes (M = 38%) than those with little (M = 27%) or no musical experience (M = 24%) (Fig. 2).

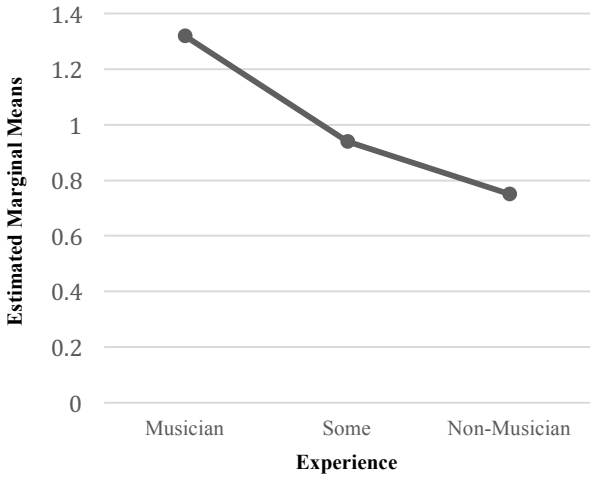

Figure 2. Estimated Marginal Means for imagery based on musical experience

A repeated measures ANOVA was carried out on the number of INMI episodes with a within-subjects factor of 'piece' and a between-subjects factor of 'musical experience' which showed a significant main effect of musical experience ($F(2,15) = 10.931$, $p < .001$) on the piece imagined. Post-hoc tests using Games-Howell comparisons revealed significant differences between musicians and those with some musical experience (mean difference = 0.3667, $p < .05$) and also between musicians and non-musicians (mean difference = 0.5667, $p < .01$). However, the difference between non-musicians and those with some musical experience was not found to be significant.

Musical experience was further shown to be related to not only the prevalence of INMI episodes, but also to the type of music imagined (Fig. 3). Musicians generally displayed more episodes of the prescribed stimuli than the other two groups, and INMI induction of certain pieces only seemed to be possible in those with musical experience, which is likely to be due to the intrinsic characteristics of the work.

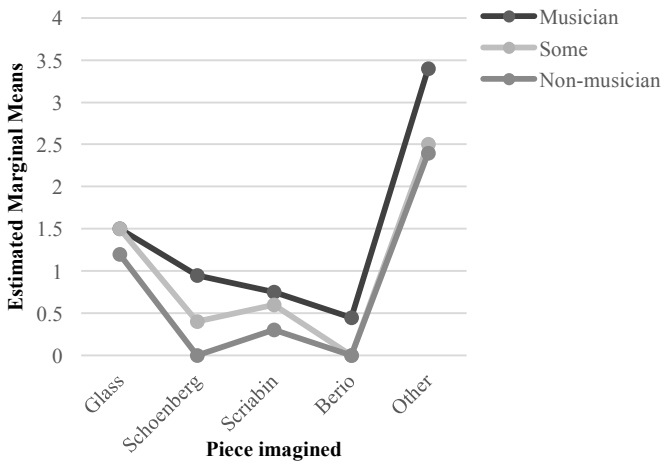

Figure 3. Estimated Marginal Means for each piece based on musical experience

For the purpose of exploring the relationship between familiarity and occurrence of INMI episodes relating to the prescribed piece, all participants have been considered as one group. Table 1 shows the results of a Spearman's rank correlation test, and it can be seen that only the piece by Philip Glass produced a significant correlation (.440, $p < .05$), which shall be explored in more depth later in this paper. The correlation with the occurrence of non-prescribed stimuli was also significant (.684, $p < .001$) which may be due to a response bias.

General trends between prescribed stimuli and familiarity (indicated by the data point in the study) can be seen in Figure 4, which also highlights certain anomalies in the data set, which may have caused skew in the correlational analysis.

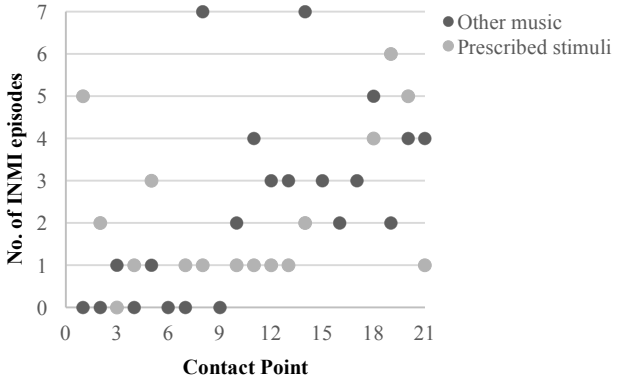

Figure 4. Correlation between familiarity and all INMI episodes for prescribed pieces

For each prescribed imagery episode, vividness ratings were recorded for the musical dimensions of melody, timbre, harmony, expression, dynamics, and texture. Ratings were collated and a mean value for each dimension per prescribed stimuli was calculated. These data were analysed with a one-way ANOVA and the result was significant ($p < 0.001$). Melody and expression are rated as being the most vivid dimensions of musical imagery overall, with timbre being rated as the least vivid. Figure 5 illustrates the resultant hierarchy of vivid features (1 = absent, 7 = very vivid), averaged across all participants. Despite having a clear melodic line, dynamics and texture were the most prominent features of the Schoenberg, which may be due to the atonal nature of the piece. The complexity of the Berio is evident here, as participants struggled to develop a vivid image of any of the dimensions, with the exception of dynamics. Further discussion of how intrinsic characteristics relate to the likelihood of the piece to emerge as INMI will be discussed subsequently.

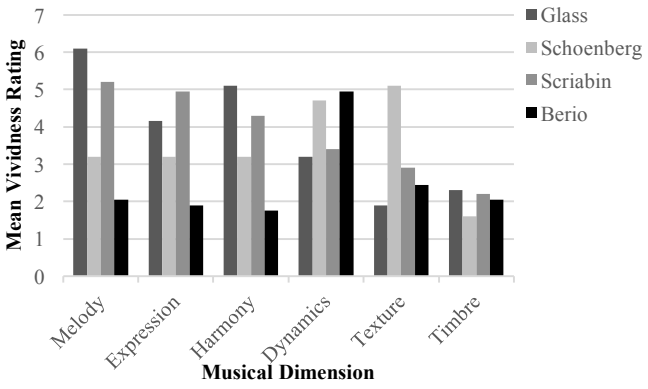

Figure 5. Vividness of Imagery for Musical Dimensions within the Prescribed Stimuli (Scale 1–7)

Table 1. Spearman's rho correlation for familiarity and prescribed INMI occurrence

			Day	Glass	Schoenberg	Scriabin	Berio	Other	Sum of prescribed pieces
Spearman's rho	Day	Correlation Coefficient	1.000	.440	-.133	.396	-.429	.684	.376
		Sig. (2-tailed)	.	.046	.564	.076	.053	.001	.093
		N	21	21	21	21	21	21	21

An aim of the study was to determine the relationship of imagined to heard experiences of music. Two questions on the ESF addressed this question directly: 'Had you actually heard the music since the last time you were contacted?' and 'If possible, please explain why you might have been imagining that particular music'. In response to the first of these, 53% said 'yes' and 47% said 'no'. This question only related back in time to the last call received and it is possible that hearings of music less recently, such as within the last week, might also have an important influence on the music imagined. The second question allowed for a more open-ended explanation for the possible occurrence of particular music to account for this. Results in Figure 6 have been categorized according to the eight dominant themes that form the illustrative model of themes proposed by Williamson et al. (2012).

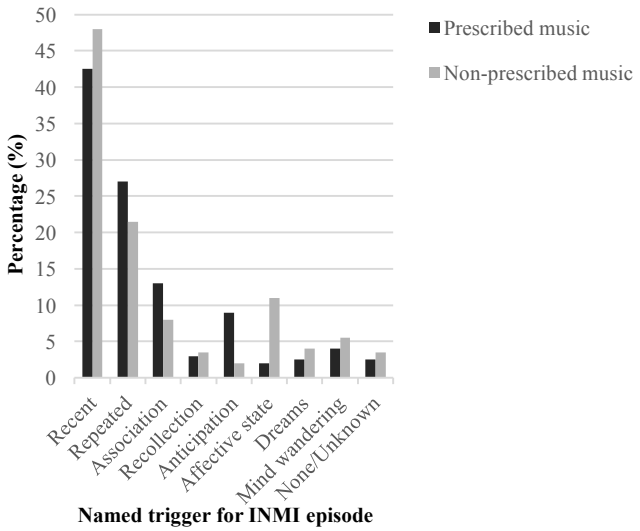

Figure 6. Frequency of reported triggers for INMI episodes for both prescribed and non-prescribed music

Having heard the piece of music recently was the most common reason provided for subsequently imagining it. Across all episodes, respondents were able to name the majority of their INMI episodes (95%). This suggests a high level of familiarity with the original music, which also suggests an association between hearing and subsequently imagining a particular piece of music. Repeated exposure to a piece was the second most reported trigger for INMI episodes, and was particularly valid with relation to the prescribed stimuli. Participants also reported 'association' as being a common trigger for imagining one of the prescribed stimuli, and free descriptive responses revealed that for several participants they likened the prescribed stimuli to other familiar pieces in an attempt to familiarize themselves with them and gauge a better understanding of the works. Only 10% of responses overall reported 'anticipation' as a trigger for INMI. However, four out of five of these responses stated that imagery was experienced as a reaction to the experiment.

IV. DISCUSSION

A summary of the finding from the completed ESFs implies a strong association for familiarity and INMI more generally, as participants were able to name the majority of their imagery, and also regularly reported having heard the piece recently prior to experiencing it as a form of musical imagery. In this study, over half of all INMI episodes (53%) resulted from having heard the music since last being contacted, which provides strong support for what is known as the most recent activation hypothesis. Cognitive psychologists use the concept of serial position to explain this phenomenon, and lab-based studies provide support for the recency effect, showing that a piece which has been heard aloud more recently is more likely to become INMI than a piece heard less recently (Hyman et al., 2013; Liikkanen, 2012b). Although recent exposure is the dominant trigger for INMI, other research has also supported the importance of repeated exposure. Beaman and Williams (2010) suggest that only 'overlearned' pieces are likely to appear as INMI. However, the researchers do not define the point at which a piece of music is considered overlearned, although it is possible that this may differ from person to person, which may explain the individual differences evident between participants in this study, and the rate at which they began to experience INMI episodes of the prescribed pieces. Margulis (2005) suggests that expectations begin to arise after the 'fourth or fifth time' of listening, whilst Byron and Fowles (2015) found that participants who were exposed to a previously unfamiliar song six times were more likely to experience the song as INMI. Experience-sampling commenced after seven consecutive days of listening to the prescribed stimuli, with the assumption that all participants would have heard each piece a minimum of seven times at this point, and subsequently could be considered "familiar" with them. However, the results from this study evidently indicate that the relationship between familiarity and INMI is much more complex, given that participants varied greatly in both the frequency of their INMI episodes, and the pieces that they experienced.

A large portion of the research on INMI suggests that memory is a significant factor in its emergence. Shouse (2001) suggested that INMI results from the memory process of 'chunking' and that the mental repetition we experience is a means of retaining the information. INMI can be constructed from long-tern memory, but also relies on the phonological loop – a short-term memory system in the auditory cortex. However, Kellaris (2008) proposed that only certain pieces of music are capable of arousing the brain's attention and forcing the song to repeat in the phonological loop, and it is this repetition which is essential for INMI, or what Kellaris has labelled, the "cognitive itch". The most significant predisposing factors identified were: accessibility, diatonicism

and melodic contour (Francès, 1988). Based on these features it is possible to see why the pieces by Scriabin, Schoenberg and Berio did not produce a significant correlation between familiarity and INMI occurrence. Generally, works by these composers are not easily accessible, especially for those with little or no musical training. Atonality makes it difficult for listeners to develop expectations about how a piece will progress, due to a lack of tonal hierarchy or harmonic progression. Furthermore, the complex rhythms and disjunct motion in Berio makes both pulse and melody hard to discern. Although a lyrical melody is evident in Schoenberg, a tonal hearing is hard to sustain. Those who did experience INMI of these works tended to have a reasonable level of musical experience, allowing them to experience more complete episodes, which became more musically embellished as familiarity also increased. For those who could not access the intrinsic working of the pieces, priming of the memory networks in listening to music was unlikely to occur, and therefore the original stimuli was unlikely to be encoded or recalled.

This study found a significant association between musical experience and INMI, both with regards to the prevalence and also which pieces were likely to be imagined. Musicians generally tended to experience more INMI episodes than the other two groups, and they were also the only group to report episodes relating to all four prescribed stimuli. The Berio, which was considered the most complex of the pieces, was only experienced as INMI by musicians. However, musicians and those with some musical experience did not differ with regards to the Glass, which may suggest that the complexity of the music is a significant factor in INMI occurrence. More simplistic and repetitive works tend to be accessible to all, whereas the intrinsic features of both the Berio and Schoenberg proved too complex for any form of schema to develop in the minds of those with no musical experience. It is important to note however that musical training is also likely to have enabled descriptions of musical dimensions and experiences that may prove more challenging for a non-musician.

Although there is still no definitive evidence explanation of why INMI occurs, this research has provided a new insight into what may now be considered a tripartite system, consisting of situational, extra-musical and intra-musical factors that contribute to creating INMI episodes. Thus far, pitch-based features tend to be the most veridical and have been reported to influence INMI more than other musical dimensions, which demonstrates the appropriateness of the expression "tune on the brain". Francès (1988) specifically highlighted the importance of melodic contour, and previous research has shown that adult listeners remember familiar music in terms of their intervallic structure, focusing on the interval between adjacent notes, rather than the specific pitches themselves (Hannon and Trainor, 2007). The two features used in analysis of the prescribed pieces were pitch range and pitch entropy. However, as the pieces lack a distinct melody, this analysis may not be thorough enough to support a conclusion as to whether the piece has INMI potential or not. Timbre was reported as the least vivid dimension in imagery. This constraint may be attributed to the vocal system's lack of capacity to stimulate different timbres. Furthermore, research has shown that imagined music for an instrument which the listener plays may retain timbral vibrancy in a way that it may not for others (Crowder, 1989), and thus we may conclude that people can only veridically imagine sounds which they can physically produce. Data from the Likert scales in Part C of the ESF revealed that those who reported experience of piano training did in fact report stronger vividness for timbre, and also texture, than those who played other instruments. Vocalists, or those with choral experience, also tended to display a greater awareness of the melodic content of the Schoenberg, as indicated in their free descriptive responses to the open-ended question about noticeable features of the imagery episode. However, it is worth noting that the overall sample size was relatively small and therefore some of these findings lack generalizability as they are based only on a small number of episodes.

Previous experience-sampling studies have used varying ranges of signals per day, and therefore it could also be argued that more cues were needed in order to gauge an accurate impression of the week. However, results from this study do correspond with previous research which suggest there is approximately 35-45% chance of hearing music when signalled. Unusually, this study also saw a significant increase in imagery episodes relating to non-prescribed pieces over the duration of the week which may relate to general trends of increased listening as a consequence of the study. This data may reflect demand characteristics, as awareness of the investigator's interest in INMI experiences might have encouraged participants to exaggerate their real imagery experiences or the process of introspection may have resulted in a more conscious awareness of imagery experiences than usual. Nonetheless, experiencing-sampling is advantageous due to the breadth and depth of data it produces, and it being the closest possible method to observing real-time experiences.

The melodic analysis software used in this study (FANTASTIC; Müllensiefen, 2009) relied on pitch range and pitch entropy, but did not examine any other features in order to assess INMI potential. However, ratings for vividness of musical dimensions reveal that for certain works, other features were more veridical. The pieces used in this study do not represent music as a whole, and the atonal nature of the works mean that a more comprehensive analytical method of assessing INMI potential needs to consider other significant compositional features not represented within the single-line melodic analysis implemented in FANTASTIC, such as harmonic content or chord structure of the music, articulation, and expressive timing, which could contribute to the INMI nature of a piece.

One of the main reasons that INMI is such a difficult concept to explain resides with the fact that the likelihood of a piece becoming INMI is influenced by a wide array of factors, and having heard it recently is just one of these. Based on the results, it would appear that regular exposure to music and familiarity can too induce INMI, however, this may differ dependent on individual differences, such as musical experience. Future research may look at extending this study to include a larger sample size and more regular signals, whilst also reworking the ESF in a way that it may gauge a more in-depth exploration of the situational, extra-musical and intra-musical factors influencing an INMI episode at any one time.

REFERENCES

Bailes, F. (2002). *Musical imagery: hearing and imagining music*. PhD thesis, University of Sheffield.

Bailes, F. (2007). The prevalence and nature of imagined music in the everyday life of music students. *Music Psychology, 35*(4), 555–570.

Bailes, F. (2015). Music in Mind? An Experience Sampling Study of What and When, Towards an Understanding of Why. *Psychomusicology: Music, Mind, and Brain, 25*(1), 3–4.

Beaman, C. & Williams, T. (2010). Earworms ('stuck song syndrome'): Towards a natural history of intrusive thoughts. *British Journal of Psychology, 101*, 637–653.

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

Beaty, R., Burgin, C., Nusbaum, E., Kwapil, T., Hodges, D. & Silvia, P. (2013). Music to the inner ears: Exploring individual differences in musical imagery. *Consciousness and Cognition, 22*(4), 1163–1173.

Brown, S. (2006). The Perceptual Music Track: The Phenomenon of Constant Musical Imagery. *Journal of Consciousness Studies, 13*, 43–62.

Byron, T. & Fowles, L. (2015). Repetition and recency increases involuntary musical imagery of previously unfamiliar songs. *Psychology of Music, 43*(3), 375–389.

Clynes, M. & Walker, J. (1986). Music as Time's Measure. *Music Perception: An Interdisciplinary Journal, 4*(1), 85–119.

Crowder, R. (1989). Imagery for musical timbre. *Journal Of Experimental Psychology: Human Perception And Performance, 15*(3), 472–478.

Finkel, S., Jilka, S., Williamson, V., Stewart, L. & Müllensiefen, D. (2010). *Involuntary musical imagery: Investigating musical features that predict earworms*. Paper presented at the Third International Conference of Students of Systematic Musicology (SysMus10). University of Cambridge, UK.

Floridou, G. & 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., Williamson, V., & Müllensiefen, D. (2012). *Contracting Earworms: The Roles of Personality and Musicality.* Paper presented at the 12th International Conference on Music Perception and Cognition. Thessaloniki, Greece.

Francès, R. (1988). *The perception of music*. Hillsdale, NJ: Lawrence Erlbaum Associates. (Original work published 1958).

Hannon, E. & Trainor, L. (2007). Music acquisition: effects of enculturation and formal training on development. *Trends In Cognitive Sciences, 11*(11), 466–472.

Hektner, J., Schmidt, J. & Csikszentmihalyi, M. (2007). *Experience sampling method: Measuring the Quality of Everyday Life*. Thousand Oaks, Calif.: Sage Publications.

Hemming, J. (2009). Zur Phänomenologie des Ohrwurms. *Musikpsychologie, 20*, 184–207.

Hyman, I., Burland, K., Duskin, H., Cook, M., Roy, C., McGrath, J. & Roundhill, R. (2013). Going Gaga: Investigating, Creating, and Manipulating the Song Stuck in My Head. *Applied Cognitive Psychology, 27*(2), 204–215.

Jakubowski, K., Farrugia, N., Halpern, A., Sankarpandi, S. & Stewart, L. (2015). The speed of our mental soundtracks: Tracking the tempo of involuntary musical imagery in everyday life. *Memory and Cognition, 43*, 1229–1242.

Jakubowski, K., Finkel, S., Stewart, L., & Müllensiefen, D. (2017). Dissecting an earworm: Melodic features and song popularity predict involuntary musical imagery. *Psychology Of Aesthetics, Creativity, And The Arts, 11*(2), 122–135.

Kellaris, J. J. (2008). Music and consumers. In C. P. Haugtvedt, P. Herr & F. R. Kardes (Eds.), *Handbook of consumer psychology* (pp. 837–856). New York: Taylor and Francis.

Kvavilashvili, L. & Mandler, G. (2004). Out of one's mind: A study of involuntary semantic memories. *Cognitive Psychology, 48*(1), 47–94.

Levitin, D. (2006). *This is your brain on music: The science of a human obsession*. New York: Penguin.

Liikkanen, L. (2012a). Musical activities predispose to involuntary musical imagery. *Psychology Of Music, 40*(2), 236–256.

Liikkanen, L. (2012b). Inducing involuntary musical imagery: An experimental study. *Musicae Scientiae, 16*(2), 217–234.

Margulis, E. (2013). *On Repeat: How Music Plays the Mind*. New York: Oxford University Press.

Müllensiefen. D. (2009). FANTASTIC: Feature ANalysis Technology Accessing STatistics (In a Corpus): Technical Report. Retrieved from http://www.doc.gold.ac.uk/isms/m4s/FANTASTIC_docs.pdf

Müllensiefen, D., Jones, R., Jilka, S., Stewart, L. & Williamson, V. (2014). Individual Differences Predict Patterns in Spontaneous Involuntary Musical Imagery. *Music Perception: An Interdisciplinary Journal, 31*(4), 323–338.

Sacks, O. (2007). *Musicophilia*. New York: Alfred A. Knopf.

Shouse, B. (2001). 'Oops! I did it again!' *New Scientist*, 2301, 44–45.

Williamson, V., Jilka, S., Fry, J., Finkel, S., Müllensiefen, D. & Stewart, L. (2012). How do "earworms" start? Classifying the everyday circumstances of Involuntary Musical Imagery. *Psychology Of Music, 40*(3), 259–284.

Williamson, V. & Müllensiefen, D. (2012). Earworms from three angles. In E. Cambouropoulos, C. Tsougras, K. Mavromatis, K. Pastiadis (Eds.) *Proceedings of ICMPC-ESCOM 12*. Thessaloniki, Greece.