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Earworms from Three Angles: Situational Antecedents, Personality Predisposition and the Quest for a Musical Formula

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ABSTRACT

Involuntary, spontaneous cognitions are common, everyday experiences that occur against a backdrop of deliberate goal-directed mentation (Christoff, Ream & Gabrieli, 2004). One such phenomenon may hold special promise for empirical investigation of this often elusive experience. Involuntary musical imagery (INMI) or 'earworms' are vivid, identifiable, and affect 91.7% of the population at least once a week (Liikkanen, 2012).

Utilizing an online survey instrument (http://earwormery.com/) we collected several thousand reports of earworm episodes, in collaboration with the BBC. Study 1 employed a qualitative grounded theory analysis to explore themes relating to the situational antecedents of INMI experiences (Williamson et al., 2011). The analysis revealed four main trigger themes for INMI experiences and categorized the role of different music media. Study 2 used structural equation modeling (SEM) to relate individual differences in INMI characteristics and isolated an influence of obsessive compulsive traits. Study 3 comprised a computational analysis of the musical structure of several hundred earworm tunes and compared them to matched control tunes. A statistical classification model was employed to predict whether a tune could be classified as an earworm based on its melodic features.

The use of INMI as a model of spontaneous cognition has generated findings regarding the phenomenological experience as well as the role of different behavioural and cognitive contributing factors. This body of work demonstrates the feasibility of studying spontaneous cognitions through musical imagery, which has the potential to enhance our understanding of the intricate relationships between cognitive control, involuntary memory, and the environment.

I. INTRODUCTION

The majority of modern psychology and neuroscience has explored behaviour and brain states when individuals are engaged in a task. More recently however, attention has turned to the 'resting state' brain and a particular phenomenon which characterizes non-goal directed mentation outside of conscious control; spontaneous, involuntary cognitions (Andrews-Hanna, Reidler, Huang, & Buckner, 2010; Klinger & Cox, 1987; McVay, Kane & Kwapil, 2009)

Spontaneous, involuntary cognitions are common, everyday experiences that occur against a backdrop of deliberate goal-directed mentation (Christoff, Ream & Gabrieli, 2004). Estimates are that between 30-40% of daily thoughts may be unrelated to the task at hand, a statistic that hints at the potential importance of this type of cognition to the everyday activity of the brain (Hurlburt, 1979; Kane et al. 2007; McVay et al. 2009). However, there are inherent difficulties in studying spontaneous cognitions that speak to the heart of their nature; they are unpredictable, frequently ephemeral and often isolated.

There is an example of spontaneous, involuntary cognition however, that holds particular promise for empirical investigation due to the fact that it is regular (Liikkanen, 2012), identifiable, and easy to track as part of everyday life (Bailes, 2007; Halpern & Bartlett, 2011). Involuntary musical imagery ('INMI' hereafter) describes the mental experience of hearing a short musical excerpt in the absence of an any external, physical stimulus, which then goes on to repeat for a period of time outside of conscious control (Liikkanen, 2012; Williamson et al. 2011). The colloquial term associated with INMI is '*earworms*' (a translation from the German '*Ohrwurm*'; Beaman & Williams, 2010). Other terms that have been used in the literature include 'stuck song syndrome' (Levitin, 2006), 'brain worms' or 'sticky music' (Sacks, 2007) and 'spontaneous musical imagery' (Wammes & Barušs, 2009).

There has been a scarcity of research into INMI until recent times (some notable exceptions are discussed below) however, there has been a productive field of study devoted to voluntary auditory and musical imagery. Such studies have provided insights into the neurological underpinnings of auditory imagery (Halpern & Zatorre, 1999; Herholz, Lappe, Knief, & Pantev, 2008; Kleber, et al. 2007; Kraemer, Macrae, Green, & Kelley, 2005; Meyer, Elmer, Baumann, & Jancke, 2007; Zatorre & Halpern, 2005), the everyday experience of musical imagery (Bailes, 2006; 2007; Halpern, 1988; Janata & Paroo, 2006), and the impact of imagery upon behaviour, including musical practice (Brodsky, Henik, Rubinstein, & Zorman, 2003; Chaffin & Logan, 2006; Freymuth, 1999; Highben & Palmer, 2004; Holmes, 2005; Wöllner & Williamon, 2007). This literature provides an essential background for the interpretation of new studies into INMI.

By comparison, studies of INMI have only recently begun to explore the phenomenology, aetiology, and patterns of the experience, such as its frequency. Notable past published papers include a study of personal INMI experiences (Brown, 2006), a survey of music students that touched on aspects of INMI (Bailes, 2007) and exploratory survey/ diary studies (Beaman & Williams, 2010; Halpern & Bartlett, 2011). Liikkanen (2012) was the first large-scale study to elucidate some of the major characteristics of the phenomenon. This study of over 11,000 Finnish internet users uncovered several interesting patterns of INMI occurrence including a higher frequency in females compared to males and positive correlations between INMI frequency and musical activities (including listening). This study was also the first to document the frequency of INMI, establishing that 91.7% of respondents experienced INMI at least once a week.

The present paper aims to build on the initial work carried out by Liikkanen (2012), and investigate INMI in an international survey in collaboration with the British Broadcasting Corporation (BBC). One of the main remits of the online survey was to collect 'earworm stories' in addition to basic demographic statistics. This additional qualitative data allowed us to investigate the circumstances of INMI occurrence in a more focused and directive way (Study 1), as well as to conduct computational analysis on the musical structure of the reported INMI (Study 3).

In 2010 we launched an internet survey called 'earwormery.com' (henceforth the 'earworm questionnaire') in collaboration with the BBC radio station 6Music, and promoted the site within the UK and internationally (as well as through various media over the internet). The survey contains the following pages:

1) Person details: Gathers demographics (e.g. age, gender and level of education)

2) The Obsessive Compulsive Inventory Revised (OCI-R; Foa et al, 2002).

3) The 'Musical Behaviour Questionnaire' (MuBQ): Assesses participants' level of musical experience and training using standard measures such as years of practice, number of exams taken and public performances. Participants are also asked to classify their musical identity (professional musician, music-loving nonmusician, etc) and singing ability (including whether they possess absolute pitch), to report on their degree of daily interaction with music as well as their listening habits, and to describe the importance of music to them. The majority of items are presented as ordinal scales, although some utilize a written response.

4) The 'Musical Imagery Questionnaire' (MIQ): Contains two pages, the second of which is relevant to the data in the present paper. The first page assesses general experiences of musical imagery and comprises 24 items based on Wammes and Barušs's (2009) scale. The second page contains INMI specific questions and took inspiration from Beaman and Williams (2010) 'Catchy tune questionnaire'. It includes questions relating to frequency and length of INMI experiences, and the level of interference experienced relating to everyday tasks. We also expanded upon questions about INMI management and tactics for INMI control, as well as the level of anxiety generated by INMI.

5) The 'Earworm Stories': Prompts participants to give details of two different INMI experiences; a recent earworm and a frequent earworm. Both pages request information on the name of the music and the artist/composer (if relevant), as well as specific detail about the music heard (e.g. chorus, opening piano section, or an example of the lyrics heard). Participants are then asked two final questions and are invited to respond in free form text: 'Where were you and what were you doing the last time you noticed this earworm?' and 'Do you have any idea what might have triggered the earworm?'

The data collection from the earwormery.com is ongoing at the point of writing and the data presented here were extracted at various points since 2010. In the present summary paper we provide an overview of the findings from our earworm research projects that address the following 3 questions: What triggers INMI in everyday life? (Study 1) Who is more likely to get INMI? (Study 2) What are the consistent musical features of INMI? (Study 3)

II. STUDY 1

The aim of the first study was to isolate and categorize the situational antecedents of INMI experiences. This study has been published (Williamson et al. 2011) so here we present an outline of the method and the main findings, as well as some new points for discussion.

A. Introduction

Previous studies of INMI experiences highlighted a strong role for musical memory, as the vast majority of imagery often stemmed from well-known melodies and recent exposure to musical tunes (Beaman & Williams, 2010; Brown, 2006; Liikkanen, 2012). However, to date there has been no investigation of the different ways in which memory activity may be associated with the onset of an INMI episode. Furthermore, no study has documented the fuller range of different situational antecedents that precede the onset of an INMI experience. This data has the potential to expose the mind and body states that might facilitate an INMI experience and thereby inform theories regarding a potential purpose for some INMI episodes.

The aim of Study 1 was to categorize the different situations that were associated with an INMI experience in a large group of individuals spanning different genders, age groups, nationalities, and educational/vocational backgrounds. A secondary aim was to categorize the ways in which different musical media were linked to INMI experiences, and therefore explore the role of music exposure in greater depth compared to previous studies.

B. Method

1) Design and Participants

In order to study the situational antecedents of INMI we selected data from two different sources and carried out qualitative thematic analysis (Charmaz, 2008).

The first source of data was the 'earworm stories' section of the earworm questionnaire (henceforth the 'internet database'). Individuals who chose to complete this section of the questionnaire provided a written description of the circumstances surrounding the onset of their earworm and, if known, described the trigger for the experience. Reports were collected between May and September of 2010. In this time, 271 individuals had completed the relevant page of the earworm questionnaire (117 male; M age = 36.30). From this sample, 238 (87.82%) people reported that they currently play or had played a musical instrument at some point in the past. In the whole sample, 57.57% classified themselves as 'musicians' (4.43% 'professional, 8.49% 'semi-professional', 16.24% 'serious amateur and 28.41% 'amateur) and 42.43% classified themselves as 'nonmusicians' (31.73% 'Music loving nonmusician' and 10.70 'Nonmusician').

The second source of data was a database of 333 anonymous email and text messages sent directly to BBC 6Music by the general public (henceforth the '6Music database'). Because of the nature of this data collection no information was available regarding the demographics of individual participants.

However, figures obtained from Radio Joint Audience Research (RAJAR), the official body in charge of measuring radio audiences in the UK, indicated that at the time of data collection the average 6Music listener was 38 years of age: 68% of the listeners were male and 78% had managerial, professional, administrative and clerical job roles.

2) Analysis

Reports from the two data sources were treated in the same manner for the purpose of the present analysis. The stories were imported into NVivo software and were first read extensively by two coders (VJW and Sagar Jilka). The two coders then began a process of independently classifying the themes within the 6Music database using a process akin to that described in inductive, generative, grounded theory analysis. This involved line by line coding of each report followed by the development of representative 'theme' labels that that summarized the codes as succinctly as possible (Charmaz, 2008). In the final stage of the analysis the two coders compared and merged their individual analyses, ensuring that the coding and categorization of each report was agreed upon.

Once the internet database coding process had been saturated the coders began a similar analysis on the internet database. In this case however, they began by applying the themes generated in the analysis of the 6Music database and only generated a new code where necessary. This process resulted in the generation of two new themes that were not present in the 6Music database (termed 'Rhythm' and 'Mind Wandering').

By this iterative process two hierarchical models emerged; one for each data source. These models captured the highest level of theme coding that could be applied to the data and therefore represented situations that were associated with the onset of an INMI episode.

As well as the coding of situational antecedents the coders also kept a record of any mention of a medium by which music was heard that was later reported as an INMI experience. These music exposure codes were entered into a similar iterative coding process in order to identify modes of music performance that were associated with INMI.

C. Results

Both the models (6Music and Internet) were highly similar in terms of their component themes although they differed in the relative number of reports that were assigned to each theme. For example, the 6Music database contained twice as many 'Live Music' triggers as a proportion compared to the Internet database, which may reflect a bias in this participant population for attending concerts and music gigs. Full details of the themes, including examples from the databases can be found in Williamson et al. (2011). For the purpose of this report we list the final codes within their implied hierarchical structure. In total, four abstract categories were identified (numbered in the following section) that described the situational antecedents of INMI, each of which contained a number of subthemes (bullet points).

1) Themes: The abstract categories and their subthemes below are given in order of their average weighting in the models, as measured by the number of participant reports.

1. Music Exposure
   - Recent exposure - An individual reports that they recently heard music that later appeared in an INMI episode.
   - Repeated exposure – An individual reports hearing the INMI music on multiple occasions prior to the onset of an INMI episode

2. Memory Triggers
   - Association – A dominant theme representing a number of sub-dominant themes that relate to ways in which stimuli from the environment, other than the music itself, can trigger an INMI tune. The subdominant themes included 'Words', 'Situations', 'Persons', 'Sounds' and 'Rhythms'
   - Recollection – The INMI episode is related to the experience of personal '*mental time travel*' (Tulving 2002), defined as retrieval from autobiographical memory.
   - Anticipation – An individual reports recalling details from an upcoming event that is connected to music, which is later experienced as an INMI episode.

3. Affective States
   - Mood – An individual states that their mood is associated with the INMI. No assumptions are made about mood given circumstances; the person has to overtly mention a mood state.
   - Stress – An individual reports experiencing anxiety or trauma at the time of the INMI episode.
   - Emotion– An individual mentions that the onset of an emotional state precedes the onset of an INMI episode. An emotion state is defined by the presence of a clear trigger event as opposed to a mood state where no cause need be identified (based on definition of mood and emotion by Ekman, 1999).
   - Surprise – An individual reports a surprise reaction to hearing the tune that is later experienced as INMI.

4. Low Attention States
   - Dreams – A person reports that their INMI is connected to events in a dream. Dreams are not coded under 'Music exposure' because the individual did not hear the music in the environment.
   - Mind wandering **–** The start of the INMI episode is marked by a period of absentmindedness or engagement in monotonous tasks.

2) Musical Media. In total 8 different codes were assigned to examples of music exposure that were associated with an INMI episode. These are listed here according to their average weightings across the two datasets. Note that the first two codes received the same average weighting (i.e. relative frequency of occurrence in the databases).

1. Live Music (concerts or gigs; attendee or performer)
1. Video Media (TV, film, internet)
3. Radio
4. Private Music (in the home or the car)
5. Contagion (another individual singing or humming)
6. Learning (practising for performance or a lesson)
7. Public Music (restaurant, shop or gym)
8. Ringtones

D. Discussion

The present qualitative analysis of a large number of earworm stories from two populations (6Music listeners and a general internet audience) revealed similar patterns of situational antecedents to INMI experiences. If the number of reports is taken as a measure then music exposure is the most common trigger of earworms, a finding that is aligned with the theory of Sacks (2007) that the ubiquity of modern music is an important contributing factor to INMI experiences. This finding also supports previous reports suggesting a high level of association exists between musical exposure and INMI frequency (Bailes, 2007; Liikkanen, 2012).

One notable finding that goes beyond this initial conclusion relates to the high number of INMI episodes that result from the activity of general memory processes. According to these reports there are a number of non-musical stimuli in the environment that can trigger the memory of a musical excerpt that then goes on to be experienced as an earworm. These include associations between music and situations, words, people and other non-musical sounds.

In many cases individuals in both databases described these types of memory experiences as involuntary or not under conscious control. In other words, the individual did not mean to remember the song or melody at the time but rather the presence of the trigger (be it the word, situation or person) automatically brought to mind the music that would then go on to be experienced as INMI. This was also a frequent finding among other 'Memory Trigger' themes, including within 'Recollection' and 'Anticipation', whereby instances of mental time travel (Tulving, 2002) to events that were associated with music occurred in an apparently spontaneous way.

This pattern of findings suggests that the action of general involuntary memory processes are an important trigger for INMI and supports the need for future studies to consider the literature on involuntary autobiographical memory (IAM; Bernsten, 2009) and involuntary semantic memory (ISM; Kvavilashvili & Mandler, 2004) when considering the aetiology of earworms.

The role of memory processing outside the auditory domain is highlighted within the musical media list, where the two most frequently reported themes, 'Live music' and 'Video media', are forms of multimodal presentation (visual and auditory). The multimodal nature of these themes is not the only variable that differentiates them however, the finding that these media are more frequently associated with an INMI experience compared to simple audio exposure is supported by findings in the memory literature including the levels of processing effect (Craik & Lockheart, 1972; Kapur et al. 1992) and the modality effect, whereby visual memories are more distinct and often more accurate compared to audio only memories (Pierce & Gallo, 2011).

Another finding of note relating to memory was the number of associations reported between certain mind and body states and INMI experiences. The role of heightened emotional states is consistent with the results of INMI interviews into the types of tunes that are likely to be recalled involuntarily (Hemming, 2008, 2009) and evidence that emotional arousal influences general memory encoding, whereby emotional memories are more likely to be recalled compared to neutral events (Hamann, 2001; Reisberg & Heuer, 1992; Ritchey, LaBar & Cabeza, 2011). This process may explain why live music was so frequently associated with INMI experiences, as individuals who attended or performed in concerts reported much higher levels of excitement, anticipation and emotion (positive and negative) compared to those feelings reported during exposure to other musical media. This range of heightened emotions during live music is akin to those reported in a recent study of strong musical experiences (Lamont, 2011).

The results from the present study indicate the existence of another level of interaction between INMI and emotional states; that INMI is more easily triggered or retrieved in emotional states. This hypothesis could be tested in future studies, as could the idea that there is a degree of congruency between an emotional state and INMI experiences; in other words that a happy mood would be more frequently associated with happy music compared to sad music. There were not a sufficient number of reports in the present dataset to allow a reliable test of this hypothesis although the findings were indicative of such a pattern.

States of minds that may also be of interest to future research include 'Mind wandering' or waking from dreaming. Within the data, these daily points of altered focus and concentration levels were marked as states where some individuals claim they are particularly vulnerable to INMI experiences.

In summary, the present study demonstrates that there are patterns in the situational antecedents of INMI that may be indicative of the types of external stimuli, cognitive activity or body states that are maximally facilitative to the experience of repetitive INMI.

III. STUDY 2

One clear general finding from both the 6Music and internet databases is that INMI is a highly idiosyncratic phenomenon. At the time of writing there are over 7000 contributors to the online survey and the majority of INMI reports are unique.

Despite this variety in the reports, previous studies have found small but significant associations between individual differences and patterns in INMI experiences, including positive correlations between INMI frequency and gender, musicality, and music listening time (Liikkanen, 2012). Beaman and Williams (2010) also reported that individuals who placed a high degree of importance on music were more likely to experience INMI that was frequent, lengthier and more troubling compared to those who rated music as not important. These studies set a precedent for examining the role of stable individual differences in INMI experiences, especially with relation to musical life experiences, in order to better understand the aetiology of the phenomenon.

The present study builds on previous work and explores the relationship between INMI and musical expertise/experience/daily behaviours using the most comprehensive assessment of musicality used to date in INMI studies. The MuBQ (part 3 of the earworm questionnaire) is an early version of the Goldsmiths Musical Sophistication Index (Gold MSI: Müllensiefen et al. 2011). As well as asking questions about years of musical training and number of hours spent listening to music each day, the MuBQ also includes items that explore musical vocations (e.g. DJ or sound engineer), perceived musical skill (e.g. singing ability), reactive musical behaviours (e.g. singing along) and musical investment (e.g. attending concerts).

A second individual difference factor of interest to the present study was the influence of non-clinical obsessive compulsive (OC) trait. A number of the features of INMI, such as its repetitive nature, lack of control over volitional cessation, and tendency to disrupt normal thinking processes, has lead authors to speculate about an association between this phenomenon and the thought patterns seen in obsessive compulsive disorder (Levitin, 2006; Sacks, 2007). Critics of this approach however, point out that the majority of INMI episodes are viewed as 'pleasant' which marks them as different from the distressing experience of pathological obsessive thoughts (Beaman & Williams, 2010).

The debate regarding the potential role of obsessive compulsive traits in INMI experiences remains unresolved, and to date no study has explored the role of sub-clinical OC trait in the experience. Studies indicate that individuals who measure highly on sub-clinical OC traits experience a greater number of intrusive thoughts that are more disturbing, akin to the pattern seen in clinical OCD (Garcia-Soriano, Belloch, Morillo, & Clark, 2011; Wegner et al. 1987). The present study sought to determine whether a similar relationship exists with relation to INMI.

A. Introduction

The tendency towards experiencing spontaneous cognitions is a stable cognitive characteristic, '*representing an individual difference that is reliable across time, activities, and contexts'* (McVay et al. 2009, p.5). However, the reasons for individual differences in the characteristics of INMI and the experience of spontaneous cognitions based on musical imagery, are not yet well understood. The present study used factor analysis and structural equation modelling techniques to determine whether aspects of musicality or obsessive compulsive trait can reliable explain any of the variance in a number of INMI characteristics, namely frequency, length, intrusiveness, valence and controllability. The full version of this paper has been submitted for publication, so a summary is provided here.

B. Method

The data for the present study were gathered from the earworm questionnaire between May 2010 and March 2011. We excluded participants who reported any degree of hearing problem. In total, 1536 participants (58.1% women) remained in the sample for the subsequent analysis (M Age = 34.2, SD = 12.6, range: 12-75 years).

Responses to three sections of the earworm questionnaire were analysed for the present study; score on the The Obsessive Compulsive Inventory Revised (OCI-R; Foa et al, 2002), and responses to the MuBQ and page two of the MIQ (which referred specifically to INMI experiences). As a first step in the analysis, data from 512 participants were randomly selected for exploratory factor analysis, which was necessary in order to delineate the underlying structures of the new scales (MuBQ and MIQ). The data of the remaining 1024 participants was subsequently used to confirm the factor structures of the new scales as well as to test the hypotheses from the literature regarding the influence of sub-clinical OC traits and musical behaviour on the quality and quantity of INMI episodes.

The MuBQ comprises 16 items relating to musical behaviour and experience. It includes assessment of the amount of attentive and background listening, the number of concerts attended, self-assessed singing ability and the frequency of sing-along behaviour, as well as the importance of music in the participant's life, their self-defined levels of musical competence, the type and extent of musical training on an instrument or voice and other skilled musical activities, and the possession of absolute pitch.

A series of maximum-likelihood principal factor analyses were carried out on 14 of the items in order to determine the underlying latent structure of the MuBQ. Two of the original 16 variables, absolute pitch possession and musical job vocations, had to be excluded as they proved to be of little utility when discriminating between participants (with more than 85% of the participants falling into a single category). The final four-factor solution explained 52.6% of the variance among the variables. The four factors entered into further analysis as musical behaviours and experience were termed *Musical Practice*, *Music Professionalism, Listening Engagement* and *Singing.*

A similar factor analysis protocol was carried out on responses to the MIQ. The original seven questions were entered into a correlation structure. The final factor structure did not resemble the Thurstonian ideal of a simple structure in factor analysis (Thurstone, 1931) therefore we excluded the three items with the highest uniqueness scores (*INMI Frequency*, *INMI Length*, *INMI Unpleasantness*) from the analysis and treated them as distinct variables. Repeating the factor analysis with the four remaining items (varimax rotation) revealed one common factor ($\chi 2$=0.19, df= 2, p=.91). This final factor was termed *INMI Disturbance* as it represented, among other variables, the urge to get rid of an INMI experience and the effort needed to expunge it.

Once the individual scales were analysed we carried out confirmatory structural equation modelling on the correlation matrices from the remaining 1024 participants. Factor scores for the 1024 participants were computed for the four latent factors of musical behaviour (*Musical Practice, Music Professionalism, Listening Engagement* and *Singing*) as well as the four INMI factors (*INMI Frequency*, *Length*, *Unpleasantness and Disturbance*). Subsequently, correlations between these factors and the OC trait subscales were computed, which described the relationships between all pair-wise combinations of factors from all three questionnaires. In order to explore the underlying (causal) structure manifest in the pair-wise correlations we used the package *sem* (Fox, 2006) within statistical software R to fit a structural equation model. This *sem* package employs a maximum-likelihood criterion and

a non-linear minimization algorithm to find a structural equation model from a correlation matrix.

C. Results

From the pair-wise correlation matrix we found several positive but minor correlations between OC-subscales and *INMI Frequency* and *Disturbance*. *INMI Frequency* and *INMI Length* were mildly correlated with *Singing*.

The structural model fitting went through several iterations, which confirmed the measurement structure derived from the exploratory analysis, minimised the impacts of weak correlations and removed any paths with high error probability. The strongest relationships were found between OC traits and INMI. The only musical behaviour to retain significant predictive influence within the models was *Singing*.

The final model fitted the data well ($\chi 2(85) = 397.79$, $p < .0001$, adjusted goodness-of-fit = 0.929, RMSEA index = 0.06, BIC = -191.38) and we report here the strength of the most important regression coefficients (β) from musical behaviour and OC traits onto the different INMI factors. The analysis revealed that high OC trait was positively related to *INMI Frequency* ($\beta = .22$) and to *INMI Disturbance* ($\beta = .31$). Higher *INMI Disturbance* then lead to longer INMI experiences. However, higher OC trait did not lead to higher *INMI Unpleasantness*. In terms of musical behaviours, participants who scored higher on *Singing* reported that their INMI was more disturbing ($\beta = .1$) but not unpleasant ($\beta = -.15$). They also reported more frequent INMI episodes ($\beta = .24$) that were longer ($\beta = .11$).

D. Discussion

The current study provides evidence to support the existence of a relationship between sub-clinical OC trait and INMI experiences. In line with the hypothesis of Beaman and Williams (2010) the majority of INMI was seen as a pleasant or neutral experience, and the data also suggest that individuals with high OC traits were no more likely to view INMI as unpleasant. However, individuals with high OC trait were more likely to report experiencing more frequent INMI. Furthermore, there was an evaluative 'loop' relationship between an individual's aesthetic response to an INMI episode and their experience of that same episode: If an individual is high on OC trait and they find an earworm disturbing then they are more likely to report that it lasts longer.

This series of relationships between OC trait and INMI in the present study is indicative of one of the paradoxical relationships found in clinical OCD whereby efforts to suppress unwanted and intrusive (i.e. disturbing) thoughts leads a higher likelihood that these experiences will appear more frequently over time (analogous to the Rebound effect; Wegner et al., 1987). The present data therefore support the hypothesis that OC traits, even in a sub-clinical population, can have a mild but significant effect on an individual's experience of INMI (Levitin, 2006; Sacks, 2007). However, increases in the length of INMI (analogous to the Immediate enhancement effect; Wegner et al., 1987) were only found if individuals high on OC trait judged their INMI episode to be disturbing (i.e. gets in the way of daily life). This finding is supportive of a similar pattern in aesthetic judgement response seen in the general OCD literature (Purdon, 2004).

On first reading it may appear that the relationships found between musical behaviour and experiences in the present study were minimal compared to those found in previous studies (Beaman & Williams, 2010; Liikkanen, 2012). However, it should be noted that previous correlations between musical experience and INMI were typically small effect sizes. Furthermore, the present study has built on more general reports of a link between musical behaviour and INMI and, by the use of discrete questioning, uncovered a focused effect on INMI based on one active musical behaviour, namely singing, indexed by the urge to sing along and self-assessed singing ability.

Why might singing be linked to more frequent, lengthy and disturbing INMI (n.b. not unpleasant)? Neuroscientific studies have established that there is considerable overlap in the neural activity seen when people engage in real and imagined musical behaviours, and studies in this area have frequently focused on singing as a musical behaviour that does not require specialist training (Halpern & Zatorre, 1999; Hickok et al. 2003; Zatorre & Halpern, 2005). The neural underpinnings of INMI have yet to be established but it is reasonable to presume that they will at least partly overlap with those seen in studies of purposeful musical imagery listed above.

Given this supposition, one hypothesis may be that more frequent activations of the brain areas associated with singing is related to more frequent spontaneous activations that are not under conscious control. The relationship between these factors is unlikely to be simple and unidirectional, otherwise singers would be expected to experience INMI most frequently, a supposition which is not borne out in the data from the present study. However, future studies could seek to determine the extent to which patterns of activation in areas of the brain associated with singing are associated with patterns of INMI experiences.

The present study is based on self-report so it is not possible to dissociate an individual's true experience of a phenomenon from any individual biases in retroactive report from memory. The relationships uncovered here however, have lead to experimental hypotheses for future studies concerning the associations between stable personality traits and specific musical behaviours that may influence the experience of INMI.

IV. STUDY 3

Studies 1 and 2 looked at contributions of situational antecedents and context as well as individual differences and personality traits to the experience of INMI. A remaining question concerns the relative contribution of the music itself to the emergence of INMI. Simply put: Could any music be the content of an INMI episode with equal likelihood or are there certain melodic features that predispose music to become INMI? Study 3 investigates precisely this question via the use of a computational software package for the analysis of melodic structure (Müllensiefen, 2009). At the time of writing the project is still on-going and final results of a larger analysis are being prepared for journal publication. The pilot results presented here have been reported (Finkel, 2010) but not previously published. The point of the present pilot study

outline is not to provide a definitive formula for INMI at this early stage but to explain how it is possible to study the influence that melodic structure has on the propensity of a tune to get stuck on someone's mind.

A. Introduction

There are plenty of anecdotal accounts regarding tunes that are likely to feature as INMI and music analysts such as de la Motte (1993) have speculated about the features of melodic structure that facilitate involuntary mental playback. However, despite the fact that the computational analysis of music at a symbolic (i.e. score) level has a history of more than 50 years there has yet been no systematic attempt to identify and quantify the melodic-structural aspects of INMI tunes.

In the present study we use the term 'tune' to refer to the short sections of largely pop or rock music that were reported as earworms in the internet database and were found to be suitable for the present analysis (see details in the Method section below). It should be noted that this analysis technique examines the structure of melody only.

B. Method

From the 'Earworm stories' section of the earworm questionnaire we compiled a list of all the tunes that had been named by more than one participant. Out of the 1449 tunes that 1014 participants had mentioned as INMI tunes (up to August 2010) only 75 had been named more than once (n.b. The distribution of tune reports follows a negative exponential function and has a long tail of examples only mentioned by a single participant)

In an initial analysis step, and before looking at melodic structure, we accounted for effects of popularity and recency that might have influenced the number of times a tune was mentioned. Data relating to popularity (number of weeks in charts, highest position in charts, days since chart entry and chart exit) and recency (days since release of the song) was collected for each tune from UK chart database polyhex.com. We fitted a poisson regression model to this data which was highly significant ($\chi^2(2, N = 110) = 19.218$, $p < .001$) and, after variable selection, the model only made use of two significant predictor variables (the highest chart position and the chart exit date) in order to predict the number of times a tune had been mentioned as INMI. We then selected the 29 tunes with a positive residual from the model prediction; these tunes could be thought of as having 'INMI quality' beyond that which could be explained purely by popularity and recency. We then used Gower's similarity coefficient (Gower, 1971) to identify 29 tunes that were similar to those 29 INMI tunes across a number of variables (including genre, artist and chart variables).

In a final analysis step we constructed a binary logistic regression model to explain the classification of INMI tunes vs. matched control tunes using features of melodic structure as predictor variables. All 58 melodies were analysed using the FANTASTIC software toolbox for melody analysis (Müllensiefen, 2009). This software package computes numerical features for different aspects of melodic structure (i.e. pitch, intervals, contour, rhythm, implied tonality, repetition rate etc.). FANTASTIC implements 58 different features and we used a backwards variable selection strategy using the Bayes Information Criterion (BIC) to arrive at a compact model.

C. Results

The final model only included two variables of melodic structure as significant predictors and was significant ($\chi^2(2, N = 58) = 6.662$, $p = .0358$). The two significant predictors were the statistical mode of the distribution of intervals in the melody ($\beta = - 0.7228$) and the median of the note durations ($\beta = 0.0643$). Together these features indicate that, in general, INMI tunes tend to contain notes with longer durations but smaller pitch intervals as compared to the matched control tunes that were not mentioned as INMI in our internet database.

D. Discussion

The short description of Study 3 aims at sketching out a systematic way by which to identify features of melodic structure that contribute to the likelihood of a tune being reported as INMI. However, the logistic regression model described in the results section should be no means be regarded as the final and definite 'earworm formula' as it will be updated in due course by our research group on the basis of a much larger sample of INMI reports and matched control tunes. Nonetheless, at first glance these two features make intuitive sense, in that a preponderance of longer notes and smaller intervals would make tunes easier to sing in general, a finding which ties back to sing-along behaviour and the active reproduction of tunes that was revealed in Study 2 as a contributing factor to INMI.

One clear limitation to this analysis technique is that it allows us to examine only one aspect of INMI, namely the melody. We make no assumptions regarding the influence of other musical features including lyrics and instrumentation, which would make interesting variables for future studies that employ a similar systematic approach.

In any case, the step-wise analytical procedure applied here is capable of producing valid and reliable results and it is noteworthy that, even using a comparatively small sample of INMI reports, it is possible arrive at a model that can distinguish between INMI and non-INMI tunes at a statistically significant level looking only at melody. The analytic procedure took into account the specific distribution of the frequency counts of the INMI tunes as well as popularity and recency as two major factors that drive INMI occurrences (evidenced by the highly significant poisson model). We also accounted for influences of artist, genre and other potential factors by finding matched control melodies that were used in the final classification model. In addition to these analytic steps, we are currently exploring several alternatives in terms of modelling the INMI frequency counts as well as for the final classification model and evaluation (e.g. cross-validation).

V. CONCLUSION

This paper presents the findings of three studies that have explored different features of the earworm phenomenon; situational antecedents, individual differences and the influence of musical structure. One of the main aims of this report was to demonstrate the validity of a variety of methods that can be utilized to explore INMI and to advocate the position that this broad empirical approach is essential in the quest for a

comprehensive understanding of the aetiology, phenomenology and implications of this everyday musical experience.

In summary, our results indicate that a wide variety of influences play a role in each experience of INMI and therefore, the question of 'what causes earworms' will never have one simple answer. On any one occasion the appearance of an earworm may be influenced by a multitude of external stimuli and cues, internal physiological states and responses, involuntary cognitive processes, evaluative and aesthetic judgments (which are influenced by stable individual traits), as well as the structure of the music. The key to future INMI research will be to explore each of these influences, as well as those yet to be identified, and to document their interactive relationships.

The high prevalence and ubiquity of INMI, as well as the readily identifiable nature of the experience, all lend it special promise as a future tool by which to investigate spontaneous cognition and mental imagery. These areas have often been viewed as beyond the remit of empirical investigation however, recent interest into the nature of the 'resting brain' and subconscious processing (Andrews-Hanna et al. 2010; Christoff, Ream & Gabrieli, 2004; Kane et al. 2007; Klinger & Cox, 1987; McVay et al. 2009; Mason et al. 2007) has placed renewed value and focus on experiences such as INMI. The present paper has demonstrated how the study of earworms can provide insights into a number of influences on subconscious processing activity including involuntary memory, aesthetic responses and stimulus structure.

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