Investigating the Relationship Between Involuntary Musical Imagery and Other Forms of Spontaneous Cognition

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Declaration of Originality

I, Georgia Aristi Floridou, certify that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated.

Signed Georgia Aristi Floridou

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Abstract

Music can exist without sound. In the absence of sound, the mind can, deliberately or not, recall familiar music or generate novel musical material. The ubiquitous, internal experience of music that comes to the mind unintentionally and repeats itself, known as involuntary musical imagery (INMI), constitutes the focus of the present thesis.

The aim of this research was to investigate the relationship between INMI and other forms of spontaneous and creative cognition in order to (a) elucidate the cognitive states preceding INMI, (b) identify individual differences related to spontaneous phenomena, and (c) describe phenomenological aspects of novel INMI. Three studies focused on the connection between INMI and spontaneous cognition. A probe-caught experience sampling and a behavioral study showed that the cognitive states associated with INMI occurrence are related to low cognitive load, as holds for other involuntary phenomena. The development of a scale measuring different INMI aspects revealed similarities with other forms of spontaneous cognition and allowed the exploration of individual differences as well as the investigation of relationships with other aspects of musical behaviors and auditory imagery abilities. A fourth, interview-based study explored the relationship between novel INMI and creative cognition and by elucidating the phenomenological aspects of the experience as well as of the translation of the inner experience to an external outcome, identified similarities with familiar INMI, voluntary musical imagery, and creative musical imagery.

Overall, the results of this research suggest that INMI overlaps to some extent with other forms of spontaneous and creative cognition, music perception, and voluntary musical imagery. Novel methodological tools that were developed for the purposes of this research and findings regarding the subjective evaluation of the experience and the element of repetition will also be discussed. Finally, issues related to terminology, length of the experience, research methodology, future avenues, and possible applications will be considered.

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Statement of Publications

The results from Chapters 2 and 4 appear in the following publications:

1. Floridou, G. A., & Müllensiefen, D. (2015). Environmental and Mental Conditions Predicting the Experience of Involuntary Musical Imagery: An Experience Sampling Method Study. *Conscientiousness & Cognition, 33*, 472-486.

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Chapter 1. Music in the Mind: Literature Review

1. Introduction

"Musics are those temporally patterned human activities, individual and social, that involve the production and perception of sound and have no evident and immediate efficacy or fixed consensual reference" (Cross, 2001, p. 99).

Music is universal and omnipresent. It can be traced back to prehistoric times in all of civilisations (Zatorre & Peretz, 2001), while its role in contemporary human culture is more prevalent than ever. The word «music» originates from the Greek word μουσική (*mousike*), which refers to the Muses, daughters of Zeus and Mnemosyne (Memory), who are the goddesses of inspiration in the arts, the sciences, and literature (Murray & Wilson, 2004).

The nature of music, including its origin and function, has been the focus of various categories of researchers. Musicologists, psychologists, neuroscientists, and philosophers have explored different aspects of music in isolation or in combination and have proposed several theories about its origins and the purpose it serves (Peretz, 2006; Levitin, 2007).

The evolutionary origins and adaptive function of music have puzzled scientists since the time of Darwin (1871). Some have argued that music is a "by-product" of auditory adaptations, like speech and animal vocalizations (Pinker, 1997), while others have suggested that it might be an adaptation of biological functions like sexual selection and social cohesion (Cross, 2001;

Darwin, 1871; Hagen & Bryant, 2003; Huron, 2001; Merker, 2000; Miller, 2001). Because there is little physical evidence about music's past, many studies are still required in order to obtain clearer answers to such questions and disentangle the roles of genetic from environmental factors in music-related mental phenomena. But studies related to music are not only specific to questions about its origins. They also explore other questions related to music's function and they can inform us for other domains, which could overlap to music.

"One thing we know for certain is that music leaves few traces – except in the minds of those who engage with it. It is quite likely that the trace that it left in our ancestors' minds still resonate in our contemporary, everyday world, in the agility of our thought, in the complexity of our social interactions. Without music, it could be that we would never have become human" (Cross, 2001, p. 101).

A stream of research that could shed light on music's origins but also provide useful information about other aspects of musical experience is the one which addresses the question of how music is used, i.e. music's functions. The main purposes, functions, and benefits of music depend on the situation within which it can be found in the cognitive, emotional, and social domains. The most basic functions of music are related to aesthetic pleasure, social, entertainment, emotional management and regulation, as well as enhancement of cognitive abilities (von Georgi, Grant, von Georgi, &

Gebhardt, 2006; Juslin & Sloboda, 2001; Saarikallio & Erkkilä, 2007; Waterman, 1996; Zillmann, 1988).

One of the domains which functions of music are widely incorporated and taken advantage of is that of marketing and consumer behavior. The increased possibilities available in contemporary life to impose music on individuals without their control provide new opportunities for the use of music in consumer behavior (Shapiro, 2004). Kellaris, a researcher interested in the influence of music on consumer behavior attempted to identify the properties of the musical tunes that repeat in people's minds (Kellaris, 2001). However, it was subsequently realised that the study of what was later called involuntary musical imagery is of wider interest and can provide important insights in the context of other areas of psychological research. This realisation has led to studies which focus on the experience of involuntary musical imagery per se, aiming to describe and understand this phenomenon.

Music can also exist without sound. In the absence of sound, the mind can recall already known music but also generate novel musical material. Such experience of music in the absence of corresponding external sounds can be under different degrees of control by the individual, including being involuntary just like that arising from uncontrolled external exposure to music as mentioned above or from controlled exposure to preferred music. The internal experience of music (familiar, unfamiliar or novel) that comes to the mind unintentionally and repeats itself constitutes the focus of the present

thesis and will be explored in relation to different aspects of spontaneous and creative cognition. Additional information about musical imagery, voluntary and involuntary as well as their relationship to music perception will also be explored.

1.1 A General Introduction to Involuntary Musical Imagery

1.1.1 Definition and Terminology

Involuntary Musical Imagery (INMI or “earworms”) refers to the internal experience of a section or whole piece of music, in the absence of a stimulus from the physical environment, which comes to the mind unintended (without any intention to recall the music) and then repeats itself at least once, on a loop, without the individual voluntarily making an effort to recall the music (Floridou, Williamson, Stewart, & Müllensiefen, 2015; Liikkanen, 2012a; Williamson et al., 2012).

INMI is one of the three main forms which musical imagery can take. The other two are voluntary musical imagery, which is the ability to recall music purposefully in the absence of an external stimulus (Halpern & Zatorre, 1999; Zatorre & Halpern, 2005) and anticipatory imagery, which occurs when the musical features of a piece can be predicted based on prior exposure and experience (Leaver, Van Lare, Zielinski, Halpern, & Rauschecker, 2009; Rauschecker, 2001).

Two of the key features that differentiate INMI from the other forms of musical imagery are: (a) its unintenionality in terms of the onset (recall process) and (b) its repetitive character, which is beyond voluntary control. The element of repetition primarily refers to the replay of part of a tune on a loop, as well as repeated intermittent appearance in the mind of the INMI section. Its unintentional character differentiates it from “voluntary musical imagery” (Zatorre & Halpern, 2005) and its repetitiveness from “musical

mind-pops", which are one-off occurrences of music and do not repeat (Kvavilashvili & Anthony, 2012).

Individuals who experience INMI are able to recognize that the music they "hear" is generated in their mind rather than outside of it in the physical environment. It is important to note that INMI occurs in the absence of neurological pathology and hearing impairments, which can be related to musical obsessions and musical hallucinations.

The colloquial term "earworm", which has been widely used to describe INMI, derives from the German term "Ohrwurm" (Kellaris, 2001; Hemming, 2009). Other colloquial terms which have been used include sticky tunes (Williamson et al., 2014), stuck tune syndrome/cognitive itch (Kellaris, 2003), perpetual music track (Brown, 2006), stuck song syndrome (Levitin, 2006) and brainworms/sticky music (Sacks, 2006).

1.1.2 INMI Classification

The phenomenon of INMI can be classified as a form of (a) spontaneous cognition, (b) imagery, and (c) memory. The classification and inclusion under these broad categories can help us extend our understanding regarding INMI.

1.1.2.1 Spontaneous Cognition

The spontaneous nature of INMI makes it part of a broader category of cognition, namely that of spontaneous cognition. Spontaneous cognitions, in

several different forms, are universal human experiences, occupying a significant portion (almost 50%) of our waking thought (Kane et al., 2007; Killingsworth & Gilbert, 2010; Klinger & Cox, 1987; Kvavilashvili & Mandler, 2004; Singer, 1966). The majority of studies looking into spontaneous cognition investigate it more as a state, namely that of mind-wandering (Smallwood & Schooler, 2006; Smallwood, McSpadden, & Schooler, 2008). Few studies focus on specific types of spontaneous cognition and their characteristics such as Involuntary Autobiographical Memories, Involuntary Semantic Memories, and future thoughts (Berntsen, 1996; Berntsen, Rubin, & Salgado; Kvavilashvili & Mandler, 2004).

A type of spontaneous cognition, which is ubiquitous and specific and holds promise for the understanding of stray thoughts, is INMI. Comparative research on the phenomenological aspects, individual differences, and neural correlates between INMI and other forms of spontaneous cognition can help us better understand their unique characteristics as well as their shared processes to comprehend their function. The extra key element of repetition makes INMI interesting to study since its reappearance makes it more observable and identifiable.

Another form of spontaneous musical cognition, which is distinct from INMI, is musical mind-pops (Kvavilashvili & Anthony, 2012; Kvavilashvili & Mandler, 2004), a term which refers to musical images which are involuntary in nature but not repetitive. Research on musical mind-pops is at a very early stage, with only two reported studies focusing on them (Kvavilashvili & Anthony,

2012; Kvavilashvili & Mandler, 2004). A comparison between this phenomenon and INMI, as two types of involuntary musical imagery, could prove useful in helping to disentangle the role of repetition in the subjective experience.

Spontaneous musical cognitions that are involuntary in nature and can be repetitive but concurrent to pathological conditions, are classified as either musical obsessions or musical hallucinations. These two experiences also share phenomenological characteristics with INMI such as the type of music that is experienced (familiar and with lyrics). The main difference between musical obsessions and INMI relates to the fact that, musical obsessions (Taylor et al., 2014) are longer in duration and are mostly perceived as unpleasant. On the other hand, musical hallucinations are very vivid and are perceived by the individual as real music (Kumar et al., 2014; Stewart, von Kriegstein, Warren, & Griffiths, 2006) in contrast to INMI where the individual knows the music is generated in its own mind.

1.1.2.2 Imagery

Mental imagery is a semi-perceptual experience of a stimulus in the absence of it. Visual imagery has been described as seeing with the mind's eye and auditory imagery hearing with the mind's ear. Research has mostly focused on specific modalities of imagery such as the visual domain (Finke, 1980, 1985, 1989) but auditory imagery and specifically musical imagery is a common everyday experience (Hubbard, 2010) that holds potential to understand the overlap between perception and cognition and their unique

characteristics.

So far most related studies have focused on voluntary musical imagery, mainly because the transient character of INMI makes it challenging to capture. Behavioral and brain imaging methods have revealed similarities between perception and voluntary imaging of auditory features such as pitch (Halpern, 1989), timbre (Crowder, 1989; Halpern et al., 2004), and tempo (Halpern, 1988). Similarly, findings from neuroimaging studies have revealed substantial overlap in brain areas activated during music listening and voluntary musical imagery (Janata, 2001; Kraemer, Macrae, Green, & Kelley, 2005; Scaefer, Vlek & Desain, 2011; Scaefer, Desain & Farquhar, 2013; Zatorre & Halpern, 1993; Zatorre et al., 1996; Zatorre, Halpern, Perry, Meyer, & Evans, 1996). Despite differences regarding onset and possibly functions, findings from studies of voluntary musical imagery could inform INMI research and help to test hypotheses in terms of musical features and brain areas which are activated during the experience.

1.1.2.3 Memory

INMI can also be classified as a type of memory, namely in the category of involuntary memories and specifically of Involuntary Semantic Memories (ISM; Kvavilashvili & Mandler, 2004; Williamson et al., 2012). ISMs are memories such as words, images, smells, and melodies which have been encountered in one's past but the context which surrounds them has been lost (Kvavilashvili & Mandler, 2004). In fact, INMI has been reported as the most prevalent type of ISMs (Kvavilashvili & Mandler, 2004; Liikkanen,

2012a). Although differing from other forms of ISM in terms of repetition, INMI can be informed from research on ISM and other types of involuntary memories such as Involuntary Autobiographical Memories (IAM) with regard to factors related to its onset and function.

1.2 Phenomenological Qualities

Although research on INMI started only recently (Kellaris, 2001), references to the phenomenon appear since a long time ago in films, series, poems, and books (Twain, 1876), long before the omnipresence of music in everyday life. Reik (1953), a famous psychoanalyst and Freud's student, referred to INMI in his book "The Haunting Melody" and analysed this experience from a psychoanalytic perspective.

This section will focus on the findings regarding the main phenomenological qualities which contribute to our general understanding of INMI.

1.2.1 Frequency

The experience of INMI is ubiquitous, with more than 90% of people in Western societies experiencing it at least once a week and 33.2% every day (Liikkanen, 2012a). Although these numbers come from only one large-scale study (~12,000 individuals; Liikkanen, 2012a), they provide an indication of the omnipresence of the experience. Amongst all types of involuntary imagery and involuntary semantic memories, INMI is the most prevalent (Bennett, 2002, Kvavilashvili & Mandler, 2004, Liikkanen, 2012a) in

comparison to involuntary speech, visual, gustatory (taste), tactile (touch) and olfactory (smell) imagery and memory.

1.2.2 Length

The length of the INMI experience refers to two different aspects of time, (a) the length of the section of music which is experienced as INMI and (b) the length of an INMI episode, i.e. the length of time for which the experience of a specific tune or section of a tune remains active in someone's mind, either intermittently or continuously.

Findings about the length of INMI sections are sparse. Beaman and Williams (2010) suggested that it cannot be longer than 3 min, given that the majority of tunes experienced as INMI are from popular music whose duration is normally not longer than this.

Retrospective reports about the length of INMI episodes show that such episodes have a relatively well-defined life expectancy lasting for hours or days (Sacks, 2006). Beaman and Williams (2010) found that INMI occurs over a period of hours or longer, it is unlikely to appear more than once during the same day, and is over by the next day. They also reported that, based on their diary study, the average episode length was 27.25 min. A similar finding comes from Halpern and Bartlett (2011) who reported a length range from 2 min to 240 min (median 36 min). On the other hand, it is noted that more recent findings suggest longer length of the INMI episodes. Thus, Williamson and Jilka (2013) reported that some participants experienced

INMI episodes for hours, a finding confirmed by Hyman et al. (2013, 2015) who also found that the experience can continue for days, intermittently rather than continuously.

From the above it is apparent that literature findings regarding INMI length are mixed, possibly because of inadequate clarification of the questions addressed to the participants with regard to the length of INMI episodes and INMI section. It is clear that for a proper understanding of the phenomenon these two aspects should be both addressed distinctly, and this will be attempted in this thesis.

1.2.3 Type of Music

The type of music most frequently experienced as INMI is music that is familiar to the individual and has lyrics (Beaman & Williams, 2010; Byron & Fowles, 2013; Halpern & Bartlett, 2011; Hyman et al., 2013, 2015; Kellaris, 2003; Liikkanen, 2012a). Nevertheless there are reports about people who experience novel (original) music as INMI (Halpern & Bartlett; 2011; Liikkanen, 2012a; Wammes & Barušs; 2009; Williamson & Jilka, 2013), however because of the way participants were asked about their INMI in the corresponding studies (Beaman & Williams, 2010) it proved difficult to capture their frequency. In this thesis, the occurrence of novel music experienced as INMI will be investigated in more depth and will be used to explore another domain, that of creative cognition.

Findings regarding the level of complexity of the type of music experienced as INMI are mixed. Williamson and Jilka (2013) conducted an interview study on 6 individuals with different levels of musical experience and reported that some of their participants (specifically highly trained musicians) experienced complex arrangements like symphonies and operas. On the other hand, all of the interviewees experienced low-complexity INMI such as jingles, simple melodies, bells or sirens. Although based on a small number of participants, this study illustrates the range of complexity in the types of music which can be experienced as INMI. In a diary study, after looking into the tunes that the participants reported as INMI, Beaman and Williams (2010) found that jingles, TV/radio themes, and children's songs were the most frequent. They suggested that this may be so because such tunes can be learned faster than more complicated ones and speculated that exposure to the tune itself is more important for triggering the INMI experience rather than the tune's musical features.

In an induction study, Hyman et al. (2013) used tunes from contemporary female artists and from The Beatles but did not identify any effects of music type on INMI induction. However it is noted that it is not clear what the difference in terms of music type between these stimuli is, besides how recently they had been released (past, vs. present)

In conclusion, the findings regarding the types of music that is experienced as INMI show that they include a variety of genres, complexity and levels of familiarity, rather than involving only a specific type of music. This may result

from the plethora of music to which individuals are exposed to and prefer to listen to. Another potentially interesting cause could lie in the musical features of the original tune experienced as INMI.

1.2.4 Musical Characteristics of the Tune

Identifying a “formula” which can predict the tunes that are likely to be experienced as INMI is a challenging issue. Several musical characteristics have been suggested in the literature but, with no experimental studies to confirm the findings, these remain largely speculations.

Kellaris (2001) was the first who suggested that some pieces of music might have certain properties responsible for stimulating an abnormal reaction of the brain and leading to a “cognitive itch”. According to this suggestion, there are three main properties that tunes should have in order to be experienced as INMI, (a) repetition within the musical stimulus (phrase, motif, sequence), (b) musical simplicity, and (c) incongruity within a musical phrase and listeners’ expectations (violation of previous schema). The importance of simple and repetitive properties was also suggested by Beaman and Williams (2010).

It would be premature to say that INMI is limited to simple and repetitive tunes. Beaman and Williams (2010) found that, out of the 199 tunes that were named as having been experienced as INMI in their survey, only 10 were reported by more than one individual and that there was little

reoccurrence within individuals. A similar finding comes from Halpern and Bartlett (2011) who reported a wide variation of INMI-associated tunes within and between individuals. Additionally, Byron and Fowles (2013) found that only 4 tunes out of 148 were experienced as INMI by more than one participant and that 3 of them were amongst the top-selling singles in the country where the experiment was conducted. Hyman et al. (2013) reported a similar finding, with 75.1% of their participants experiencing a unique INMI and only 24.9% having the same INMI with another respondent. Furthermore, only nine tunes were experienced as INMI by more than two people and these were popular tunes when the survey was conducted. Finally, Hyman et al. (2015) also found variability in the tunes reported as INMI in a survey of 212 individuals, with only 8 being reported by more than one person. All these findings illustrate the variability of the tunes experienced as INMI, which cannot be easily limited to specific “earworm tunes”.

Research has also focussed on the features of a tune that can contribute to a subsequent INMI experience. This task proves challenging in view of the wide variety of tunes which, as described above, can be experienced as INMI. Researchers (Finkel, Jilka, Williamson, Stewart & Müllensiefen, 2010; Williamson & Müllensiefen, 2012) who are in the quest for the “INMI formula” have examined the structure of the melody and reported their initial, tentative findings. They suggest that the statistical mode of the distribution of intervals in the melody and the median of the note durations are two significant variables that can predict which tunes can end up as INMI. Specifically it is

suggested that tunes which contain notes with longer durations but smaller pitch intervals have a higher tendency to end up as INMI. It is possible that these characteristics may make such tunes easier to sing – a property which, having in mind the already reported relationship of singing with INMI length (Müllensiefen et al., 2014), may make them result in INMI more easily than other tunes.

The above results, in combination with the findings regarding the type of music usually experienced as INMI, indicate that there is a great variety of tunes reported as INMI and contradicts claims about simplicity and repetitiveness being the primary determinants. They reveal that the experience is highly idiosyncratic and that it may be associated more with individuals' music listening habits (Halpern & Bartlett, 2011) than the tune itself. This suggestion is also in accordance with the findings of another study (Kvavilashvili & Anthony, 2012), which reported that Christmas songs are more frequently experienced as "musical mind-pops" during December. This illustrates the long-term priming hypothesis, according to which recently encountered stimuli activate in the mind matching and related representations for a long period of time. Subsequent encounters of a cue related to the recently encountered stimulus can re-activate its representation and result in a mind-pop (Kvavilashvili & Mandler, 2004)

1.2.5 Part of the Tune Experienced as INMI

The majority of the findings so far show that, while the chorus/refrain, or a few lines from the chorus, is the part of the tune most frequently experienced

as INMI, this can vary and sometimes the whole tune can also be experienced (Beaman & Williams, 2010; Hyman et al., 2013). One possible explanation for this variability is that working memory is involved in the generation of INMI. Because this system is limited and can process only a short amount of auditory material (Smith, Wilson, & Reisberg, 1995), this might explain why INMI is short and usually involves only the chorus. A better understanding of individual differences in working memory capacity can shed light into the variation of the reported part and length of INMI tunes.

Levitin (2006) claimed that the section of a tune which is usually experienced as INMI is less that the average auditory memory capacity, which he claimed to be 15-20 s long. Auditory memory capacity is responsible for retaining auditory information for a short period of time after exposure to auditory stimuli. This has been shown to be 3-4 s (Radvansky, 2005), however the specific length varies. Beaman and Williams (2010) investigated this claim and concluded that the length of the INMI tune is longer (approximately 27 min) than the reported average auditory memory capacity, suggesting that INMI is retrieved from long-term memory.

More behavioral research is needed to clarify the relationship between the part of the tune that is experienced as INMI, its length, and their association to individual auditory and working memory capacity by measuring the latter and associating it to individual reports of INMI length. Such research should ensure that questions to participants regarding the length of INMI should

clearly distinguish between the length of the section of music experienced and that of the INMI episode.

1.2.6 Subjective Evaluation of the INMI Experience

While anecdotal reports suggest that INMI is perceived as a negative and annoying experience, published research findings to-date from different types of studies do not support this common belief. Despite the fact that INMI was considered to be the most annoying spontaneous cognition amongst a range of different types examined (visual, words, odours, tastes etc.), only a quarter of a total of ~12,000 participants of a study (Liikkanen, 2012a) described their INMI as negative, with musicians reporting less negative feelings than non-musicians. A similar finding comes from Beaman and Williams (2010) who conducted a survey and diary study and found that, for the majority of people, INMI is not considered problematic but is evaluated as pleasant. Halpern and Bartlett (2011) also found the majority of INMI experiences to be described as pleasant or mixed/neutral.

Finally, Hyman et al. (2013) reported that two thirds of their participants liked their INMI, a finding that was replicated with regard to both the most recent INMI experience and also general long-term INMI experiences (Hyman et al., 2015). In the same study individuals reported that they do not find INMI distracting and therefore they do not try to terminate the experience. Furthermore, an association was found between the original tune being liked and the likelihood of it being experienced as INMI, while similar emotions

were experienced when hearing a tune and when the INMI of the same tune occurred.

Williamson and Jilka (2013) also found that the majority of INMI is experienced as pleasant, although in some cases over time the evaluation changed from positive to negative. The pleasant aspect was associated with non-intrusiveness, simulating energy, and providing entertainment through singing. Characteristics which contributed to a negative evaluation of INMI include its repetition as well as the fact that it was experienced against the individuals' will and outside their control. An interesting finding comes from Williamson et al. (2014) who reported that the type of evaluation towards INMI, positive or negative, resulted in a range of coping behaviors.

A possible explanation for the common belief that INMI is considered unpleasant may lie in reporting bias. When individuals are asked retrospectively, they are more likely to recall and report annoying experiences, something which leads to a negative bias given that memory and emotion are linked in the brain (Kensinger, 2007). Further diary and experience sampling studies are required to shed light on this hypothesis and a first attempt will be made in this thesis.

In conclusion, it is clear that, while some individuals find their INMI troublesome and unpleasant, the majority enjoy it. To understand this range of subjective evaluations, future studies need to consider individual differences associated with pleasure/displeasure (either exclusively for tunes

or for spontaneous and repeated thoughts in general), as well as examine combinations of INMI characteristics, such as tune repetition and length of the episode which could lead to a negative evaluation.

1.3 Methods and Techniques to Measure and Assess INMI

Methodology constitutes a major challenge for INMI research. One of the reasons for this relates to INMI's nature as an inner mental experience, which makes it difficult to measure. A variety of methods and techniques have been used for this purpose so far, including (a) self-report measures such as surveys, open text responses, diary, and experience sampling studies, (b) behavioral measures, and (c) brain imaging methods. Each of these methods offers different types of information about the phenomenon and has advantages and disadvantages. This section will review these methods, aiming to highlight the different types of information they can provide and discuss their advantages and limitations in view of the use of some of them in the studies described this thesis.

1.3.1 Self-report Measures

Self-report measures are the most common type of method which has been used to investigate INMI since the beginning of related research, with surveys being most prevalent (Beaman & Williams, 2010, 2013; Floridou, Williamson, & Müllensiefen, 2012; Liikkanen, 2012a; Müllensiefen et al., 2014a; Wammes & Barušs, 2009). The reason for this lies mainly in the possibility which surveys allow for processing large amounts of information related to INMI characteristics, individual differences, and situational

antecedents in a relatively short time. On the other hand, this efficiency is achieved at the cost of recall bias since most surveys are retrospective in nature and therefore of relatively limited accuracy (Coughlin, 1990).

The next most common method within self-report measures are naturalistic observations, including diary and experience sampling studies, which are self-reports about ongoing experiences (Kahneman et al., 2004). These types of reports are essential for the study of spontaneous phenomena like INMI which are very common in everyday life. So far a handful of diary studies related to INMI have been conducted (Beaman & Williams, 2010; Halpern & Bartlett, 2011; Hyman et al., 2013, 2015; Jakubowski, Farrugia, Halpern, Sankarpandi, & Stewart, 2015), with most focusing on the characteristics of INMI episodes (e.g length, subjective evaluation, and distraction activity) and only one experience sampling study (after laboratory INMI induction) looking at time of the day the experience occurred, familiarity with the stimulus tune, and INMI triggers (Byron & Fowles, 2013).

The main advantage of diary (self-caught) and experience sampling (probe-caught) studies is that they provide information about INMI at the moment it occurs and without the risk of recall bias. On the other hand this type of method has the limitation that participants are aware that they will answer questions about their INMI, which could prime their experiences and influence their answers. There are additional advantages and limitations in the two methods, one of them being that in the case of diary studies, participants may underestimate the proportion of times they experience

mental phenomena in comparison to probe-caught experience sampling (Ward & Wegner, 2013). Nevertheless, both of these methods can provide a large amount of data in a relatively short amount of time and they can be considered as the most instant methods, providing information about the phenomenon the moment it occurs. Yet more studies of this type are required to unlock their potential and the advancement of technology and exploitation of smartphone applications offer promise for their easy and inexpensive exploitation.

1.3.2 Behavioral Measures

Although INMI research has mostly benefited from retrospective and naturalistic self-report studies, behavioral research provides additional advantages, including the possibility to test and verify the results of such reports. So far such studies have mostly focused on the initiation, maintenance, and termination of INMI (Beaman, Powell, & Rapley, 2015; Campbell & Margulis, 2015; Floridou et al., 2012; Hyman et al., 2013, 2015; Liikkanen, 2012b). The advantages of laboratory experiments include the possibility for control and manipulation of the variables of interest, something which can facilitate obtaining insights into the cognitive mechanisms associated to INMI's onset, maintenance, and termination. On the other hand, limitations include the fact that INMI induction in the laboratory can prove challenging since the efficiency of stimulus tunes to induce INMI may be different from natural situations and that individuals can become aware of the purpose of the study, which can influence their responses.

The handful of studies that have been conducted in this area have first attempted to establish successful INMI induction paradigms either using cued recall and anticipation paradigms (Liikkanen, 2008), or music exposure and cued recall paradigms (Floridou et al., 2012). Once successful INMI induction was established, the studies that followed investigated various characteristics including repetition (the frequency with which a tune is heard), recency (how recently a tune was heard), levels of processing (if the heard tune has autobiographical or semantic associations to the individual, Byron & Fowles, 2013), motor involvement (Campbell & Margulis, 2015): overt (singing, tapping, movement) and imagined (imagining the continuation of an interrupted tune), and the role of cognitive resources and articulatory motor planning (Beaman, Powel, & Rapley, 2015) on INMI occurrence. A more detailed description of the behavioral studies can be found in section 1.4.3 of this thesis.

1.3.3 Brain Imaging Methods

The neural basis of INMI has started to be studied only recently, mainly because of (a) the unpredictable nature of INMI and (b) issues related to the functionality of the imaging equipment used for data collection, such as noise which can prevent or reduce the probability of INMI occurrence. The first and only neuroimaging study so far related to INMI (Farrugia, Jakubowski, Cusack, & Stewart, 2015) is based on structural Magnetic Resonance Imaging (MRI) data and self-report data from the Involuntary Musical Imagery Scale (IMIS; Floridou, Williamson, Stewart, & Müllensiefen, 2015; see

Chapter 4) which measures a range of INMI aspects, and revealed individual differences in cortical structure related to the INMI experience.

Brain imaging research would be particularly valuable if focused especially on the moment at which INMI occurs. This appears feasible since behavioral experiments (Byron & Fowles, 2013; Floridou et al., 2012; Hyman et al., 2013, 2015) have provided us with means for successful INMI induction. Furthermore a functional Magnetic Resonance Imaging (fMRI) study (Delamillieure et al., 2010) which used a retrospective questionnaire after participants were in rest condition (doing nothing) while being scanned showed that 6% of people experienced musical mental activity during scanning. It appears, therefore, that it may be possible to overcome the main limitations of brain imaging studies and make more extensive use of EEG (electroencephalography) and fMRI to better understand the INMI neural correlates.

1.4 Individual, Environmental and Cognitive Factors Associated with INMI

Although INMI research is still in its infancy, with approximately 20 peer reviewed published studies which have utilized the methodologies described above, it has already generated a plethora of information regarding individual differences, environmental, and cognitive factors associated with the INMI experience. These findings will be presented in this section.

1.4.1 Individual Differences

Although INMI is a very common experience globally (Liikkanen, 2012a; Liikkanen, Jakubowski, & Toivanen, in press), its characteristics vary between individuals. Research on individual differences has shed light on the reasons for this variability, focusing on a range of parameters such as demographics, personality, cognitive traits, musicality, mood, and brain structure, which will be discussed below.

1.4.1.1 Demographics

Despite the growing interest in INMI research, there have only been a few studies looking at the effect of age on INMI occurrence. An early finding came from Bennett (2002), who reported a negative correlation between the two. Liikkanen (2012a) confirmed the decline of INMI occurrence with increasing age, while a similar finding comes from Involuntary Autobiographical Memories (IAM) literature with regard to the relationship of their frequency with age (Schlagman, Kliegel, Schulz & Kvavilashvili, 2009). Finally, Hyman et al. (2015) developed the Frequency of Involuntary Thoughts Scale (FITS), which includes INMI as one of its items, and reported a negative correlation between age and the frequency of involuntary thoughts. All the above findings indicate a decline in INMI as age increases. Future studies should study the differences in the cognitive mechanisms associated with ageing and their possible role in this decline.

Another interesting demographic parameter is gender, however findings about its relationship with INMI are mixed. A handful of studies (Bennett, 2002; Liikkanen, 2012a) reported women experiencing more INMI as

compared to men, while other studies (Beaman & Williams, 2010, 2013; Hemming, 2009; Hyman et al., 2013) did not find a gender effect. Future studies should use larger samples of individuals but also take into account other characteristics such as non-binary gender to provide a clear picture of whether there is indeed a gender effect.

1.4.1.2 Personality and Cognitive Traits

Personality and cognitive traits are of great interest in INMI research because they can help to unravel characteristics about individuals' thinking styles and behavior which could be related to INMI. One of the first studies that looked into personality factors and INMI prevalence was that of Wammes and Barušs (2009). These researchers first developed the Musical Imagery Questionnaire (MIQ), which addressed INMI experiences. Two of the MIQ factors revealed two previously unexplored INMI aspects. The factor "Entertainment" links INMI with personal preferences and situations where external stimulation is low, while the factor "Completeness" suggests an association between INMI and current issues in an individual's life. The same study also examined the relationship of MIQ with "Transliminality" (Thalbourne, 1998), i.e. the susceptibility to and awareness of self-generated thoughts, and also utilised data from the Six Factor Personality Questionnaire (SFPQ; Jackson, Paunonen, & Tremblay, 2000), which measures "Extraversion", "Agreeableness", "Independence", "Openness to Experience", "Methodicalness" and "Industriousness". Positive correlations with "Transliminality" and three of the MIQ factors, namely "Unconscious", "Persistence" and "Distraction", and a negative association with

“Entertainment” were found. The association of INMI with the personality factors observed in this study was weak, however further information on this question has been obtained from studies which utilised other measures.

Using one of the most famous personality inventories, the Big Five Inventory (BFI; John, Donahue, & Kentle, 1991), which measures “Openness to Experience”, “Consciousness”, “Extraversion”, “Agreeableness” and “Neuroticism”, Floridou et al. (2012) looked specifically into the relationship between personality and INMI characteristics. It was found that INMI frequency did not correlate with any of the BFI factors, while “Neuroticism” was the only factor which correlated with most INMI characteristics (“Strategy”, “Pleasantness”, “Controllability”, “Length”, “Interference” and “Worrying”) as measured by a questionnaire associated to INMI experiences. “Extraversion” was negatively correlated with the control which individuals have over their INMI (“Controllability”), while “Openness to Experience” was associated with INMI length and “Interference” (degree to which INMI interferes with other activities). Another study (Kellaris, 2003) that looked at “Neuroticism” found a link with the frequency but not the length of INMI. All these findings show that negative INMI characteristics are related to neurotic tendencies, something which could be attributed to the previously reported association between “Neuroticism” and negative repetitive thoughts (Segerstrom, Stanton, Alden, & Shortridge, 2003).

Beaman and Williams (2013) investigated the relationship between INMI and mental control using the White Bear Suppression Inventory (WBSI; Wegner

& Zanakos, 1994). They also looked into proneness to psychosis (schizotypy), which is characterised by reduced cognitive inhibition, using the Schizotypal Personality Questionnaire (SPQ; Raine, 1991). They found that schizotypy was positively correlated to worry associated with INMI, interference and stopping daily business, INMI length, and difficulty to dismiss it. The WBSI was associated with INMI stopping daily business, length and difficulty dismissing them. These findings indicate that cognitive styles associated to reduced control of thoughts have a negative impact on the INMI experience rather than its frequency.

An additional study (Hyman et al., 2015) explored the relationship of INMI to mental control using three measures of consciousness control. It used the WBSI (Wegner & Zanakos, 1994), mentioned in the preceding paragraph, in order to measure suppression tendencies, while also employing the Cognitive and Affective Mindfulness Scale – Revised (CAMS-R; Feldman, Hayes, Kumar, Greeson, & Laurenceau, 2007) to measure mindfulness and the Dissociative Experience Scale (DES; Bernstein & Putnam, 1986) to measure dissociative experiences that vary in the population. The study found an association of the two WBSI factors, namely “Suppression Tendencies” and “Involuntary Thoughts” and the Frequency of Involuntary Thoughts Scale, and proposed that people who actively try to suppress their thoughts may experience a rebound effect and have more involuntary thoughts in general, including INMI.

In the literature there have been claims about a potential link between INMI and Obsessive Compulsive Disorder (OCD; Levitin, 2006) because of their similarity in terms of repetitive intrusions, however the existence of such a relationship was uncertain because of the absence of sufficient data. Müllensiefen et al. (2014a) were the first to investigate this claim empirically. They found that subclinical OC (Obsessive Compulsion) influences mildly INMI frequency and more strongly INMI disturbance (urge to get rid of the INMI and effort needed to expunge it). OC does not lead to longer INMI (mediated by the degree to which INMI is disturbing). There was no direct link between OC and INMI unpleasantness, however individuals with OC report higher INMI-related worry and interference and greater difficulty to suppress them, while they also make more attempts to get rid of their INMI. Findings from this study support previous conclusions (Beaman & Williams, 2013; Hyman et al., 2015) that attempts to suppress INMI are counterproductive. This is in agreement with the theory of ironic mental control (Wegner, 1989, 1994; Wegner, Schneider, Carter, & White, 1987), which states that trying to control the content of thoughts has the opposite effect because one needs to evaluate whether the thought has been expunged or not, something which has the result of bringing it back to consciousness.

Taken together, the above findings suggest that INMI frequency appears not to be associated with personality, behavior, and thinking styles and that personality and cognitive traits may be associated with only certain INMI characteristics, such as length, worrying, and interference. These types of

traits are linked with increased thought awareness and attempts for control over such thoughts. This may explain why these individuals are more troubled by their INMI, since they are more aware of them, and why they try to have control over them, which in turn has a rebound effect and makes them more noticeable. Future studies should explore in depth other factors beyond personality in relation to the interindividual variation of INMI frequency. They should also compare the characteristics of other involuntary thoughts to INMI in certain personality traits so as to understand whether such relationships are specific to INMI or concern involuntary thoughts in general.

1.4.1.3 Musicality and Musical Behaviors

The musical element in the INMI experience is what distinguishes it from other types of spontaneous cognition, memories, and imagery. For this reason the question of how musical an individual is and how musicality is associated to INMI characteristics is of particular importance. However, the relevant findings in the literature do not currently provide a straightforward answer. This may be due to deficiencies of the tools used to measure musicality or it may reflect the high complexity of the relationship in question.

The first speculations about the relationship between INMI and musicality, and more specifically musical training, claimed that musicians experience INMI more frequently than non-musicians (Levitin, 2006). Beaman and Williams (2010) were the first to explore this claim and their findings did not confirm this anticipation. They found that musical training was not associated

with any of the variables of interest, although the subjective importance ascribed to music was related to INMI frequency, length (longer INMI), and how troubling the INMI is. In addition, Liikkanen (2012a) found that the amount of music practice was only slightly associated with INMI frequency while self-assessed musicality was more strongly correlated. He also found an association between the use of portable music devices and INMI frequency, providing support for the claim of a relationship between musical engagement and INMI frequency.

A closer examination of the findings about how musicality affects the INMI experience showed that musicians experience more instrumental tunes, novel INMI, and longer INMI segments (Liikkanen, 2012a). Musicians at the top end of the scale (more than 15 years of practice) experience INMI less frequently than the least trained individuals (Liikkanen, 2012a). This is in accordance with a finding coming from an interview study (Williamson & Jilka, 2014) in which highly trained musicians reported reduced INMI frequency. Liikkanen (2012a) suggested that this may be related to highly trained musicians having developed a method to control their INMI. On the other hand findings from Williamson and Jilka (2013) suggest that this could be explained by the higher exposure of highly trained musicians to music (because of their jobs) making it difficult for INMI to occur.

Floridou et al. (2012) used version 0.9 of the Goldsmiths Musical Sophistication Index (Gold-MSI; Müllensiefen, Gingras, Stewart, & Musil, 2011), a measurement instrument for musical sophistication, which

measures a range of factors related to musicality, namely “Importance”, “Perception and Production”, “Musical Training”, “Emotions”, “Body”, “Creativity”, and “Openness and Events”. They found an association between INMI frequency and all Gold-MSI factors except “Musical Training” and “Openness and Events”, something that probably reflects the improved ability of the newly developed Gold-MSI, used for the first time in INMI studies, to systematically measure all musicality related factors.

Contrary to their initial findings in 2010, Beaman and Williams (2013) found a negative association between importance of music and INMI frequency. Hyman et al. (2013) found that, relative to non-musicians, musicians experienced INMI more frequently and with more musical aspects of the tune. Also individuals, who were exposed to music more often, even if they were not musicians, experienced INMI more frequently. A similar finding comes from a more recent study of the same researchers (Hyman et al., 2015) where they used three different measures of musicality (musical training, current musical ability, and music listening) and found that all were moderately correlated to INMI frequency. Finally, Müllensiefen et al., (2014a) found an association between singing and longer INMI, as well as between music listening and higher INMI frequency. They explained this result by saying that INMI comprises activations of recent musical memories, meaning that people who listen to a lot of music will likely activate their musical memories more regularly.

From the above results it appears that music-related behaviors can explain INMI characteristics such as frequency or length more than personality traits do. Both musical training and musical engagement are activities associated with exposure to the music, which subsequently activates INMI. The extent of involvement and the type of musical activity could explain other INMI characteristics such as length. Future studies should use diary and experience sampling studies and investigate in more detail the relationship of exposure and type of musical activities and subsequent INMI experiences.

1.4.1.4 Mood

Although the occurrence as well as the subjective evaluation of INMI may possibly also relate to the momentary concurrent mood state of the individual, the relationship of INMI with mood states has not yet been fully explored and the evidence remains sketchy at best. One relevant finding comes from Williamson et al. (2012) who found that affective states, including the current mood state, are generally associated with the onset of INMI. However no details of the particular moods involved are provided by that study.

Momentary concurrent mood state can be best studied with experience sampling studies (either self or probe-caught). Two experience sampling method (ESM) studies (Bailes, 2007; Beaty et al., 2013) on musical imagery (voluntary and involuntary) provide some preliminary information about the role of mood states. The findings presented by Bailes (2007) indicate an association between positive mood (happy and relaxed) and high arousal

(alert and energetic), on one hand, and the appearance of musical imagery on the other. This is not fully congruent with the results of Beaty et al. (2013) who reported that people experienced musical imagery when they were happy or worried. However, the fact that both of these studies did not distinguish between voluntary and involuntary musical imagery means that their results can only serve to generate hypotheses regarding the impact of mood states on INMI experience that still need to be tested.

Findings from an interview study (Williamson & Jilka, 2013) indicate that INMI can have either an energetic or relaxing effect on the individual, partly supporting the results of Bailes (2007), and also report an associated feeling of nostalgia. Finally, a recent diary study (Jakubowski et al., 2015) reported an association between arousal and INMI tempo.

More diary and experience sampling method studies are needed to shed light into the mood associated with INMI and factors related to it. One of the studies in this thesis will explore this question. Future studies should also use elaborated mood scales which can allow the identification of the range of mood someone can be in when INMI occurs. In addition, they should also look at mood traits rather than just mood states.

1.4.1.5 Brain Structure

The first reported neuroimaging study (Farrugia et al., 2015) examined brain structure and individual differences related to INMI. For this purpose it used structural Magnetic Resonance Imaging (MRI) and two different measures of

brain structure (voxel based morphometry and cortical thickness). It also made use of a recently developed self-report measure, the Involuntary Musical Imagery Scale (IMIS; Floridou et al., 2015; discussed in Chapter 4), which measures different aspects of the INMI experience, such as evaluations, reactions, and behaviors. The study found that INMI frequency correlated with brain areas associated with auditory perception (Griffiths & Warren, 2002), auditory imagery (Herholz, Halpern, & Zatorre, 2012), voluntary musical imagery (Halpern, 2001; Halpern & Zatorre, 1999; Zatorre et al., 1996), and pitch memory (Albouy et al., 2013; Hyde & Peretz, 2004; Hyde et al., 2007), but also with self-generated thoughts (Bernhardt et al., 2013). INMI evaluative aspects (as measured by IMIS) were associated with brain areas that have been shown in the past to be related to affective processes in music as well as with self-generated thoughts (Koelsch, 2014; Koelsch, Skouras, & Jentschke, 2013; Ruby, Smallwood, Sackur, & Singer, 2013a).

The above study provides the basis for future investigations of the neural correlates of INMI. Behavioral studies have provided multiple ways of inducing INMI experimentally (Byron & Fowles, 2013; Floridou et al., 2012; Hyman et al., 2013), an advance which can be used further in neuroimaging studies to explore the neural correlates of INMI at the time of their occurrence.

1.4.2 Environmental Factors

A variety of factors found in the environment of the individual play an additional role, besides individual traits, in the onset, maintenance, and termination of the INMI experience. Exogenous factors which, in combination with endogenous individual factors, can act as cues for the INMI experience, are reviewed in this section.

1.4.2.1 Situational Antecedents

Findings from a large survey based on retrospective reports (Liikkanen, 2012a) suggested that INMI appears most frequently when individuals work alone, travel or exercise. The same study also found that INMI occurs least during activities requiring auditory engagement (e.g. conversing, which was mentioned by only 10.9% of the participants of this survey). However, the same study also reported that watching TV and listening to music was the fifth most common situation (42.3%) associated with INMI, even though these activities also require auditory engagement.

In a study on both voluntary and involuntary musical imagery, Bailes (2006) reported that socializing was the most frequent activity in the context of which musical imagery tends to appear, a result which conflicts with Liikkanen's findings (2012a) described above. Other activities associated with INMI occurrence, as reported by Bailes (2006), are working and travelling as well as waiting and getting up in the morning, while INMI was reported less commonly during audio/visual activities like watching TV and listening to music. Hyman et al. (2013) found that INMI appears during activities that reflect low cognitive load such as walking, exercising, and other daily

routines. They also found that it appears during schoolwork that is described by high cognitive load. The authors conclude that the findings show that INMI occurs in a cognitive load continuum, in the context of activities described by both low and high cognitive load.

Taken together, findings to date suggest that INMI tends to occur more frequently when the activity that a person is engaged in is not demanding, is associated with low cognitive load, and tends to be monotonous and automatic. More research is needed to confirm these findings and also to identify the preceding cognitive states and the effect of level of cognitive load on INMI occurrence, as well as momentary assessment of the activity. These questions constitute part of the focus of this thesis.

1.4.2.2 Triggers

Like non-musical involuntary memories (Berntsen, 1996; Berntsen, 2001; Rasmussen & Berntsen, 2009), INMI is generally assumed to be triggered by external or internal cues, with the major difference that in the case of Involuntary Semantic Memories (ISM) the majority of the people (63% according to Kvavilashvili & Mandler, 2004) are not able to report what preceded them, whereas in the case of INMI triggers can be identified most of the time.

In a survey by Williamson et al. (2012) which investigated cues that precede and ultimately trigger INMI, in addition to being asked to chose between possible answers, participants also provided an open-text response resulting

in 604 reports, which were analysed using grounded theory (Payne, 2007; Charmaz, 2008). The study identified four abstract categories, with a number of sub-themes within each. The first category described is “Music Exposure”, which includes as sub-themes “Recent” and “Repeated” exposure. The second category is “Memory Triggers”, including (a) “Association” (“Person”, “Situation”, “Word” and “Sound”), (b) “Recollection”, and (c) “Anticipation”. The third category is “Affective States”, which refer to the feelings surrounding the onset of INMI, including “Mood”, “Stress”, “Emotion”, and “Surprise”. Finally, the fourth context-related category identified is “Low Attention States”, including the sub-themes of “Dreams” and “Mind-Wandering”. Regarding the latter sub-theme in particular, i.e. mind-wandering, Bennett (2002) found that the appearance of INMI is always associated with lack of focus and relaxed states or situations in which the brain needs to have a pause or distraction, something that Kellaris (2001) underlined by stating that «earworms eat idle brains».

Behavioral studies (Byron & Fowles, 2013; Floridou et al., 2012; Hyman et al., 2013) established that recent exposure to the music is a successful trigger. More empirical research is needed to identify additional triggers, while more diary and experience sampling studies are required to capture more fine details of what primes INMI, something that will be explored in one of the studies in this thesis.

1.4.2.3 Coping Strategies and Behaviors

Since the very first study on INMI (Kellaris, 2001), one of the most interesting questions identified relates to they ways in which people can suppress and have control over it. In a preliminary analysis of the methods used in the attempt to expunge INMI, Kellaris (2003) found that strategies such as replacement (listen to a different tune), distraction (do something else), social (talk to somebody), completion (listen to the same tune) as well as doing nothing were the most effective ones. Beaman and Williams (2010) confirmed some of these strategies, including musical displacement (listening to or thinking of a different tune), general displacement (staying busy/geting on with work), and inactivity (do nothing or go to sleep) but also extended the findings with INMI elaboration (listen to or think about the tune). Halpern and Bartlett (2011) also reported similar findings, such as listening to other music or engaging in other activities, but also reported that INMI can retreat on its own.

Williamson et al., (2014) presented two different models of coping strategies based on two different populations (Finish and UK). They reported that the most popular response to pleasant INMI was to be passive. Engaging with the tune was the second most popular behavior associated to both positive and negative evaluations of INMI and included listening to the tune in question, singing it, and imagining it. The next behavior that applied to negative evaluation of INMI was “Distraction”, involving musical, verbal, and visual tasks, physical activities such as exercise and breathing as well as demanding activities or attentionally demanding tasks. The same study also

identified some “cure” tunes which people used in order to stop their INMI such as “Happy Birthday” and “God Save the Queen”.

To sum up, studies of strategies employed by individuals to cope with their INMI show that they are characterised by variety and complexity, that situations which enable the onset of INMI have also been reported as valid for their termination (e.g. mind-wandering) and that some people are able to control INMI. Future studies should employ strategies found from retrospective reports in behavioral experiments, as well as diary and experience sampling studies, to identify the cognitive mechanisms that maintain or terminate INMI.

1.4.2.4 Time of the Day

One of the first sections participants have to complete in an Experience Sampling Form (ESF), of a self or probe-caught study, is the time of the day at which the experience occurred. Findings about the relationship between time of the day and the likelihood of INMI occurrence are mixed. In Halpern and Bartlett’s (2011) diary study it was found that mornings favour INMI occurrence (34%), followed by the afternoon (20%), evening (20%), and night (10%). On the other hand, in the study of Bailes (2007) the musical imagery (voluntary and involuntary) rate was found to be almost constant throughout the day, dropping to half during the night. Byron and Fowles (2013) found no significant difference between the frequencies of INMI occurrence at different times of the day. The authors argued that the contradiction between their findings and those of previous studies could be

due to chance or - in the case of Bailes' 2007 study - the inclusion of voluntary imagery in the observations. It is unclear if the discrepancy between the conclusions of the different studies results from the use of different methods (self and probe-caught). More diary and experience sampling studies are required to shed light in this contradiction and this is an issue that will be tackled in this thesis.

1.4.3 Cognitive Mechanisms Associated with INMI

While much can be learned from studies of qualitative reports of INMI, in order to understand the cognitive basis of this type of imagery, it is desirable to be able to induce such a phenomenon within a laboratory context, so that contributing variables may be systematically manipulated. The current section focuses on studies which have attempted to induce INMI in the lab and controlled variables related to its induction, maintenance, and termination.

1.4.3.1 How Does INMI Start?

The first INMI induction study explored recency and priming effects and used a cued recall paradigm, most commonly employed for recalling memories, to achieve it (Liikkanen, 2009; 2012b). Approximately 9,000 individuals completed an online experiment, in the context of which they were asked to complete the missing lyrics of 9 songs. This study for the first time demonstrated that INMI can be induced experimentally using a musical image scanning task (cued recall). It also demonstrated a recency effect for the last tune presented to participants and then experienced as INMI.

Building on Liikkanen's (2009) paradigm, Floridou et al. (2012) tested two different induction procedures to explore different memory mechanisms for their ability to induce INMI. One was similar to that of Liikkanen (2009), using the cued recall paradigm, while the second involved musical exposure. The induction stimuli employed were high and low in probability to induce INMI. No differences between the two methods were observed, indicating that recalling lyrics from long-term memory can be as efficient in INMI induction as recent activation of music. The study also reported a recency effect for the last tune similar to that of Liikkanen (2009), thus supporting the idea that recent activation of music in memory enables subsequent INMI onset. Taken together, these findings show that INMI occurrence results from preceding activation of musical memories triggered by an auditory or visual cue.

One of the limitations in the types of experiments described above is that they sample for INMI shortly after the induction procedure. Byron and Fowles (2013) commented that INMI induction in the previous studies could be the result of short-term memory traces after the cued recall. In order to overcome this limitation, in their study, they combined the experiment with a 3-day probe-caught experience sampling study. They explored the effect of repetition, recency, and levels of processing on INMI induction (using unfamiliar tunes) by asking either questions about how the tune is related to the individuals' lives - autobiographical association - or general questions about the music - semantic association. The authors did not find any significant differences between autobiographical and semantic association in

INMI rates, a result which is in accordance with the absence of level of processing effects with unfamiliar music (Halpern & Müllensiefen, 2008). Byron and Fowles (2013) also claimed that this finding suggests a difference between INMI and Involuntary Autobiographical Memory mechanisms. In addition they observed a recency effect and more frequent INMI reports when sampling immediately after the experiment rather than later, which is consistent with the findings of Floridou et al. (2012) and Liikkanen (2009, 2012b). Finally they reported a repetition effect on INMI occurrence. The more times a tune was played to participants the higher the probability that the tune would be experienced as INMI later on. Both the repetition and recency effects are in accordance with the findings of Williamson et al. (2012).

1.4.3.2 How Does INMI Start and Terminate?

A multi-study paper by Hyman et al. (2013) investigated cognitive load, recency, and Zeigarnik effects in relation to INMI occurrence. According to Zeigarnik (1967), individuals keep incomplete tasks active in their consciousness because of the need to complete the task, which suggests that unfinished thoughts and activities remain active in memory and consciousness for longer than completed ones. Hyman et al. (2013) looked for possible Zeigarnik effects in two ways: (1) they experimentally manipulated the tunes that were played to the participants by interrupting them (or not) in the chorus and (2) they examined the association between INMI being reported immediately after the induction (incomplete active thought) and again in the following 24 hours. They did not find a Zeigarnik

effect using the first approach in any of the 4 experiments they conducted, but reported one with the second approach, which is not a typical presentation of the effect as they commented. These results should be interpreted with caution since the study assumed the presence of incomplete INMI in participants' minds without directly testing for this.

Another aspect that was explored in the study (Hyman et al., 2013) was that of cognitive resources available when INMI occurs. They conducted 2 experiments to study the effect of cognitive load on INMI occurrence and reported the findings in combination with the results of a survey. They claimed that INMI occurs more during low (survey) and high (experiments) cognitive load, in a cognitive load continuum, when more cognitive resources are available, similar to mind-wandering episodes (Kane et al., 2007; McVay & Kane, 2010; Schooler, 2002; Smallwood & Schooler, 2006). Another finding was that during a verbal task, which required the involvement of the phonological loop in working memory, INMI occurred less in comparison to a non-verbal task. Finally, in accordance with the findings of Liikkanen (2009, 2012b) and Floridou et al. (2012), they observed a recency effect for the last tune which was presented to the participants and was experienced as INMI later.

1.4.3.3 How is INMI Terminated?

The most recent experimental study to date which has explored ways of eliminating INMI comes from Beaman, Powell, and Rapley (2015). The authors explored an anonymous online report that chewing on cinnamon

sticks proved effective in removing INMI and instead they used chewing gum, which has been shown to degrade short-term memory performance and auditory imagery. They explored the effects of articulatory motor activity (in comparison to no activity and non-articulatory motor activity) on INMI occurrence. The results showed that chewing gum is efficient in reducing both the number of voluntary and involuntary musical imagery instances by interfering with articulatory motor programming. This finding is in accordance with a study which showed that chewing gum affects immediate memory retrieval (Kozlov, Hughes, & Jones, 2012).

Questions to address in further studies relate to the duration of the effectiveness of an INMI-terminating activity and whether it has the same effect on INMI that has been triggered in different ways other than music exposure.

1.5 Questions Emerging from the Literature To-Date

A common pattern which emerges from the literature reviewed above, across different specific topics and methodologies, relates to the link of INMI occurrence with cognitive states associated with low attention, a link already known to exist for other forms of spontaneous cognition (Kane et al., 2007; Smallwood, Nind, & O'Connor, 2009). Another interesting observation which emerges concerns novel INMI occurrence, a phenomenon which, although reported in a few studies (Bailes, 2007; Liikkanen, 2012a; Wammes & Barušs, 2009; Williamson & Jilka, 2013), has not been explored in the same depth as INMI arising from familiar or unfamiliar music.

The association between cognitive states described by low attention and INMI occurrence reported by Williamson et al. (2012) and Hyman et al. (2013) is in accordance with findings from early INMI research. Bennett (2002) suggested that INMI appearance is always associated with a lack of focus and relaxed states in which the brain is in a condition of break or distraction, while Hemming (2009) found that INMI occurs more frequently when doing nothing important. This is also in line with Kellaris (2001) assertion that «earworms eat idle brains». Similarly it has been found that other forms of spontaneous cognition are more likely to occur when the mind is in an unfocused state, characterised by low attentional engagement and cognitive load (Christoff, Ream, & Gabrieli, 2004; Klinger & Cox, 1987) of the kind exemplified by studies of mind-wandering (Mason et al., 2007) and involuntary memories (Kvavilashvili & Mandler, 2004).

The relationship between INMI and other forms of spontaneous cognition has never been explored before in terms of the cognitive states that precede its generation or individual differences in the proneness to INMI and other forms of spontaneous cognitions in general. This question will be addressed in the present thesis, along with the occurrence of novel INMI, which has been reported in the literature although not in much detail. In view of the limited nature of previous studies, this work will mostly focus on the phenomenology of novel INMI and propose a theoretical framework for its understanding.

1.6 Theoretical Framework of the Current Thesis

Spontaneous cognition is a key concept for understanding human cognition. This is evident since a substantial portion of our waking thoughts are not under our conscious, voluntary control (Killingsworth & Gilbert, 2010; McVay, Kane, & Kwapil, 2009) and are represented by various modalities such as memories, imagery (visual, speech, and music), future plans, and fantasies (Baars, 2010). This spontaneous stream of thoughts continues even when we sleep and dream, where it reflects similarities with our waking thoughts (Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013).

A ubiquitous form of spontaneous mentation is that of INMI which, although prevalent, was considerably understudied until recently, as also holds for other forms of spontaneous cognition owing to their transient character. The most widely studied form of thought is goal-directed, and that is also the case within the musical imagery context, where voluntary musical imagery (Crowder, 1989; Halpern, 1988; Halpern, 1989; Halpern et al., 2004) has been mostly studied in comparison to its counterpart, INMI.

Creative thought is believed to lie in the middle of a plausible thought continuum between two extremes, that of goal-directed and spontaneous thought, sharing characteristics with both (Christoff, Gordon, & Smith, 2008). By analogy, in the case of musical imagery, creative musical imagery, in the form of novel INMI, is assumed to stand between voluntary and involuntary musical imagery.

INMI is a ubiquitous, distinct and recognizable mental experience, which holds promise as a tool for studying spontaneous as well as creative cognition. Since other forms of spontaneous and creative cognition have been studied more widely, the studies described in this thesis focus on their relationship with INMI with the aim of informing and extending our understanding of the different types of spontaneous and creative thoughts.

1.7 Thesis Objectives

1.7.1 Aims

One of the advantages of investigating INMI is that it represents, and can help us understand different types of cognition such as spontaneous cognition, memory, and imagery. The ubiquity of INMI (Liikkanen, 2012a) and the willingness of people to share information about it provides us with a platform to study and understand the phenomenon itself but also to connect it with other similar and complex phenomena.

This thesis intends to build upon and extend knowledge already acquired through different methods used in the literature and to investigate the relationship of INMI to other forms of spontaneous and creative cognition. The emphasis in this thesis is on the individual, its environment, and the cognitive mechanisms which lead to INMI, rather than the features of the music associated with INMI.

The first major aim of the work described in the current thesis was to conduct an empirical evaluation of INMI in relation to other forms of spontaneous

cognitions, by determining directly and empirically whether different cognitive states precede INMI occurrence and by identifying individual differences in the INMI experience and in relation to other spontaneous cognitions. It also aimed to place INMI in a theoretical framework based on current knowledge and future work. To achieve this, a mixture of methodologies, such as probe-caught experience sampling, survey, and behavioral measures were employed. The second major aim was to explore for the first time novel INMI from the point of view of creative cognition approach with a semi-structured interview.

The use of INMI as a form of spontaneous cognition and the combination of experience sampling, survey, and experimental methods, as well as the exploration of novel INMI as a form of creative cognition with an interview method, provides a unique opportunity to explore fundamental questions about spontaneous and creative cognition as well as for understanding INMI in more depth.

1.7.2 Structure

The current thesis reports findings from a mixture of quantitative and qualitative studies which investigated questions that have emerged from the literature on INMI and in the theoretical framework of spontaneous and creative cognition discussed in this chapter. The first three studies explore the relationship of INMI with other forms of spontaneous cognition using different methodologies, while the fourth and last study attempts to bridge the

gap between goal-directed and spontaneous cognition by investigating novel INMI and its relationship to creative cognition.

The thesis is structured around the following series of studies:

Study 1: An experience sampling method study (probe-caught) was conducted to investigate the relationship of INMI to the cognitive process of mind-wandering, mood states, INMI triggers, subjective evaluation, and other transient characteristics.

Study 2: A behavioral laboratory INMI induction study was conducted to explore the cognitive states as defined by the amount of cognitive resources available preceding INMI occurrence. Cognitive load was manipulated (4 levels) and its effect to INMI occurrence and length was measured via a novel covert sampling method.

Study 3: A scale, measuring INMI behaviors, evaluations, and emotions was developed to study individual differences in the INMI experience and its relationship to other forms of spontaneous cognition, musical behaviors, and auditory imagery.

Study 4: Finally, an interview study with composers explored the phenomenological aspects of novel INMI and its relationship to creative cognition.

Chapter 2. Environmental and Mental Conditions Predicting the Experience of Involuntary Musical Imagery: An Experience Sampling Method Study

Abstract

An experience sampling method (ESM) study on 40 volunteers was conducted to explore the environmental factors and psychological conditions related to Involuntary Musical Imagery (INMI) in everyday life. Participants reported 6 times per day for one week on their INMI and mind-wandering experiences, relevant contextual information and associated environmental conditions. The resulting data were modeled with Bayesian networks and led to insights into the interplay of factors related to INMI and mind-wandering experiences. The activity that a person is engaged in was found to play an important role in the experience of mind-wandering, which in turn activates INMI. INMI occurrence is independent of the time of the day while the INMI trigger affects the subjective evaluation of the INMI experience. The results are compared to findings from earlier studies based on retrospective surveys and questionnaires and highlight the advantage of ESM in research on spontaneous cognitions like INMI.

2.1 Introduction

Motivated by recent findings on the exogenous and endogenous factors described in the Introduction (section 1.4) that seem to affect INMI experiences (such as mood, time of the day, situational antecedent, INMI triggers) the current study explores the relationships and interplay between INMI and mind-wandering and aims to construct a common framework which facilitates the description of the relationships between these mental phenomena.

Mind-wandering is one of the states that Williamson et al. (2012) found to be among the precursors of INMI experiences. It is characterized by a shift of attention from a main task that the individual is engaged in towards internal information such as the processing of memories, current concerns, and future plans (Christoff, Ream, & Gabrieli, 2004; Smallwood & Schooler; 2006, Smallwood, Baracaia et al., 2003; Smallwood et al., 2004a; Smallwood, Obonsawin, & Heim, 2003; Smallwood, O'Connor, Sudberry, & Ballantyre, 2004b). Different terms have been used to describe this phenomenon, including task-unrelated thought (Smallwood et al., 2004a), stimulus-independent thought (Antrobus, 1968; Teasdale, Lloyd, Proctor, & Baddeley, 1993), mind-pops (Kvavilashvili & Mandler, 2004), and zone outs (Schooler, 2002; Schooler, Reichle, & Halpern, 2005). There are minor differences between the exact meaning of these terms but all of them generally characterize a process of self-generated thought (Smallwood, 2013a, b). The latter term covers experiences which arise intentionally but also unintentionally and it can be task related or unrelated.

Exogenous factors associated with the mind-wandering experience, and more specifically situational antecedents that allow its occurrence, are described by low attentional states (Mason et al., 2007; McVay & Kane, 2009; Teasdale et al., 1995) which are usually enabled by monotonous and repetitive tasks. Low attentional states have also been found to be associated with INMI occurrence based on retrospective reports and behavioral measures (Hyman et al., 2013; Liikkanen 2012a; Williamson et al., 2012). It was hypothesized that low attentional states will be found to be associated with both of the INMI and mind-wandering experiences based on experience sampling probe-caught reports. The current study would also identify states and activities where INMI occurrence will decrease given the probe-caught measure and it is expected that high attentional states would prevent its occurrence.

As regards additional factors which may affect the INMI experience, such as mood and time of the day, the picture is not clear. Findings regarding the impact of mood come from studies on both voluntary and involuntary musical imagery (Bailes, 2007; Beaty et al., 2013), however as these studies were not targeted specifically on INMI they do not lead to clear conclusions. As regards the role of time of the day, the conclusions are mixed since findings come from a study (Bailes, 2006) on involuntary and voluntary episodes and another one which focused on INMI (Halpern & Bartlett, 2010) pointing to different parts of the day. Mood and time of the day will be investigated in this study with no specific hypothesis, given the lack of previous literature or bidirectional findings.

Based on an analysis of the reports of thousands of people about what triggers their INMI experiences in their everyday environment, Williamson et al. (2012) provided four core categories of triggers: exposure to the music, memory triggers, affective states and low attention states. The first two have been replicated in studies using behavioral measures (Byron & Flowles, 2013; Floridou et al., 2012, Liikkanen, 2012b) while the other two are yet to be confirmed. In another study lead by Williamson (Williamson et al., 2014), the researchers classified people's reactions to their INMI experiences based on the participants' subjective evaluation. Findings confirmed that the evaluation of INMI varies, even though it is mostly described as pleasant (Halpern & Bartlett, 2010). The current study will attempt to disentangle the factors that influence the range of the subject's evaluation of INMI.

The principal aim of this study was to investigate INMI and its characteristics the moment it occurs, with a special focus on factors that have not been clarified by the existing literature. Previous studies on INMI have made use primarily of retrospective reports via surveys (Liikkanen 2012a; Williamson et al., 2012) and, to a smaller extent, data from behavioral measures (Byron & Fowles, 2013; Floridou et al., 2012; Hyman et al., 2013) and diary studies (Beaman & Williams, 2010; Halpern & Bartlett, 2011). In the present study, experience sampling method (ESM) probe-caught is used.

ESM has been used for the exploration of everyday occurrences (Csikzentmihalyi & Larson, 1987; Kubey, Larson, & Csikszentmihalyi, 1996;

Reason & Mycielska, 1984) and can provide rich data regarding the experiential nature and causes of INMI as and when it occurs in everyday life as well as on situations where it does not occur. Thus, the ESM data from the current study can complement the findings of previous research that used other data collection methods. Data on INMI experiences can be easily collected via ESM, given that they are ubiquitous, experienced by more than 90% of people at least once per week, and by 33.2% everyday (Liikkanen, 2012a).

A second novel methodological aspect of the present study is the use of Bayesian networks as a data analysis technique. This technique offers the possibility to construct network models of causative associations between relevant environmental and psychological variables around the experience of INMI, which make it possible to understand the potentially complex interactions between different factors leading to the experience of INMI and mind-wandering.

2.2 Method

2.2.1 Participants

A total of 40 individuals (24 females), 18-72 years of age, were recruited from the "Goldsmiths Earwormery Questionnaire" (http://earwormery.com/) database. Of these, 20 had previously declared experiencing INMI frequently (more than once a day) while the other 20 participants had claimed to experience INMI rarely (less than once per month or never). Two of the participants were discarded because they either did not complete the

required forms or completed them hours later than when contacted, leaving a total of 38 participants.

2.2.2 Ethics Statement

The study protocol was approved by the Ethics Committee of Goldsmiths, University of London, UK. All participants gave written informed consent for their participation in the study.

2.2.3 Materials

Participation in the study required the use of a mobile phone, which individuals had to carry with them all the time, and an Experience Sampling Booklet (ESB). The ESB was sent to the participants along with a consent form, which they were asked to complete and return, and an information/instruction sheet about the study. This sheet also contained the definitions of INMI ("An earworm[1] refers to the experience whereby a tune comes to your mind unbidden and repeats itself (i.e. it gets stuck in your mind) without your conscious control") and mind-wandering ("Mind-wandering describes the experience of the mind drifting away from a person's main activity at the time to other «internal» things such as memories, feelings, inner thoughts and fantasies. An example of mind-wandering is when we are reading a book and, after a couple of pages, we realize that we can't really say what the story is about because while we were reading we had something else in our mind") so as to help the participants to identify these phenomena when they occurred.

[1] The term INMI is used throughout this thesis to describe the phenomenon in exploration but when referred to participants the term earworm is used.

The ESB contained 42 Experience Sampling Forms to be completed (ESF; 6 per day, for one week). Each ESF (see Appendix 1.1) contained slots for the following information: date, time when message was received and time when the form was completed. Two sections followed: Section A contained information items that had to be provided at all times regardless of whether or not the participants were experiencing INMI at the time of the prompt (when they would receive the text message). If they experienced INMI they would continue to Section B, otherwise they would stop after completing Section A. Section A asked for the following information: Occurrence or not of INMI and mind-wandering at the time of the prompt, current activity the participant was engaged in (12 categories: housework, getting dressed, in the bath, travelling, working, studying, reading a book, shopping, exercising, socializing, listening to music, and other), and rating of 6 bipolar items for the assessment of the current mood state using a 7-point rating scale (see Sloboda, O'Neill, & Ivaldi, 2001). If the participants did not experience INMI but did experience mind-wandering, then they would complete the questions related to mind-wandering as well as the rest of the general questions of Section A.

Section B of the ESF asked for details of the INMI experience, including the title and artist of the music piece involved in the INMI, the subjective pleasantness of the experience as rated on a 11-point rating scale 0-10 (Not at all pleasant-Love it) and the participant's suggestions of potential triggers of the INMI experience based on the trigger themes proposed by Williamson et al. (2012) (11 categories: Recent Music Exposure, Association, Person,

Association, Sound, Association, Word, Recent/Upcoming event, Dreams, Current thoughts, Other). If mind-wandering was experienced at the time of the prompt, then five items about the mind-wandering content (taken from the mind-wandering inventory by McVay et al., 2009) had to be rated on a 7-point rating scale (1 = not at all, 4 = moderately, 7 = very much): 1) I was aware my mind was wandering in the moments before the beep, 2) I allowed my thoughts to wander on purpose, 3) I was thinking about personal concerns or things I need to do, 4) I was daydreaming or fantasizing about something, 5) I was worrying about something. Two additional items were included to explore the mind-wandering content: 6) I was remembering something, and 7) My mind was occupied only by the earworm.

2.2.4 Procedure

During the observation period (Monday-Sunday, 8am-11pm), participants were contacted, by text message via an online messaging service (www.fastsms.co.uk), on six occasions per day at random times. As soon as they were contacted they had to complete one ESF from the booklet. The completion of an ESF took between 3 to 5 min, depending on whether INMI was experienced and the level of detail the participant was able to convey about the musical piece and potential triggers.

2.3 Data Analysis

Data was obtained for 1374 out of the total of 1596 prompts (86% compliance). Bayesian networks analysis was employed on the 14 variables from the ESFs. The Bayesian network approach (e.g. Korb & Nicholson,

2010) enables the identification of dependencies and influences within a potentially large set of variables. Bayesian networks combine principles from graph theory, probability theory, computer science, and statistics. They are graphical models, which encode probabilistic relationships between the variables of interest using nodes and edges as graphical elements. The nodes in the graph represent random variables and the edges connecting the nodes represent probabilistic dependencies between the variables. The graph represents the qualitative (or structural) part of the model while the quantitative parameters are given by the conditional probability distribution in additional Tables that hold the local probabilities for the conditional dependencies between nodes that are connected. One important aspect of Bayesian networks is that they encode information about the dependence/independence of pairs of variables, conditional on sets of other variables. In highly multivariate datasets, where large sets of variables appear to be related to each other, identifying the conditional independence structure can greatly simplify the network of related variables and help to identify important causal relationships.

Due to the logical dependencies between questions, the data was divided into three sets for which separate networks were constructed. The first dataset included all 1374 episodes, regardless of whether or not INMI or mind-wandering had occurred (INMI and mind-wandering Bayesian network). The second dataset included only the 644 episodes were INMI was experienced (INMI Bayesian network) and the third network included only the 335 episodes where mind-wandering was experienced (mind-wandering

Bayesian network). The data were analyzed using the R software environment for statistical computing (R Core team, 2013) and the bnlearn package (Nagarajan, Lebre, & Scutari, 2013; Scuttari, 2010).

The networks were constructed in three stages. First, cross-validation was used to identify the optimal combination of the components of the network learning algorithm (i.e. goodness-of-fit criterion, type of learning algorithm, criterion for model selection). Then, the structure of the network was learned using the combination of components identified in the first stage. Finally, in the third stage, the parameters of the local distributions were computed from the network structure identified in the second stage. This generated the model-based contingency tables for all variables in the network.

2.4 Results

An initial analysis of the dependent variable 'INMI occurrence', which represented the occurrence of INMI during the ESM study, showed that those participants who had indicated on the Earwormery database that they experience INMI either *never* or *not very often* in the context of the current study they reported INMI frequencies in the range of 3-35 episodes per week, which is comparable to that reported by participants who had indicated that they experience INMI *always* (range: 16-38). A chi-square test was performed to determine if there was a difference between the people who frequently experience INMI and those who do not in relation to the total number of INMI experienced during the current study. The total number of INMI was equally distributed: $\chi^2(1, N=3) = .33$, $p > .05$, indicating that there

was not a significant difference between the two groups. This might indicate a key difference between self-report data from retrospective questionnaires and reports prompted via the ESM. Based on this finding, all participants and their INMI episodes were treated as a single group.

An independent sample t-test was performed to compare the subjective pleasantness associated with INMI in the high (M = 5.6, SD = 2.7) and the low INMI frequency (M = 5.9, SD = 2.7) group. The result indicated that there was no significant difference between the two groups of participants in terms of subjective pleasantness of their INMI experiences, $t(642) = 1.3$, $p = 0.2$.

2.4.1 Data Pre-processing

Continuous variables were discretized into categorical variables because the particular class of Bayesian networks employed here requires the exclusive use of either categorical or continuous variables.

The 6 mood variables were transformed into one categorical variable (*mood state)*, with 4 discrete categories coding distinct mood states. Model-based cluster analysis was used (Mclust package for R; Fraley, Murphy & Scrucca, 2012) to group the mood ratings into 4 discrete categories. The clustering model with the best model fit (according to the Bayesian Information Criterion, BIC, used as fit index) was identified from among models having one to 9 clusters and allowing for all ten possible covariance structures. The clustering model with the best fit comprised 4 clusters with an identical covariance structure and ellipsoidal distributions. The means and standard

deviations of mood scales for the four clusters are given in Table 2.1. A simple characterization of these four mood states can be done by the attributes they are most strongly associated with relative to the other clusters: For Cluster 1 these are Drowsy, Lonely, Tired, Bored; Cluster 2: Relaxed, (Happy); Cluster 3: Sad, Tense; Cluster 4: Alert, Happy, Interested, Energetic, Connected.

Table 2.1

Means and SDs of Mood Variables for the 4 Different Mood States

Mood pairs	Mood State 1, (527 episodes) Mean [SD]	Mood State 2, (330 episodes) Mean [SD]	Mood State 3, (273 episodes) Mean [SD]	Mood State 4, (208 episodes) Mean [SD]
Alert-Drowsy	4.04 [1.60]	5.86 [.62]	6.04 [.66]	6.33 [.60]
Happy-Sad	4.61 [1.25]	5.76 [.68]	4.51 [1.38]	6.17 [.59]
Tense-Relaxed	3.31 [1.46]	2.16 [.73]	4.34 [1.28]	2.54 [1.20]
Interested-Bored	4.24 [1.16]	5.64 [.81]	5.58 [.91]	6.32 [.61]
Energetic-Tired	3.35 [1.39]	4.17 [1.25]	4.15 [1.45]	5.72 [.80]
Lonely-Connected	3.66 [1.07]	2.91 [1.19]	3.24 [1.22]	1.53 [.53]

In addition, the items “INMI pleasantness” and the 7 variables measuring mind-wandering content on rating scales we discretized using Hartemink’s Information Preserving Discretization method (Hartemink, 2001). Pleasantness resulted in three categories: 0-4, 5-7, 8-10, based on the initial 10-point Likert scale and mind-wandering content in two categories for each variable (1-3, 4-7; 1-2, 3-7). The variables “activity” and “INMI trigger” were regrouped into new categories, larger than the ones provided in the booklet. This was done either because the category “Other” was used frequently or because some of the categories were listed only infrequently.

As a result the variable describing the activity that participants were engaged in at the time of the prompt comprised the following nine categories: (1) working, (2) socializing, (3) grooming, (4) audio/visual, (5) travelling, (6) physical movement, (7) low cognitive load activities, (8) computer/leisure, (9) high cognitive load activities. For INMI triggers the following categories were identified: (1) Music Exposure, (2) Association with a Person, (3) Association with a Sound, (4) Association with a Word/Image, (5) Recent/Upcoming event, (6) Thoughts/Dreams, (7) Not aware of trigger, (8) the same as the previous INMI, (9) Default INMI (an earworm that is experienced quite frequently), (10) Memory. Finally, the time of the day when the ESF was completed was divided into 3 categories: 8am-1pm, 1:01-6pm, 6:01-11pm).

2.4.2 Descriptive Statistics

2.4.2.1 Overall INMI Rate, Percentages of INMI Triggers, and Average Pleasantness

The INMI frequency rate was calculated based on the total INMI episodes divided by the total number of surveys completed and resulted in an overall rate of 47% over a week. Participants who had indicated low INMI rates in retrospective self-reports, in this study were found to experience INMI in the same frequency as participants who had previously reported high rates.

In terms of the INMI triggers reported by the participants, the most frequent trigger was “exposure to music” (33.1%), followed by “not aware of trigger” (18.7%). The frequencies of the remaining triggers can be seen in Figure 2.1.

The percentage frequency of all identifiable triggers (except for “not aware of trigger”, “same INMI”, “default INMI”) combined is 62.3%.

The average pleasantness based on the data before the discretization is *M* = 5.76 (*SD* = 2.91) on the 0 to 10 scale, indicating that on average INMI experiences were rated as slightly pleasant.

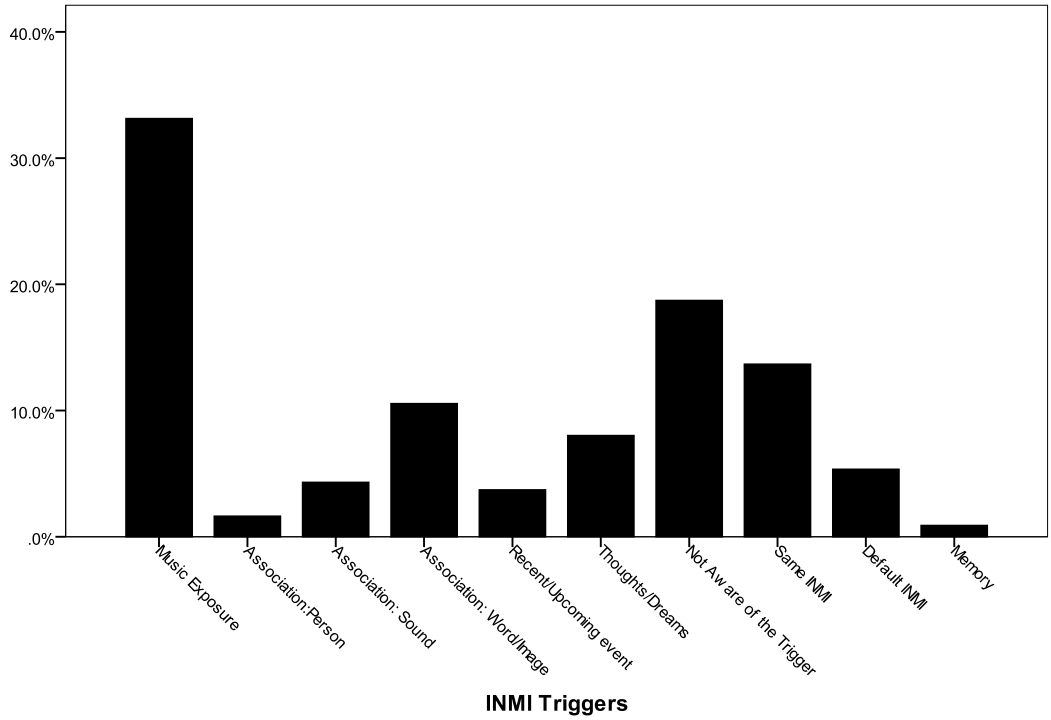

Figure 2.1. Percentages of INMI Triggers

2.4.3 Bayesian Network Models

2.4.3.1 INMI and Mind-Wandering Network

The first network included the five variables that were filled out regardless of whether or not INMI and/or mind-wandering had occurred: INMI occurrence, mind-wandering occurrence, time of the day, activity, and mood state. The network was constructed from 1374 observations. The best network was generated by the tabu algorithm (Glover, 1986), a Bayesian fitting criterion

and the Bayesian-Dirichlet equivalence (bde) score. The structure of the network is graphically depicted in Figure 2.2.

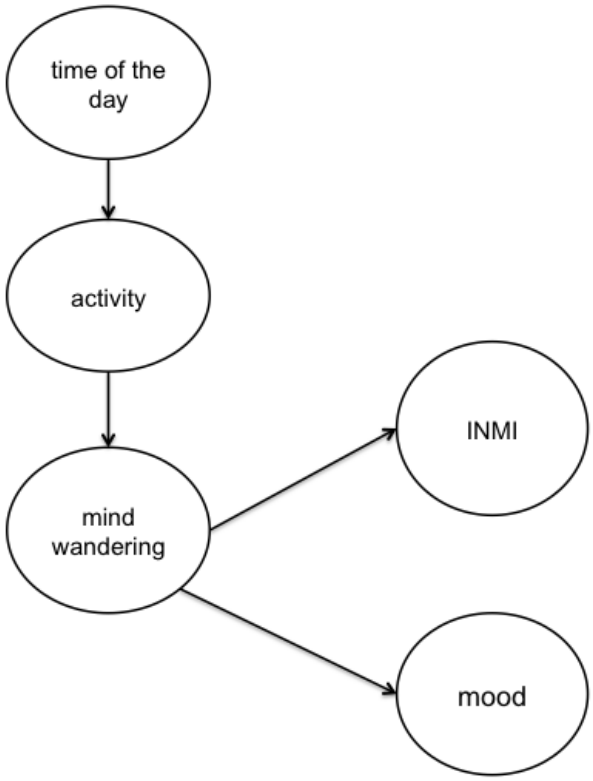

Figure 2.2. General INMI and Mind-Wandering Bayesian Network

The network shows that time of the day determines the activity that the person is engaged in, then the activity can cause the appearance of mind-wandering and, in turn, mind-wandering can cause the appearance of INMI. Mind-wandering also affects the mood state but the network does not indicate a direct effect of INMI on mood. From the contingency table of mind-wandering vs activity (Table 2.4) we can see that activities that are associated with mind-wandering occurrence are those characterized by low cognitive load (conditional probability of mind-wandering to occur is .46), travelling (.39) grooming (.36), and physical activities (.30), while those that

prevent mind-wandering are socializing (.90), activities characterized by high cognitive load (.85), audio/visual activities (.85), working (.79), and computer/leisure activities (.78).

Mood is influenced by mind-wandering, with mind-wandering leading to a mood state characterized by high happiness, relaxation, interest, tiredness, and connection (.49; see conditional probabilities in Table 2.2).

Table 2.2

Conditional Probabilities of Mind-Wandering and Mood

Mood	Mind-Wandering	
	0 (No)	1 (Yes)
1. Drowsy, Lonely, Tired, Bored	.36	.49
2. Relaxed, (Happy)	.26	.20
3. Sad, Tense	.20	.20
4. Alert, Happy, Interested, Energetic, Connected	.17	.11

The mind-wandering experience plays a key role by affecting the initiation or not of the INMI experience (.80 on 278 episodes and .20 respectively on 70 episodes; Table 2.3).

Table 2.3

Conditional Probabilities of Mind-Wandering and INMI

INMI	Mind-Wandering	
	0 (No)	1 (Yes)
0 (No)	.56	.20
1 (Yes)	.44	.80

The network also indicates that there is no direct influence of time of day on mind-wandering or INMI. The remaining of the conditional probability Tables can be found in the Appendix 2.1.

Table 2.4

Conditional Probabilities of Mind-Wandering and Activity

Activity	Mind-Wandering	
	1 (Yes)	0 (No)
Working	.21	.79
Socializing	.10	.90
Grooming	.36	.64
Audio/Visual	.15	.85
Travelling	.39	.61
Physical Movement	.30	.70
Low Cognitive Load	.46	.53
Computer/Leisure	.22	.78
High Cognitive Load	.15	.85

2.4.3.2 INMI Episodes Network

For the second part of the analysis, observations from only the instances where the occurrence of INMI was reported (n=644) were included, along with mind-wandering occurrence or not, time of the day, activity, INMI pleasantness, and INMI triggers. The network was constructed to include the structural connections identified in the first network. After cross validation, the best network was obtained with the tabu algorithm using the Bayesian-Dirichlet equivalence score and the maximum likelihood fitting method and is depicted in Figure 2.3.

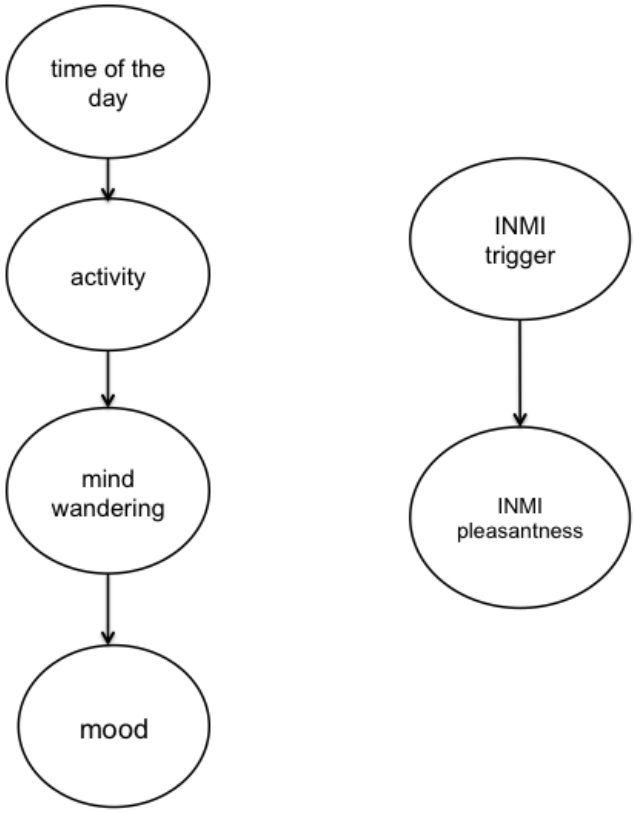

Figure 2.3. Bayesian Network Including INMI Episodes

Table 2.5 shows that INMI is evaluated as more pleasant when it is triggered by a specific memory (.67), when it has been associated with a sound (.50), the person has been recently exposed to the music (.41), and when a recent/upcoming event is being contemplated (.38). INMI is experienced as least pleasant when the person cannot identify what triggered it (.65), when the same INMI tune is experienced more than once throughout the day (.61) and when the default INMI of the individual is experienced (.49). The remaining of the conditional probability Tables can be found in the Appendix 2.2.

Table 2.5

Conditional Probabilities of INMI Trigger and Pleasantness

INMI Trigger	Pleasantness		
	Low (0-5)	Middle (5-7)	High (7-10)
Music Exposure	.36	.23	.41
Association; Person	.49	.23	.29
Association; Sound	.40	.10	.50
Association; Word/Image	.44	.22	.33
Recent/ Upcoming event	.47	.18	.35
Thoughts/ Dreams	.39	.40	.22
No idea	.15	.47	.38
Same INMI	.64	.22	.13
Default INMI	.61	.26	.13
Memory	.17	.17	.67

2.4.3.3 Mind-Wandering Episodes Network

The third part of the analysis was constructed only on the basis of those instances were mind-wandering was reported (n=335). It included the variables: INMI occurrence or not, time of the day, activity, mood, and the mind-wandering content questions. The best resulting network was generated by a combination of the max-min hill-climbing algorithm, the bde score and the Bayesian fitting method, and is given in Figure 2.4.

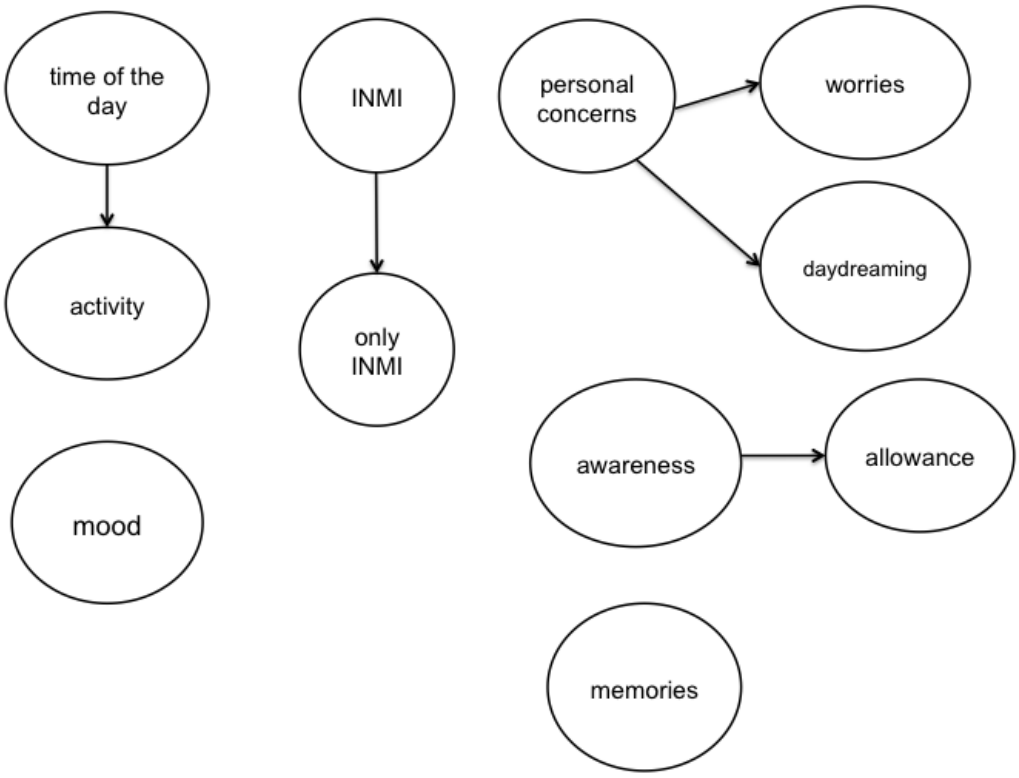

Figure 2.4. Mind-Wandering Network

The network contains several new relationships: The experience of INMI can lead to the suppression of any other mind-wandering contents when only INMI is experienced (.52). Awareness of a current mind-wandering experience can lead to a conscious decision to allow the mind to wander (.61). Thinking about personal concerns can cause daydreaming (.21) and also start worries (.60). Mood state and the engaging with memories during mind-wandering episode were found to be independent from the rest of the variables in the network. The remaining of the conditional probability Tables can be found in the Appendix 2.3. Figure 2.5 represents an attempt to depict the structural connections from all three networks in a single graph.

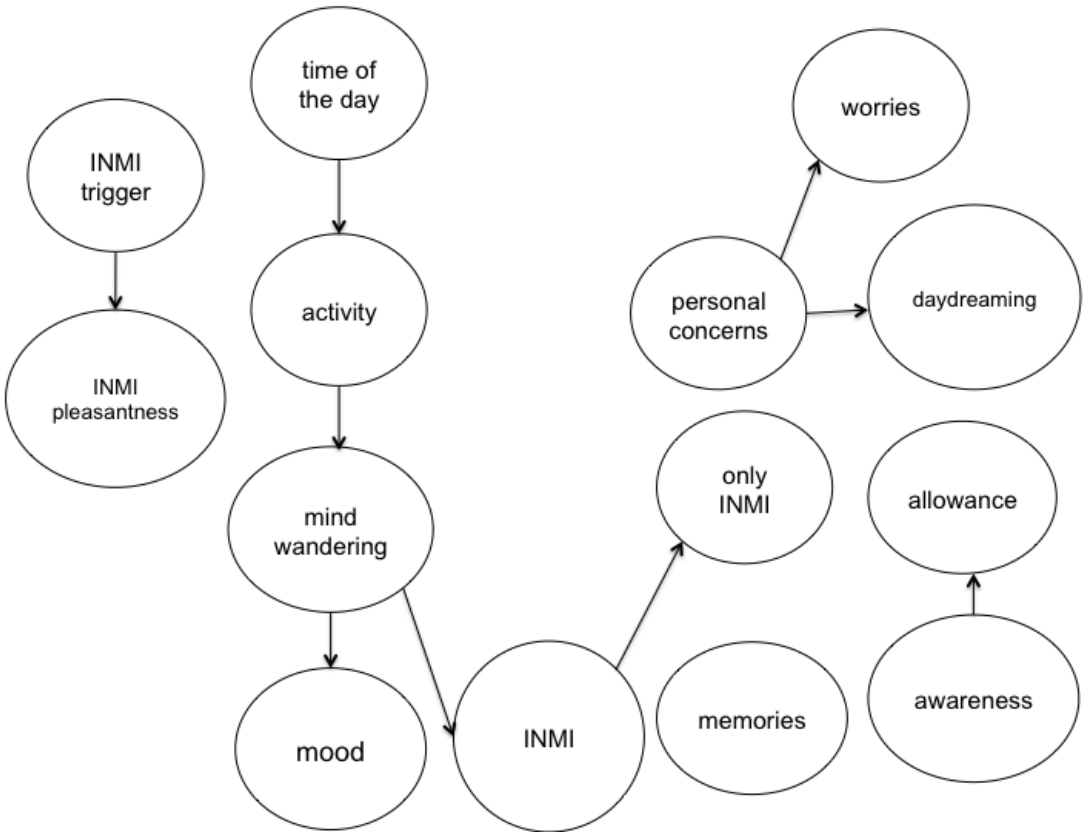

Figure 2.5. All Networks Combined Together

2.5 Discussion

The aim of this study was to examine the role of environmental conditions and endogenous states of the individual in relation to the INMI experience. The study specifically looked at interactions and causal relationships between these conditions and also investigated the relationship between INMI experiences and mind-wandering.

The current study used the Experience Sampling Method (ESM) to study INMI experiences in real-life situations. An important finding is the discrepancy of the frequency of INMI experiences as obtained via ESM reports in comparison with that obtained via retrospective estimates from the

same individuals. Kvavilashvili and Mandler (2004) reported a similar discrepancy between the two different measures for the same participants in relation to Involuntary Semantic Memories frequency. This suggests that, at least for certain individuals, retrospective meta-memory for involuntary semantic memories may be less accurate than measures obtained from experience sampling. A tentative explanation for this discrepancy, given by Kvavilashvili and Mandler (2004), is that "some people who do experience Involuntary Semantic Memories may not be paying attention to them and thus may tend to assume that they never experienced them" (p. 73). This finding is particularly important for future studies based on retrospective questionnaire reports for e.g. INMI frequency and other factors of interest, where poor meta-memory for INMI experiences could distort empirical results.

The overall frequency of INMI reported in this study was 47% over the course of a week. This rate is substantially greater than that reported in previous ESM studies on musical imagery, with Bailes (2006) reporting a 32% INMI rate and Beaty et al. (2013) reporting a frequency of 17%. This difference could be the result of the selection criteria of the different studies. The higher overall frequency observed in this sample could be due to a selection bias, as participants were recruited among people who had completed the "Earwormery survey" and thus it is possible that these participants were more familiar, interested and maybe more aware of their INMI. Future studies should take this into consideration and include participants that are not very familiar to INMI research.

The results suggested by the network models indicate that the activity that a person is engaged in plays the key role for the appearance of mind-wandering, which in turn enables the appearance of INMI. Conditional on the activity, INMI occurrences are independent of time of the day, a result that agrees with Byron and Fowles (2013) and resolves previous conflicting findings in the literature (Bailes, 2007; Halpern & Bartlett, 2011). Thus, according to these results it is the activity that the person engages in that causes mind-wandering and, in turn, the activity is constrained by the time of the day.

Generally, activities found to favor mind-wandering, and subsequently INMI appearance, are characterized by low cognitive load (e.g. just woke up, going to sleep), traveling (confirming the findings of Liikkanen, 2012a), housework, and physical movement. On the other hand, activities that make the appearance of mind-wandering and INMI less likely are socializing, a finding that confirms the finding of Liikkanen (2012a) but is in conflict to that of Bailes (2006). However one has to bear in mind that the latter study also included voluntary musical imagery episodes in which the participants might purposely have imagined the music in their minds.

Audio/visual activities were found to reduce the likelihood of mind-wandering experiences and subsequently INMI. This finding is in contrast with a result from a study (Liikkanen; 2012a), which was based on retrospective reports. Both, socialising and audio/visual activities, involve auditory engagement.

Neuroimaging findings (Kraemer et al., 2005; Zatorre & Halpern, 2005) show that the auditory cortex is activated in voluntary but also involuntary musical imagery activities. Taking this into consideration, it seems possible that INMI may compete for the same auditory processing resources that are engaged during socializing and audio/visual activities. This could provide an explanation for why involuntary musical imagery appearance is less likely when individuals are engaged in concurrent activities that require auditory processing.

Activities described by high cognitive load such as reading, playing Sudoku, school homework, etc., but also working and computer/leisure activities, seem to discourage INMI. This finding is at odds with the conclusion by Hyman et al. (2013) that appearance of INMI is favored by activities at both ends of the cognitive load continuum (low and high cognitive load). To resolve these conflicting findings, more experimental studies based on the systematic manipulation of the amount of cognitive load, are required. Chapter 3 in this thesis presents the first study, which performs this manipulation.

With regard to the influence of mood on INMI, the picture emerging from the data of this study is quite clear. The networks described above show that mood is independent of INMI but is affected by the occurrence of mind-wandering, which in turn enables INMI occurrence. In other words, mind-wandering is a common cause of both INMI and the affective quality of a mood state. The distribution of mood states in all the networks shows that the

participants were most often in a calm and happy mood and least likely to be in an energetic mood. This result agrees with the findings by Ruby, Smallwood, Engen, & Singer (2013b) that self-generated thought (mind-wandering) can temporally precede positive mood but contradicts those of others (Killingsworth & Klinger, 2010; Smallwood, Fitzgerald, Miles, & Phillips, 2009; Smallwood & O′Connor, 2011). This might be explained based on musical imagery findings by Bailes (2007) and Beaty et al. (2013) regarding the quality of music on mood states.

The data of this study also provide a tentative explanation for the observation that the subjective evaluation of INMI episodes can be highly variable (Beaman & Williams, 2010; Halpern & Bartlett, 2011; Hemming, 2009; Liikkannen, 2012a). According to the output of the second network, the participant's opinion about what triggered their INMI seems to determine how pleasant an INMI experience is perceived to be. Memory-associated triggers and music exposure increase INMI pleasantness. This could be explained by the fact that people listen to and are more exposed to music that they like and enjoy (North & Hargreaves, 2003; North, Hargreaves, & Hargreaves, 2004). Therefore, there is a higher likelihood of INMI triggers related to recent exposure to tunes that are perceived as pleasant.

However, when the person cannot identify the trigger, experiences an INMI more than once in a day and/or experiences his/her default INMI (i.e. INMI that reoccurs frequently), then the pleasantness of the INMI experience decreases. This could be because of the repetitive quality of INMI that can

lead to negative evaluation of the experience. The individual initially enjoys the INMI but finds it unpleasant when this experience occurs and reoccurs. It could also be explained by the findings of Müllensiefen et al. (2014a) that individual differences in obsessive compulsive trait - which is characterised by repetitive thought patterns - partially influence INMI valence (unpleasantness).

The relative frequencies of INMI triggers found in this study confirm findings by Williamson et al. (2012) but also allow direct comparisons with triggers of Involuntary Semantic Memories. A key characteristic of ISMs, in comparison to IAMs, is that identification of the ISM trigger is not easily traceable. In the present study INMI triggers could be identified in 62.3% of the instances. Kvavilashvili and Mandler (2004) reported ISMs triggers for 37% of the cases, which is approximately half the proportion reported by the current participants. This difference might suggest that INMI triggers are more identifiable than triggers of other ISMs because of their persistence that could give more time to the person to identify them.

Finally turning to the relationship between INMI and mind-wandering, all the networks derived in the present study reveal interesting relationships. Mind-wandering often seems to be the cause of INMI that follows its occurrence, i.e. it appears that the mind starts to wonder and subsequently it enables the appearance of INMI. This finding is in accordance with mind-wandering literature where a big portion of its content is reported as musical imagery (Delamillieure et al., 2010).

2.6 Conclusion

In summary, this study has demonstrated the advantages of the ESM approach for the study of conditions surrounding INMI occurrence and allows a comparison to data from retrospective self-reports. One interpretation of the discrepancy between the results from the two data collection methods suggests that retrospective self-reports can suffer from memory bias. Using Bayesian Networks as an analysis technique, it was found that INMI triggers determine whether INMI is experienced as pleasant or not. Also that INMI does not affect mood directly, but that mind-wandering is a common cause behind the two. INMI occurrence is independent of the time of day but activity is a causal link between the two. Finally, low cognitive load activities favor mind-wandering occurrence and subsequently INMI appearance.

New insights are provided into the contextual and psychological conditions that affect the occurrence and experiential quality of INMI. It uses a data collection method that is highly suited for observing these real-world contexts and a modelling approach that is suitable for identifying complex networks of interacting variables as well as causal mechanisms. The Bayesian network modelling approach appears to be appropriate for the analysis of this type of data because, as previous literature has shown, the conditions which govern INMI experiences are highly complex.

Chapter 3. A Novel Indirect Method for Capturing Involuntary Musical Imagery Under Varying Cognitive Load

Abstract

Previous studies provide conflicting reports regarding INMI onset and cognitive load. To date, the effect of a systematic cognitive load increase on INMI occurrence and duration remains unknown. In the present study 200 participants watched and immediately evaluated two non-dialogue, music-only film trailers. Subsequently, participants either closed their eyes for 5 minutes (Baseline), or engaged in one of three dot counting tasks (Easy, Medium and Hard conditions) of varying challenge and attentional demand (low, medium and high cognitive load respectively). Finally, they completed a novel “Mind Activity Questionnaire”, which allows for indirect sampling of INMI experiences rather than direct questioning. A second Mind Activity Questionnaire was completed again 24 hours later. Baseline INMI induction rate was 65%. This rate was reduced to 32.5% in the Easy condition. Further reductions in occurrence were observed in both Medium and Hard conditions, which did not differ significantly from each other. A significant (negative) linear trend was found, indicating that as cognitive load increased, INMI duration decreased. In the 24-hour follow-up, 21% of participants reported INMI. This study supports the hypothesis that INMI occurrence and duration relate to spare cognitive capacity and demonstrates an ecologically valid laboratory paradigm for covertly inducing and documenting INMI experiences.

3.1 Introduction

While much can be learned about everyday INMI from self-report descriptions and experience sampling studies, it is important to be able to induce INMI within a laboratory context in order to learn more about the cognitive factors that play a role in its onset, maintenance or termination.

Research on similar (but not musical) spontaneous phenomena, such as Involuntary Autobiographical Memories (IAM), has benefited from the use of behavioral measures. Studies have used various ways to elicit the phenomena of interest under controlled laboratory conditions (Berntsen, Staugaard, & Sorensen, 2013; Mazzoni, Vannucci, & Batool, 2014; McKiernan, D'Angelo, Kaufman, & Binder, 2006; Shlagman & Kvavilashvili, 2008; Vannucci, Batool, Pelagatti & Mazzoni, 2014; Vannucci, Pelagatti, Hanczakowski, Mazzoni, & Rossi Paccani, 2015) and have resulted in the replication of findings from self-report measures regarding prominent cues that trigger such phenomena and circumstances associated with such triggering, such as when being in a diffused state of attention (e.g. when performing boring or undemanding tasks).

Similarly studies on mind-wandering have reported findings comparable to those of retrospective and experience sampling self-reports (Killingsworth & Gilbert, 2010). Such studies have widely used undemanding tasks (e.g. looking at a fixation cross) to induce a resting state associated to the onset of mind-wandering in neuroimaging scanners and the laboratory (Mason et al., 2007; McVay & Kane, 2009; Teasdale et al., 1995).

In INMI research so far, four studies have attempted to induce it in the laboratory and have reported induction rates ranging from average to high (Beaman et al., 2015 do not provide induction rates; 32%, Byron & Fowles, 2013; 65%, Floridou et al., 2012; 75.3%, Hyman et al., 2013).

Floridou et al. (2012) focused on comparing the success of different INMI induction procedures, namely music exposure and memory triggers. For the latter they used a cued memory recall paradigm similar to the online induction paradigm of Liikkanen's (2012) where participants completed the missing lyrics of tunes on a piece of paper. Half of the tunes they used were high in probability to induce INMI (reports came from a survey: http://www.earwormery.com, which resulted in a database about tunes that were experienced as INMI as well as a musical database indicating successful chart songs) and the other half was low in probability to induce INMI (existence in musical database but not INMI related database). After induction, participants completed a 5 min visual filler task and were asked directly if they experienced INMI. The conclusion was that both paradigms and both sets of tunes were equally successful in inducing INMI and that there was a recency effect for INMI indicating that the last heard tune was higher in probability of being experienced as INMI.

Building on previous findings, Byron and Fowles (2013) investigated the impact of (1) different types of music exposure (recent and repeated) and (2) levels of subjects' processing with the exposed tune, autobiographical and

semantic, on the efficiency of INMI induction. In this study, participants first heard tunes either low or high in familiarity (based on the results of a survey) while completing a form which contained either questions about the connection of the tune to their life (autobiographical association) or general questions about the tune (semantic association). At the end of the experimental session participants completed an Experience Sampling Form with information about INMI occurrence, the tune itself and INMI triggers. They completed the same ESF 6 times a day for the next 3 days post induction. Results revealed familiarity and recency effects but no levels of processing effect.

Beaman et al. (2015) investigated the effects of articulatory motor activity (chewing gum) on INMI occurrence with 3 experiments. First they exposed participants to a tune and then they either provided them or not with gum, and instructed them to a suppression period by asking them not to think about the tune for 3 min following exposure. In the next experiment they replicated the previous but with no post-suppression period and instead instructed participants to press a button when experiencing INMI. In another experiment they included a different type of motor activity based on the participants having to tap to the beat of the tune they were listening to, so as to disentangle the effects of articulatory motor activity from those of motor activity. Results showed that chewing gum was the most effective activity for reducing the number of experienced INMI as well as interfering with voluntary musical imagery.

Taken together, the studies discussed above (1) established that recent musical exposure can be an effective trigger for INMI in a laboratory-based context and (2) revealed various factors that can either facilitate or prohibit INMI occurrence.

Following on from the above studies, laboratory studies using music exposure began to investigate the cognitive factors that influence successful INMI induction. Hyman et al. (2013) conducted 5 studies which mostly investigated the role of cognitive load, the extent to which a task requires executive resources such as working memory. After a period of music exposure, participants completed either easy or challenging Sudoku puzzles (nonverbal task; Study 4) or easy or challenging anagrams (verbal task; Study 5) and subsequently reported whether they had experienced any songs replaying in their head during the tasks. For both experiments, the authors found that INMI occurred during both easy and challenging tasks, which supported their findings from self-report measures in Studies 1 and 2. While this finding seems, at first sight, counterintuitive, the authors suggest that spare cognitive resources were present in both conditions, due to boredom (easy condition) or task abandonment (challenging condition). Thus, while the easy and challenging tasks were intended to reflect conditions of low and high cognitive load respectively, the levels of load across the two tasks had similar effects. This situation precludes any clear conclusions from being drawn concerning the impact of cognitive load on INMI induction and motivates further enquiry into this question.

3.2 The Present Study

The main aim of the present study was to investigate the role of graded cognitive load on INMI induction following musical exposure. Drawing on working memory theory (Baddeley & Hitch, 1974; Baddeley, 2002) a paradigm including a dot counting task was designed which, according to the instruction given, involved (1) visual attention only, (2) visual attention and phonological memory, or (3) visual attention, phonological memory and executive control. These three tasks equated to conditions of low, medium, and high cognitive load and will henceforth be referred to as “Easy”, “Medium” and “Hard” conditions respectively. By comparing INMI occurrence and duration across these three conditions, as well as a “Baseline” condition in which there was no task, the hypothesis that INMI would diminish as cognitive load increased was tested. This paradigm would also allow a comparison of INMI with other spontaneous phenomena such as Involuntary Autobiographical Memories and mind-wandering which most commonly occur in low attention states (Ball & Little, 2006; Berntsen, 1998, 2009; Berntsen & Jacobsen, 2008; Mason et al., 2007; McVay & Kane, 2009; Schlagman, Kvavilashvili, & Schulz, 2007; Teasdale et al., 1995).

An additional aim of the present study was to introduce a novel method of probing participants about their INMI experiences in an indirect (covert) way, in contrast to previous INMI laboratory induction studies (Byron & Fowles, 2013; Floridou et al., 2012; Hyman et al., 2013) where, at the point of probing, participants were aware that INMI was the focus of interest because they were asked directly whether the music they had been exposed to have

been “stuck” in their mind. An indirect approach, where the participant is unaware of the study’s goals, is preferable to direct questioning regarding INMI and is more comparable to studies of involuntary memory related phenomena such as mind-pops, mind-wandering, and IAMs (Kvavilishvili & Mandler, 2004; Schooler et al., 2011, Vannucci et al., 2014), where individuals are asked about different types of memories or thoughts rather than about a specific type. As pointed out by Vannucci et al., (2014), the risks associated with the non-deliberate effects are that direct questioning can have (a) a suggestion bias effect, related to the induction of a voluntary memory because of the instructions in the study, (b) a priming effect on the content of the memory, and (c) a report bias effect related to individuals awareness of involuntary memories but only reporting the well remembered ones. In the present study, both a direct and an indirect approach to INMI probing were employed in order to allow comparison of the two methods.

3.3 Method

3.3.1 Participants

A total of 200 participants (116 female), ranging in age from 17-65 (*M* = 23.9, *SD* = 8.2) took part, either for course credit or £5. They were first year undergraduate psychology students or randomly selected students, staff or visitors of Goldsmiths, University of London.

3.3.2 Ethics Statement

The study protocol was approved by the Ethics Committee of Goldsmiths, University of London, UK. All participants gave written informed consent for their participation in the study.

3.3.3 Stimuli

For the music exposure, two original film trailers with prominent soundtracks were used. One film trailer that contained music with lyrics (film “Pretty Woman”, 1990) and one that featured instrumental music (film “Casino Royale”, 2006) were selected for variety and balance. The clips were matched in duration (approximately 90 seconds) and neither had any verbal content.

3.3.4 Material

A “Film Appraisal Questionnaire” (see Appendix 3.1) was developed, to measure participants’ familiarity, liking, engagement, and emotional response to different aspects of the film clips, using a 5-point Likert scale.

In order to probe indirectly for INMI experiences, a new “Mind Activity Questionnaire” was developed and used (see Appendix 3.2). This assessment method first probed participants about general mind-wandering (“Did your mind wander to any aspect of the film during the period of silence/while playing the dot game?”). If the answer was “yes” then the remaining questions prompted participants to report any visual, musical or speech-based mental imagery, respectively, that had occurred during the 5-min post exposure task. Information regarding non-musical imagery (visuals and speech) was requested in order to support the covert nature of the study and mask specific interest regarding INMI. Participants were also asked to estimate how much of the 5 minute time period had been occupied by each type of imagery (in percentage), to report the specific content of any imagery,

and to indicate the level of control they felt in the initiation of the imagery. For the last question a 7-point rating scale was used (1. “I deliberately generated this imagery” – 7. “The imagery happened outside of my control”).

For the direct paradigm (see Appendix 3.3) participants were asked if they had experienced any INMI during the silence period and if yes, they were also asked to report the percentage of time they had been occupied by the INMI as well as to identify the music (artist and/or title) that was experienced as INMI.

An online version of the “Mind Activity Questionnaire” was created for the indirect paradigm to capture participants’ thoughts in the 24 hours period after the end of the experimental session and the time they received the e-mail prompt to complete the questionnaire (Appendix 3.4). For the direct paradigm, participants received an email for an online questionnaire to capture INMI occurrence in the 24 hours after the experimental session.

3.3.5 Procedure

One hundred and sixty participants were randomly assigned to one of each of the four conditions (Baseline, Easy, Medium, Hard; 40 participants each). Participants were tested in groups and were told that the experiment was about “Films and Attention”. All participants watched both trailers (Pretty Woman and Casino Royale) with order of presentation counterbalanced. Immediately following each trailer, participants were given a “Film Appraisal Questionnaire” form to complete.

After filling in the Film Appraisal Questionnaire, participants completed one of the four 5-min post exposure tasks, which corresponded to their assigned cognitive load manipulation (Baseline, Easy, Medium, and Hard). In the Baseline condition, participants closed their eyes for 5 min and were alerted by the experimenter when the 5 min were complete. In the Easy, Medium, and Hard conditions participants engaged in a version of a 5-min dot counting task. All dot tasks involved the presentation of a single dot on a screen, one per 1 second (the pace of which did not match the beat of the film trailer music); either blue or red in colour. For the Easy condition (low cognitive load), red and blue dots were presented in strict alternation at the set rate of one per second and participants were asked to make a mark on their paper every time they saw a blue dot. At the end of the presentation they were asked to add up the total number of marks they had made and write the total on their response form. For the Medium condition (medium cognitive load), the red and blue dots were presented in random order and participants were asked to count the blue dots silently in their head (making no marks) and report the total at the end of the task. For the Hard condition (high cognitive load), red and blue dots were presented in random order and participants were asked to count backwards in threes from one thousand each time they saw a blue dot. At the end of this task participants reported the last number they had counted.

After all groups had completed the 5-min post-exposure task they were given the Mind Activity Questionnaire to complete in silence. Following the Mind

Activity Questionnaire, participants were asked if they knew the purpose of the experiment, and if so to volunteer details about the supposed aim.

In addition to these four conditions, a fifth group of 40 participants took part in the “Direct” condition, which was identical to the Baseline condition but instead of completing the Mind Activity Questionnaire, they responded to direct questions about their INMI, in a manner comparable to previous INMI lab induction studies. This allowed for a comparison of Baseline INMI rates between the more traditional direct questioning versus the novel indirect method.

Following either completion of the Mind Activity Questionnaire (N = 160) or the direct questioning regarding INMI (N = 40), participants were asked for consent to be contacted 24 hours later. Those in the Indirect conditions who gave consent received an online link 24 hours after the end of the experimental session, prompting them to complete the Mind Activity Questionnaire with respect to the content of their thoughts during the past 24 hours since the end of the testing session (indirect paradigm; responses received - Baseline: N = 7, Easy: N = 14, Medium: N = 12, Hard: N = 20). Once again participants were asked to report if they knew the purpose of the study. Participants of the direct paradigm were sent an online link asking them directly if they experienced INMI in the last 24 hours, how frequently and which tune (responses received – “Direct”: N=8). Finally, all participants were debriefed and compensated for their participation. A visual representation of the procedure can be seen in Figure 3.1.

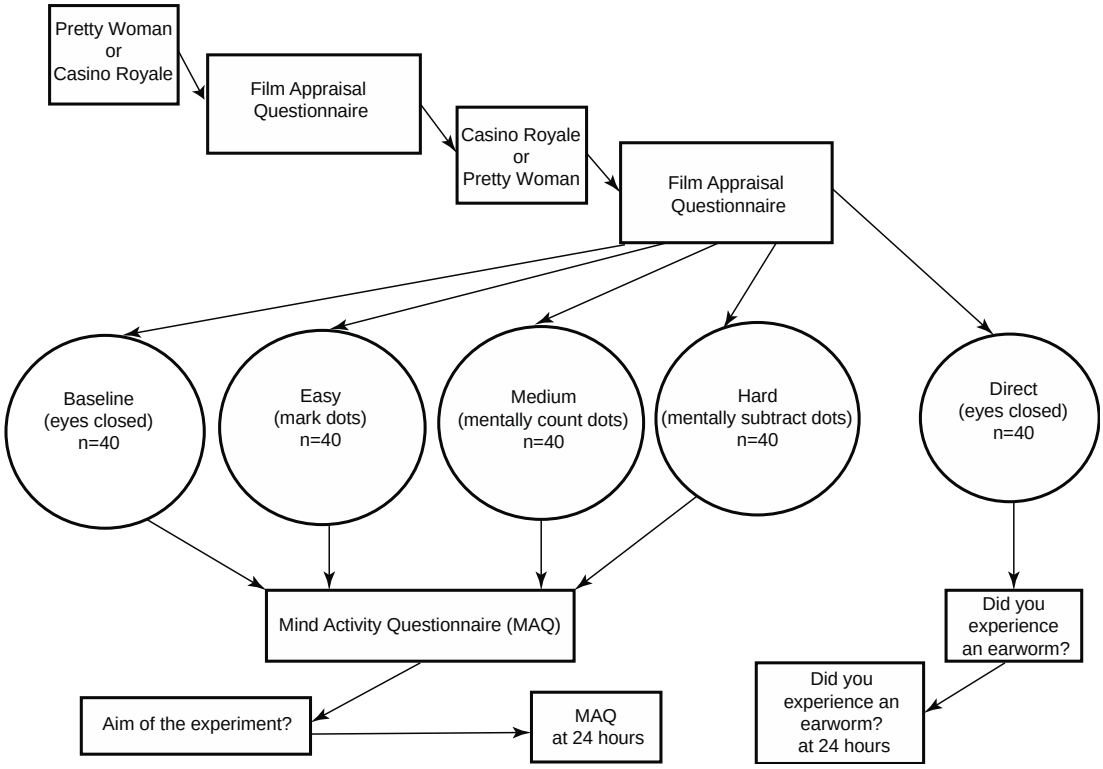

Figure 3.1. Visual Representation of the Experimental Procedure.

Experimental Checks

The three dot counting tasks were trialed in advance of the main study in order to confirm that they effectively manipulated cognitive load. Forty individuals who did not take part in the main study completed an online survey where they participated in all three tasks, in counterbalanced order (no film trailers were presented). After completing each dot task, participants rated two statements using a 5-point Likert scale to indicate how (a) challenging and (b) attentionally demanding they found each task. Two repeated measures ANOVA with a Greenhouse-Geisser correction indicated significant differences between all three conditions (challenge: $F(1.75, 68.27) = 52.47$, $p < .001$; attention: $F(1.61, 62.77) = 39.33$, $p < .001$). Post hoc tests

using Bonferroni correction revealed that the Easy condition was significantly different compared to the Medium condition (challenge: 1.80 ± .91 vs. 2.30 ± 1.18, p = .015; attention: 3.20 ±.91 vs. 3.70 ± 1.0, p = .024) and the Hard condition (challenge: 3.85 ± 1.23, p < .001; attention: 4.52 ±.784, p < .001). There was also a significant difference between the Medium and Hard conditions (challenge: 1.80 ± .91 vs. 3.85 ± 1.23, p < .001; attention: 3.20 ±.91 vs. 4.52 ±.784, p < .001). The same pattern was seen regardless of whether participants were rating tasks on level of challenge or attention required.

3.4 Results

3.4.1 INMI Occurrence

The data of primary interest for the experimental hypothesis came from the Mind Activity Questionnaire. Successful INMI induction was deemed to have occurred if a participant reported musical imagery during the 5-min post film session (or in the following 24 hours) where they experienced a lack of control in its initiation (rated 4 and above on the 7-point controllability scale). As a result a binary variable was created for successful INMI induction (yes=1) and unsuccessful INMI induction (no=0). In addition to this binary data, participants gave estimates of the percentage of time they had experienced INMI during the 5-min post-trailer period and also the title and/or artist of the music experienced as INMI.

Induction rate for the direct method was 60% versus 65% for the Mind Activity Questionnaire Baseline condition (indirect). INMI induction rates as

measured by the Mind Activity Questionnaire across the Easy, Medium, and Hard conditions were 32.5%, 25% and 20% respectively.

3.4.2 Effect of Cognitive Load on INMI Occurrence

Three binomial logistic regressions were performed to predict INMI occurrence using cognitive load (4 levels; Baseline, Easy, Medium, and Hard) as a predictor and a different reference category for the contrast each time (1^{st}=Baseline, 2^{nd}= Easy, 3^{rd}=Medium, 4^{th} = Hard). The model was statistically significant $\chi^2(3) = 21.13$, $p < .001$. This effect was driven by a difference between the Baseline condition and the other conditions (Baseline vs. Easy, $p = .004$; Baseline vs. Medium, $p < .001$; Baseline vs. Hard, $p < .001$). There were no significant differences between the Easy and Medium ($p = .46$); Easy and Hard ($p = .21$) or Medium and Hard conditions ($p = .59$).

3.4.3 Effect of Cognitive Load on INMI duration

A one-way between subjects ANOVA was conducted to compare the effect of cognitive load (4 levels: Baseline, Easy, Medium, and Hard) on INMI duration. The assumption of homogeneity of variance was violated; therefore, the Welch *F*-ratio is reported. There was a significant effect of cognitive load on INMI duration, $F(3, 159)=15.63$, $p < .001$, $\eta^2 =.14$. Post-hoc comparisons using the Games-Howell test showed that this effect was driven by a difference between the Baseline condition and the other conditions (Baseline: $M = 35$, $SD = 37.8$; Easy: $M = 15.13$, $SD = 27.9$, $p = .045$; Medium: $M = 7.90$ $SD = 20.3$, $p = .001$; Hard: $M = 10.50$, $SD = 26.8$, $p = .007$). There was no significant difference between the mean INMI duration for the Easy and

Medium (p = .55); Easy and Hard (p = .87) or Medium and Hard conditions (p = .96). A linear trend analysis on INMI duration confirmed the existence of a significant (negative) linear trend, $F(1, 156) = 15.63$, $p < .001$, $\eta^2 = .13$, indicating that as cognitive load increased, INMI duration decreased. The mean INMI duration in each condition and the linear trend can be seen in Figure 3.2.

3.4.4 Effects of Film Appraisal on INMI Occurrence

As part of the Film Appraisal Questionnaire participants were asked about their familiarity and liking for aspects of the film trailers including the visuals and the music, as well as their levels of engagement and emotional response. Binary logistic regression with ratings for both of the film trailers as predictors revealed that only one factor significantly influenced INMI occurrence as can be seen in Table 3.1; the degree to which participants reported liking the visuals of the first film they had seen (either Pretty Woman or Casino Royale) (p = .04) predicted reports of INMI occurrence. The more participants liked the visuals of the first film the more likely they were to report experiencing INMI for that music during the 5 min after watching that film clip. The same relationship was not observed for the second film in the order of presentation.

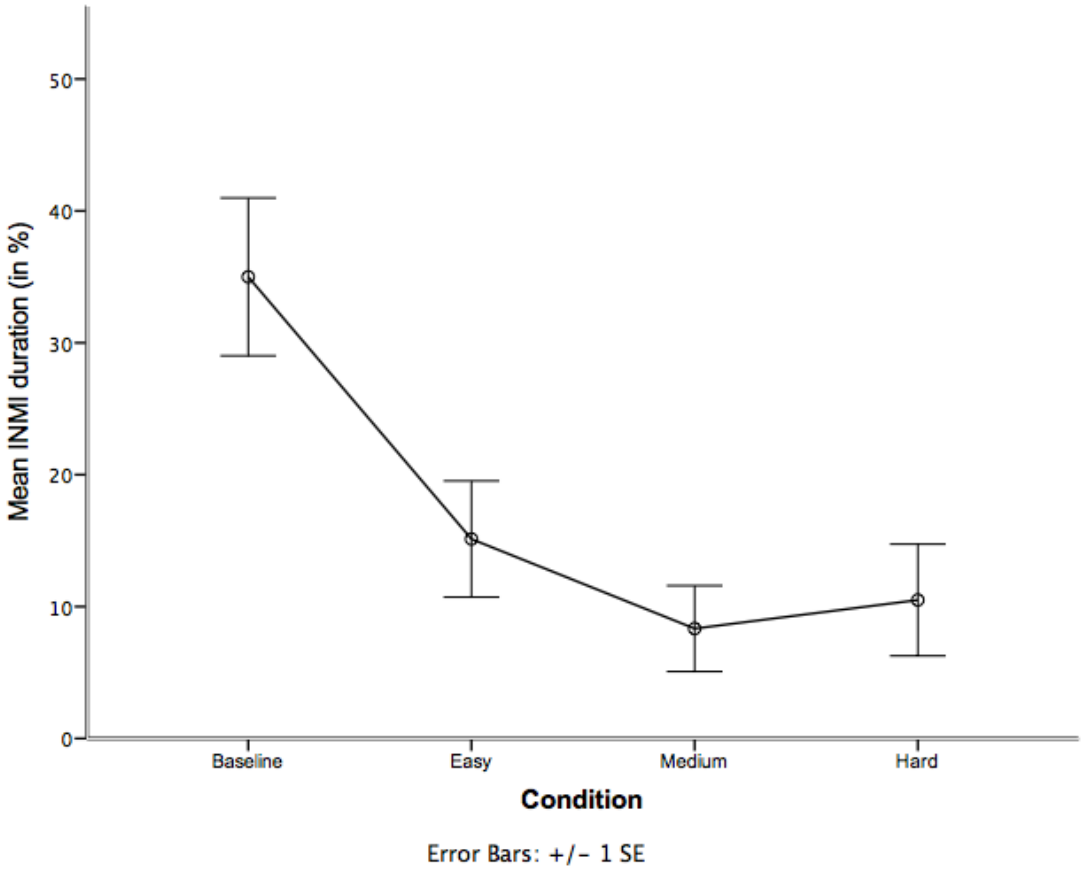

Figure 3.2. Mean INMI Duration (in percentage) in the 5-min Post Exposure Task for Each Condition.

3.4.5 Twenty-Four Hour Follow-up

In the follow-up study, 11 out of the 53 participants who completed the second Mind Activity Questionnaire (online version) reported experiencing INMI (21%). All of the INMI reports were related to the film trailers that had been viewed the previous day. Three binomial logistic regressions were performed to predict INMI occurrence in the following 24-hour period, similarly to the analysis on INMI occurrence in the lab. The model yielded no significant effect of cognitive load in regard to the 24 hour subsequent INMI occurrence $\chi^2(3) = 3.36$, $p = .34$.

Table 3.1

Coefficients of the Binomial Regressions Model with Film Appraisal Questionnaire Ratings as Predictors for INMI occurrence

		Estimate	SE	z-value	p-value
Film 1	(Intercept)	.66	.65	.49	.53
	Engagement	1.17	.23	.49	.49
	Emotional	1.13	.15	.63	.43
	Like.music	.96	.22	.04	.85
	Like.visuals	.62	.23	4.19	.04*
	Seen/know	1.14	.11	1.35	.25
	Heard/know	.99	.17	.00	.96
Film 2	(Intercept)	.68	.52	.53	.47
	Engagement	.87	.21	.46	.50
	Emotional	1.12	.14	.62	.43
	Like.music	1.32	.22	1.59	.21
	Like.visuals	.78	.22	1.32	.25
	Seen/know	.99	.12	.00	.97
	Heard/know	.90	.17	.38	.54

A chi-square test was run to test if individuals who reported experiencing INMI in the lab straight after induction would be more likely to experience it again in the 24 hour period after the experimental session. There was no significant association between INMI reported in the lab and occurrence of INMI 24 hours later, $\chi^2(1, N=53) = .784$, $p = .376$. This finding suggests that INMI can occur at any time after induction, but caution is needed with this result due to the small sample size of individuals concerned.

3.4.6 Type of Film Clip and Recency Effect

Post-hoc checks were performed to determine if presentation factors within the indirect paradigm revealed any systematic differences. A chi-square test of goodness-of-fit was performed to determine whether the two film trailers soundtracks (Pretty Woman vs. Casino Royale) were equally likely to be experienced as INMI. The data were not equally distributed ($\chi^2(1, N=65) = 4.5$, $p < .05$), indicating that the film music Pretty Woman was associated with a higher occurrence of reported INMI (41 times; 63.1%) compared to Casino Royale (24 times; 36.9%).

A second chi-square test was performed to test for the presence of a recency effect on INMI occurrence, whereby the music from the second film trailer was more likely to be reported as INMI (30 times; 69.8%) compared to the music from the first trailer (13 times, 30.2%). The data from the two presentation orders were not equally distributed, ($\chi^2(1, N=43) = 12.3$, $p < .002$), indicating a significant recency effect.

3.5 Discussion

Involuntary Musical Imagery (INMI) is usually reported in situations of low cognitive load (see Chapter 2, Floridou & Müllensiefen, 2015; Hyman et al., 2013; Liikkanen, 2012a; Williamson et al., 2012), similarly to Involuntary Autobiographical Memories and mind-wandering (Berntsen, Staugaard, & Sorensen, 2013; Mason et al., 2007; Mazzoni, Vannucci, & Batool, 2014; McKiernan, D'Angelo, Kaufman, & Binder, 2006; McVay & Kane, 2009; Shlagman & Kvavilashvili, 2008; Teasdale et al., 1995; Vannucci, Batool,

Pelagatti & Mazzoni, 2014; Vannucci, Pelagatti, Hanczakowski, Mazzoni, & Rossi Paccani, 2014). However, a recent empirical study (Hyman et al., 2013) found that INMI occurred at both low and high ends of a cognitive load continuum. A re-examination of the relationship between INMI occurrence and cognitive load was necessary to ascertain the impact of a graded cognitive load increase on INMI experience.

The present study employed a novel, ecologically valid INMI induction paradigm, based on previous INMI induction techniques (Beaman et al., 2015; Byron & Fowles, 2013; Floridou et al., 2012; Hyman et al., 2013), whereby participants were exposed to music. In the present paradigm the music was heard as part of two film trailers, in order to mask the musical nature of the study. The paradigm also used a novel method for covertly probing INMI experience, in contrast to previous approaches using direct questioning. The resulting Baseline of 65% INMI induction rate obtained compares favorably to previous rates reported in direct paradigms, which include 65% (Floridou et al., 2012) and 75% (Hyman et al., 2013). An exception to this pattern is the 32% direct induction rate obtained by Byron and Fowles (2013). This discrepancy could be attributed to experimental design. The present study probed for INMI while participants were still in the lab (as in Floridou et al., 2012 and Hyman et al., 2013) while Byron and Fowles' (2013) induction rate comes from post-experimental questioning. The rate they obtained as a result is, in fact, more comparable to the 24-hour INMI induction rate of 21% in the present study. This finding speaks to the decay rate of INMI in memory after music exposure.

The 65% Baseline induction rate obtained in the present study suggests that the INMI film induction paradigm functioned as an effective INMI trigger. It is notable that none of the participants guessed the aim of the experiment, owing to the covert nature of the paradigm, combined with the indirect questioning afforded by the Mind Activity Questionnaire. The occurrence of INMI cannot, therefore, be attributed to non-deliberate effects (Vannucci et al., 2015).

There are several additional positive aspects to the novel Mind Activity Questionnaire. The frequency of induced INMI reported was comparable to that obtained by direct questioning using the same film induction paradigm (65% indirect vs. 60% direct), suggesting that the Mind Activity Questionnaire would be effective for future studies as an INMI assessment tool in laboratory conditions where indirect probing would be critical, including for within-subjects designs and longitudinal work. Furthermore, the Mind Activity Questionnaire allows participants to rate their level of perceived control in the initiation of their musical imagery enabling researchers to differentiate between involuntary and voluntary musical imagery, and potentially to compare these two experiences. Another future advantage of the Mind Activity Questionnaire is that it might be used to compare INMI to other involuntary memory experiences, such as those associated with visual and speech imagery.

The main empirical findings from the present study relate to the comparison of INMI experiences across the indirect conditions (Baseline vs. Easy,

Medium and Hard conditions). It is evident that even a low level of cognitive load was sufficient to significantly reduce INMI occurrence in the present paradigm, as reflected in the significant difference in INMI rates in the Baseline versus Easy condition (65% versus 33%), compared to the much lower rates of INMI induction for the Medium and Hard conditions (25% and 20% respectively). Additionally, the significant (negative) linear trend that captured the reduction in INMI duration with increasing cognitive load is in accordance with reports from the INMI literature (Liikkanen, 2012a), and reports from the more general mind-wandering literature where Task Unrelated Thoughts (TUT) were significantly reduced when secondary tasks were high in load, and then increased consistently with lower cognitive load (Mason et al., 2007; Teasdale et al., 1993; Teasdale et al., 1995).

There is a contrast of note between the findings of the present study and the results of Hyman et al. (2013) who found a quadratic trend across two levels of load manipulation, whereby INMI occurred at both high and low ends of the cognitive load continuum. This discrepancy can be explained by the challenges associated with manipulating task-related cognitive load. One such challenge is maintaining a consistent level of load across a task. In the present study attention was required consistently throughout the 5 min post exposure period, in order to successfully perform the dot counting task; by contrast in Hyman et al.'s (2013) study, where either Sudoku tests or anagrams were used, it was not possible to guard against wavering attention as time elapsed. Additionally, wavering boredom/ anxiety induced by perceived levels of varying intra-task difficulty could be a factor. Since these

factors are impossible to control across each participant, there is a strong argument for the use of multiple cognitive load conditions (such as the four used in the present study), a task that requires constant focus, and the use of large participant samples.

It is notable that the Medium and Hard conditions placed additional demands on phonological processing compared to Baseline and Easy conditions due to the requirement to keep a mental count on the dots presented, and that these tasks were associated with the lowest INMI induction rates. This is interesting in view of past literature concerning the circumstances under which INMI may be suppressed or terminated. In a naturalistic study, using self-report data from INMI episodes experienced in daily life, Williamson et al. (2014) found that distraction via phonological-based tasks such as reading, word puzzles, and conversing were reported as effective in reducing or eliminating unwanted INMI. The similarity between suppression of INMI at the point of induction (i.e. the present study) and cessation (Williamson et al., 2014) leads to the hypothesis that INMI may have a cognitive origin within the phonological memory system. This hypothesis is also supported by Hyman et al. (2013), who found that verbal distractions (anagram task) lead to fewer INMI reports compared to visual distractions (Sudoku task). Future studies of this hypothesis would need to systematically manipulate the phonological content of secondary tasks to be tested at the point of INMI induction and as part of INMI cessation attempts.

In addition to the hypothesis regarding the impact of increasing cognitive load on INMI occurrence, post-hoc analysis was carried out to determine if INMI induction was affected by the choice of stimuli or method of presentation, in line with previous reports from the INMI literature. The film trailer that contained music with lyrics was reported as INMI on significantly more occasions compared to the film trailer containing instrumental music, a finding that is in accordance with comparable literature (Hyman et al., 2013; Liikkanen, 2012b). The recency effect observed in the present study is also in accordance with previous findings (Beaman & Williams, 2010; Byron & Fowles, 2013; Hyman et al., 2013; Floridou et al., 2012, Liikkanen, 2012b). Furthermore, the absence of any relationship between familiarity or liking of the music in the film trailers and INMI patterns of occurrence accords with reports that some music is reported as INMI after only one exposure, even when said music is disliked (Williamson et al., 2012). The lack of consistency between liking and familiarity effects and INMI is also in agreement with Byron and Fowles' (2013) report of a recency effect for unfamiliar music.

In summary, the present chapter has presented a novel paradigm for inducing and indirectly probing INMI experiences, as well as a method for modulating their likelihood of occurrence via systematic change in cognitive load. A direct relationship between reduced INMI occurrence and increasing cognitive load was demonstrated. Overall, the data suggest that even a slight increase in cognitive load is sufficient to prevent INMI, supporting the hypothesis that INMI occurrence relates to spare cognitive capacity.

Chapter 4. The Involuntary Musical Imagery Scale (IMIS)

Abstract

This chapter comprises three studies that delineate the development and validation of the Involuntary Musical Imagery Scale (IMIS) based on data from 2646 individuals. This new self-report inventory measures individual differences in INMI. The first study involved exploratory factor analysis, leading to the identification of a four-factor scale structure. The four factors are conceived as 'Negative Valence', 'Movement', 'Personal Reflections', and 'Help'. The second study confirmed this factor structure on an independent sample and derived indices of internal validity and test-retest reliability. The third study reports on IMIS correlates with existing measures of thinking style, imagery abilities, and music-related behaviors. Results showed that the IMIS measures a unique construct compared to existing self-report inventories. Furthermore, significant correlations were found with a combination of self-reported musical behaviors on the one hand and tendencies to engage in spontaneous thoughts on the other. Overall, these findings provide evidence that IMIS constitutes a reliable scale that captures and illuminates individual differences in INMI and that its first application reveals previously uncaptured associations between INMI and certain cognitive and behavioral traits.

4.1 Introduction

Despite the recent growth of INMI research, few studies have focused on individual differences beyond demographic and lifestyle factors. The small number of studies that have been conducted outside these basic areas focus primarily on personality factors, including the Big Five (Floridou et al., 2012), schizotypy, openness to experience, and thought suppression (Beaman & Williams, 2013), transliminality (Wammes & Barušs, 2009) and non-clinical obsessive-compulsive trait (Müllensiefen et al., 2014a).

One of the abovementioned studies, in particular, is notable since it involved the development of a Musical Imagery Questionnaire (MIQ) (Wammes & Barušs, 2009). This scale, based on the assessment of 67 individuals, was used to measure INMI presence and its relationship to transliminality, which refers to the susceptibility to and awareness of self-generated thoughts (Thalbourne & Delin, 1994). The authors identified six dimensions in the MIQ, namely Unconscious, Persistent, Entertainment, Completeness, Musicianship, and Distraction, and reported an association between transliminality and three of these factors (Unconscious, Persistent and Distraction). This questionnaire was valuable in aiding the identification of relationships between aspects of INMI experiences and individual differences, however the inclusion of items pertaining to non-spontaneous musical imagery and other musical behaviors in the scale means that it cannot be considered as a pure measure of the INMI experience.

Müllensiefen et al. (2014a) developed a questionnaire with an exclusive

focus on the INMI experience, in order to investigate associations with personality. This questionnaire was completed by 1787 individuals and factor analysis yielded a single factor, 'INMI disturbance'. This factor included items relating to the subjective valence of INMI experiences and the degree to which INMI episodes were considered disturbing. This study demonstrated an interesting correlation between scores on 'INMI disturbance' and high levels of (sub-clinical) Obsessive Compulsive Trait, but the presence of only a single factor in the scale suggests that the original questionnaire items were insufficiently broad to capture multiple aspects of the INMI experience.

The present study was conducted with the aim of developing and validating an improved questionnaire, which would capture multiple aspects of the INMI experience. So far the existing INMI related questionnaires, while informative, are either too broad or of too narrow focus to capture the multifaceted INMI experience. The existence of such a scale would allow the study of associations between distinct aspects of the INMI experience and (a) spontaneous but non-musical cognitions such as task-unrelated thoughts, (b) voluntary auditory imagery, and (c) musical background and behaviors.

4.1.1 Overview of the Studies

The present chapter presents three studies (referred as Studies 3a, 3b and 3c in this Chapter but as Study 3 throughout the rest of the thesis). Study 3a covers the development of the questionnaire items as well as an exploratory factor analysis to identify the scale factor structure. Study 3b validates the factor structure using confirmatory factor analysis on data from an

independent sample. Finally, Study 3c comprises a series of correlations between the new Involuntary Musical Imagery Scale (IMIS) and a range of existing inventories that assess thinking styles, auditory imagery abilities, musical, and nonmusical everyday behaviors.

4.2 Study 3a: IMIS Development

4.2.1 Method

First, a working definition of INMI was established: the experience of a short section of music that comes into the mind without effort (it is involuntary, i.e. it comes without any intention to retrieve or remember the music) and then repeats (immediately repeating at least once, on a loop, i.e. without consciously trying to replay the musical image). This definition is congruent with other working definitions of INMI (Liikkanen, 2012a; Müllensiefen et al., 2014a; Williamson et al., 2012) but more detailed directed to a general audience. The content of the short section of music could include lyrics and a full orchestration, or it could just be a single melody or a rhythm. This detailed definition was subsequently used to describe INMI to participants. Questionnaire item writing was informed by an extensive review of the INMI literature and existing scales/questionnaires. The most important and valuable information that was believed it would be interesting to measure was converted into an item to be used. In addition, information extracted from thousands of reports from individuals who were sending emails about their INMI experiences to the Music, Mind and Brain research group's email address, dedicated to INMI, as well as reports found in the pre-existing database of INMI reports from individuals who had completed in the past an

online questionnaire about their INMI experiences and also made personal comments about their experiences (see Müllensiefen et al., 2014a; Williamson et al., 2012; Williamson et al., 2014). Information was extracted based on a plethora of common beliefs, reactions, emotions, and behaviors individuals reported associated to INMI.

From the above studies and reports, a list of items was compiled covering reported aspects of the INMI experience. This list of 68 items (Appendix 4.1) formed the basis of the first version of the IMIS. A preliminary thematic analysis grouped these 68 items into 9 dimensions: “Intensity”, “Disturbance”, “Trigger”, “Match”, “Vividness”, “Valence”, “Content”, “Reaction”, and “Length”. For INMI “Length” a distinction was made between an INMI section (the length of the section of the musical phrase that is experienced) and an INMI episode (the period of time for which a musical phrase is experienced).

A 5-point frequency scale (ranging from Always to Never) was used for all 68 items, with an additional category of Not Applicable (N/A) in order to identify and exclude items that were not considered relevant by participants. A screening item was positioned at the beginning of the questionnaire to identify individuals who never experience INMI and therefore would not be able to complete the rest of the questionnaire (“I experience earworms”: Always-Never).

4.2.1.1 Participants

A total of 360 individuals (231 female; 3 people chose not to disclose their gender) ranging in age from 19 to 89 years (*M* = 47.61, *SD* = 14.81) took part

in Study 3a. These individuals had completed an online survey concerning INMI between 2010 and 2012 (http://www.earwormery.com) and had indicated their willingness to be contacted for future studies.

4.2.1.2 Ethics Statement

The study protocol was approved by the Ethics Committee of Goldsmiths, University of London, UK. All participants gave written informed consent for their participation in the study.

4.2.1.3 Material and Procedure

Participants were asked to fill out the new 68 item online questionnaire implemented in Qualtrics software (Qualtrics, Provo, UT). The questionnaire took about 10 min to complete.

4.2.2 Results and Discussion

An initial screening of the questionnaire indicated that 8 items had more than 5% of responses in the «Not applicable» option; these items were therefore excluded from the analysis. Four additional items were excluded because they were found to have a strongly skewed distribution. The remaining 56 items were carried forward for further analysis.

The initial exploratory factor analysis (EFA) based on the hypothesized 9 dimensions resulted in a shared variance of .32, while the scree plot of the factors' eigenvalues and a parallel analysis (Horn, 1965) suggested the

existence of 6 factors. This result indicated the need for further analyses in order to identify a coherent factor structure.

As a first step, 24 items were removed that showed only weak relationships with all other questionnaire items, as indicated by high uniqueness scores (> .50) and/or low communality scores (< .50). Thirteen items with low values on the anti-image matrix (< .70) were also excluded. This resulted in a total of 19 items remaining. A subsequent factor analysis on these 19 items using an oblique factor rotation yielded a four-factor model as suggested by the scree plot, parallel analysis, and the VSS criterion (Very Simple Structure; Revelle & Rocklin; 1979). The VSS criterion compares the fit of a number of factor solutions with the "simplified" loading matrix, that is, a matrix where only the c greatest loadings per item are retained and where c is taken as a measure of factor complexity. Four additional items were excluded from this solution because of their low loadings (<.5) and the model was then refit with the 15 remaining items. This final four-factor model explained .67 of the variance, with all factors having eigenvalues of > 1.

The next step in the analysis was to define appropriate labels for the four factors. Items that loaded on the first factor indicated a negative (vs. positive) evaluation of the INMI experience and for this reason the factor was labeled 'Negative Valence'. The second factor was related to the movement expressed while experiencing INMI and was labeled 'Movement'. The third IMIS factor concerned personal responses to INMI and was labeled 'Personal Reflections'. Finally, the fourth factor concerned the perceived

utility of the INMI experience and was labeled ‘Help’. Details of the four factors, their items and loadings, are presented in Table 4.1.

Table 4.1

Structure Matrix and Item Loadings for the Involuntary Musical Imagery Scale (IMIS)

	Negative Valence	Movement	Personal Reflections	Help
1. I try hard to get rid of my earworms	.85			
2. It worries me when I have an earworm stuck in my head	.64			
3. I find my earworms irritating	.87			
4. My earworms agitate me	.83			
5. The experience of my earworms is unpleasant	.85			
6. I wish I could stop my earworms	.79			
7. When I get an earworm I try to block it	.86			
8. The rhythms of my earworms match my movements		.78		
9. The way I move is in sync with my earworms		.87		
10. When I get an earworm I move to the beat of the imagined music		.74		
11. My earworms result from unresolved matters			.72	
12. Personal issues trigger my earworms			.78	
13. The content of my earworms mirrors my state of worry or concern			.80	
14. I find my earworms help me focus on the task that I'm doing				.84
15. Earworms help me when I'm trying to get things done				.83

The factor model represents a compact scale covering four different dimensions and 15 items in total (see Table 4.1) related to INMI experiences, which are not covered by any of the existing scales. Three items from the initial questionnaire relating to INMI Frequency and Length (section, episode) did not load on any of the factors. However, because of their individual importance when characterising the INMI experience they were retained as individual items in the subsequent questionnaire.

4.3 Study 3b: Confirmatory Factor Analysis and Test-Retest Reliability

The purpose of Study 3b was to confirm the four-factor scale structure suggested by the EFA (Study 3a), through a confirmatory factor analysis (CFA) based on a different sample of participants. In addition, a second aim was to establish the test-retest reliability of the IMIS scale (version 2) on a subset of participants from the same sample.

4.3.1 Method

4.3.1.1 Participants

A total of 2,671 individuals took part. Participants were recruited from our online databases derived from INMI studies (http://www.earwormery.com) or amusia (www.delosis.com/listening/home.html; only individuals who did not score in the amusic range), or were 1st year undergraduate psychology students who took part for credits in a “pen and paper questionnaire” session of a psychology module. Individuals who had never experienced INMI (n=29) or reported severe hearing impairments (n=356) were excluded. The final total of 2,286 participants (1370 female; 15 did not disclose their gender)

ranged in age from 17 to 81 (*M* = 42.6, *SD* = 13.5). Of these participants, 2,141 came from the online survey and 145 from the pen and paper version. A subset of the participants who completed the online survey were invited to take the questionnaire for a second time, following an intervening period of two months. In total, 649 participants (373 female), ranging in age from 19-74 (*M* = 45.71, *SD* = 12.22) took the questionnaire on both occasions.

4.3.1.2 Procedure

For the Confirmatory Factor Analysis purposes, participants received an email invitation to complete the IMIS (version 2) online or completed a pen and paper version. In both cases participants filled in additional questionnaires (reported in Study 3c). Completion of all the questionnaires took approximately 10-15 min.

Participants for the test-retest analysis received an email invitation approximately two months after the initial completion of IMIS (version 2). In addition to the IMIS they completed two new questionnaires (reported in Study 3c), which took around 10 min.

4.3.2 Results and Discussion

Confirmatory Factor Analysis and Internal Reliability: Four different factor models were assessed, each using the four factors identified in the EFA (Study 3a) but differing in the specification of the inter-factor correlations. The first model examined was the one previously identified in the EFA, which allows inter-factor correlations between all four factors. The second model

did not allow any factor inter-correlations, while the third model included a general factor subsuming the inter-factor correlations into one factor. The fourth model contained a general factor with loadings from all items while the items were also loading on one of the four factors. The first model that allowed for inter-factor correlations – as originally identified by the EFA – had the best confirmatory fit to the data (χ^2 = 819.99, *df* = 80) as can be seen in Table 4.2.

Table 4.2

Fit Indices for the Four Models Tested in CFA

	χ^2	RMSEA	CFI	SRMR	AIC	BIC
1st model	819.99	.06	.96	.05	891.99	1310.40
2nd model	2011.56	.10	.89	.15	2066.28	1310.40
3rd model	1098.5	.07	.94	.10	1166.5	433.55
4th model	851.35	.07	.96	.09	939.36	263.73

The internal reliability of the subscales associated with each factor was assessed using three different measures (Cronbach's α, MacDonald's omega total, and Guttman's lambda6). All the subscales showed good or very good estimates of internal reliability, as given in Table 4.3. Test-retest correlations of the four factors, which were found to be moderate to high (.65 to .79) and significant at the $p < .05$ level or higher are also given in Table 4.3.

Overall, the confirmatory factor analysis and the observed reliability coefficients indicated that the 15-item IMIS questionnaire possessed the required level of reliability and internal validity, justifying its use as a measurement instrument to assess individual differences in INMI experiences.

Table 4.3

Indicators of Reliability for the Four Factors of IMIS (n=2280) and Test-Retest reliability (n=649)

	Negative Valence	Movement	Personal Reflections	Help
alpha	.91	.88	.76	.84
omega.tot	.91	.88	.77	.84
G6	.9	.83	.69	.73
Test-retest	.79**	.66*	.65*	.65**

** $p < 0.01$ level.
* $p < 0.05$ level.

4.4 Study 3c: Correlates of the IMIS

Studies 3a and 3b were about the development of a scale (IMIS[2]) with four factors related to the INMI experience, while its structure was confirmed across samples and over time. Study 3c assessed correlations between the four IMIS factors, as well as items covering INMI Frequency and Length, with already validated instruments that capture potentially related thinking styles (spontaneous, task unrelated, intrusive, and repetitive), music-related behaviors, and voluntary auditory imagery abilities. Thus the overall aim of this study was to identify how the IMIS may be related to similar constructs.

4.4.1 Method

4.4.1.1 Participants

The same participants took part in Study 3b and the current study. It is noted that while all participants completed the IMIS, the collection of data was

[2] The IMIS materials, including the scale and the scoring sheet can be found online at: http://www.gold.ac.uk/music-mind-brain/imis/.

carried out across different samples and at different points in time, meaning not all participants completed all of the other questionnaires. Table 4.4 summarizes sample sizes for each of the additional questionnaires.

4.4.1.2 Materials

Questionnaires were selected that measure individual differences in (a) potentially related thinking styles, (b) voluntary auditory imagery abilities, and (c) general musical behaviors.

For thinking styles and everyday behaviors the following were selected: (1) the 'Mind-Wandering', 'Daydreaming Frequency', and 'Auditory Images in Daydreams' subscales of the Imaginal Processes Inventory (IPI; Singer & Antrobus, 1970); (2) the 'Intensity', 'Emotions', and 'Effectiveness' subscales of the Cognitive Intrusion Questionnaire (CIQ; Freeston, Ladouceur, Gagnon, & Thibodeau, 1992) and (3) the Obsessive Compulsive Inventory – Revised questionnaire (OCI-R; Foa et al., 2002). Two scales were selected in order to measure voluntary auditory imagery: (1) The Bucknell Auditory Imagery Scale (BAIS; Halpern, 2015) and (2) the Clarity of Auditory Imagery Scale (CAIS; Willander & Baraldi, 2010).

Finally, for musical behaviors: (1) The five subscales of the Goldsmiths Musical Sophistication Index (Gold-MSI; Müllensiefen, Gingras, Musil, & Stewart, 2014b), measuring 'Musical Training', 'Active Engagement', 'Perceptual Abilities', 'Singing Abilities', and 'Emotions'; (2) The 'Reactive

Musical Behavior' subscale of the Music Experience Questionnaire (MEQ; Werner, Swope & Heide, 2006).

4.4.1.3 Procedure

All participants followed the same procedure as detailed in Study 3b.

4.4.2 Results and Discussion

Given the gender bias of the sample (1,370 female, 901 male) a *t*-test was computed comparing the average INMI frequency ratings for females and males for significance. Although a significant difference was found suggesting INMI is more frequent in females ($t(2285) = -2.23$, $p = .026$), the effect size was very small ($d = .04$). Table 4.4 summarizes the correlations of the four IMIS factors and INMI characteristics with all the questionnaires used.

IMIS and INMI characteristics

'Negative Valence' (IMIS) was associated with INMI Length Episode ($r(2139) = .25$, $p < .05$). This relationship confirms previous findings that INMI disturbance is associated with the length of the episode (Müllensiefen et al., 2014a) and confirms that INMI disturbance is not related to the length of the musical section that is experienced ($r(2139) = .002$, p = ns). The correlation between INMI Frequency and all IMIS factors (except 'Negative Valence') indicates that individuals who experience more frequent INMI tend to move more with their INMI, find their INMI experiences to be related to their personal concerns and to be useful. The absence of a significant correlation between INMI Frequency and 'Negative Valence' (IMIS) fails to bear out the

commonly held view that prolific earworms are typically experienced as annoying, confirming the analogous findings of Liikkanen (2012a) and Müllensiefen et al. (2014a).

IMIS, INMI Characteristics, Thinking Styles, and Everyday Behaviors

All the IMIS factors, as well as INMI Frequency and INMI Length Episode, were significantly correlated with almost all the IPI subscales. In general, IMIS factors correlated with CIQ subscales except for 'Effectiveness' (in strategies to expunge the thought) and 'Movement' and 'Help' of the IMIS. OCI-R scores revealed significant relationships between two IMIS factors, 'Negative Valence' and 'Personal Reflections' and all OCI-R subscales, as well as total OCI-R score. This finding is in line with the relationship between high OC trait individuals and INMI disturbance as reported in Müllensiefen et al. (2014a).

IMIS, INMI Characteristics, and Auditory Imagery Abilities

No significant relationships were found between IMIS and the BAIS except for 'Movement' (IMIS) and 'Vividness' (BAIS: $r(143)= .25$, p=ns). CAIS showed significant but very low correlations (from $r(2139) = -.05$, $p<.05$ to $r(2139) = .07$, $p < .01$) with all the IMIS factors. These findings imply that there may be fundamental differences between voluntary and involuntary auditory imagery qualities.

Table 4.4 *Correlation Coefficients of IMIS and INMI Characteristics with the Goldsmiths Musical Sophistication Index (Gold-MSI), the Musical Experience Questionnaire (MEQ), the Clarity of Auditory Imagery Scale (CAIS), the Imaginal Processes Inventory (IPI), the Cognitive Intrusion Questionnaire (CIQ), Obsessive Compulsive Inventory – Revised (OCI-R) and the Bucknell Auditory Imagery Scale (BAIS).*

	Negative Valence	Movement	Personal Reflections	Help	INMI Frequency	INMI Length (Section)	INMI Length (Episode)
INMI Characteristics (n=2141)							
INMI Frequency	.03	.25**	.11**	.17**			
INMI Length (Section)	.002	.06*	-.003	.06*			
INMI Length (Episode)	.25**	.04	.06	-.06**			
Gold-MSI							
Musical Training (n=2141)	-.05*	.18**	.03	.07**	.13**	-.002	.01
Active Engagement (n=2141)	-.12**	.23**	.13**	.23**	.17**	.03	.01
Perceptual Abilities (n=649)	-.10*	.16**	.01	.11**	.24**	.11**	.16**
Singing Abilities (n=649)	-.07	.21**	.05	.15**	.26**	.09*	.14**
Emotions (n=649)	-.15**	.23**	.19**	.34**	.26**	.06	.12**
MEQ (n=2141)							
Reactive Musical Behavior	-.09**	.39**	.12**	.22**	.20**	.04	.09**
CAIS (n=2141)	-.05*	.06**	-.01	.07**	.08**	.04	.09**
IPI (n=2141)							
Daydreaming Frequency	.06**	.22**	.19**	.14**	.21**	.01	.14**
Mind-Wandering	.12**	.14**	.12**	.04	.17**	-.07**	.13**
Auditory Images in Daydreams	.05*	.28**	.18**	.22**	.26**	.10**	.14**
CIQ (n=2141)							
Intensity	.15**	.10**	.22**	.05*	.12**	.01	.11**
Emotions	.14**	.10**	.18**	.04*	.10**	-.02	.10**
Effectiveness	.11**	.02	.07**	-.04	.06**	-.03	.10**
OCI-R (n=649)							
Washing	.16**	.11**	.22**	.08*	.06	.05	.09*
Obsessing	.20**	.16**	.28**	.04	.09*	.002	.07
Hoarding	.14**	.07	.18**	-.01	.01	.04	.01
Checking	.13**	.07	.17**	.01	.05	.04	.02
Neutralising	.11**	.18**	.18**	.07	.08*	.02	.16**
Total	.20**	.16**	.28**	.05	.08	.04	.09
BAIS (n=145)							
Vividness	-.12	.25**	.16	.14	.23**	.06	.08
Control	-.01	.08	.04	.07	.13	.01	.12

** $p < 0.01$ level. * $p < 0.05$ level

IMIS, INMI Characteristics, and Musical Behaviors

'Active Engagement' (Gold-MSI) correlated with all IMIS factors, however 'Musical Training' (Gold-MSI) showed only low correlations with a subset of IMIS factors. This concurs with a similar finding reported in Müllensiefen et al. (2014a) and further contradicts anecdotal evidence that musicians experience more INMI compared to non-musicians. The only significant correlation ($r(2139)=.18$, $p < .01$) between the IMIS and 'Musical Training' (Gold-MSI) concerns 'Movement', which could be related to the fact that musicians have learned to respond through movement to music and, by extension, to INMI. In contrast, 'Musical Training' is not strongly associated with the other IMIS factors, which are more personal and subjective.

It is also important to note that although INMI Frequency is associated with all Gold-MSI subscales, it shows the lowest correlation ($r(2139) = .13$, $p<.01$) with 'Musical Training' and the highest ($r(647) = .26$, $p<.01$) with 'Singing Abilities' and 'Emotions'. This is in agreement with the report of Müllensiefen et al., (2014a) who found that 'Singing' is the only musical behavior to be related positively to the frequency of INMI experiences.

The factor 'Emotions' (Gold-MSI) is related positively to all IMIS factors and in particular to 'Help' ($r(647)=.34$, $p<.01$). This suggests a possible overlap in the roles of both real and spontaneously imagined music in regulating mood and emotions. Congruence between mood/emotion states and INMI was reported by Williamson et al. (2012) in their study of INMI situational antecedents but this is the first finding to suggest that INMI may regulate

these states as well as trigger them. The possible role of INMI as a form of regulation may extend to physical movement as well as psychological states. In the present study there were significant correlations between 'Reactive Musical Behavior' (MEQ) and all the IMIS factors, with the highest coming from 'Movement' ($r(2139)= .39$, $p < .01$). This relationship indicates similarities between physical responses to hearing real music and the experience of INMI.

IMIS Concurrent Validity

Findings that contribute to the concurrent validity of the IMIS come from the association of: (a) the 'Reactive Musical Behavior' subscale (MEQ) with the factor 'Movement' (IMIS: $r(2139)= .39$, $p<.01$); (b) all the IMIS factors (except 'Negative Valence') with the IPI subscales 'Daydreaming Frequency' (Movement: $r(2139) = .22$, $p < .01$; Personal Reflections: $r(2139) = .19$, $p < .01$; Help: $r(2139) = .14$, $p < .01$) and 'Auditory Images in Daydreams' (Movement: $r(2139) = .28$, $p < .01$; Personal Reflections: $r(2139) = .18$, $p < .01$; Help: $r(2139) = .22$, $p < .01$); and (c) CIQ subscales 'Intensity' and 'Emotion' with 'Personal Reflections' (IMIS; $r(2139) = .22$, $p < .01$; $r(2139) = .18$, $p < .01$).

4.5 General Discussion

The current chapter reports on the development of IMIS, a new self-report scale, which measures individual differences within the INMI experience. The four IMIS factors represent a range of behaviors, emotions, reactions and evaluations related to INMI. They also cover, confirm, and quantify aspects of

INMI that have been explored before in isolation, bringing them together in a single measurement instrument for the first time. The development of the IMIS factors has also permitted new insights into INMI, which are highlighted below.

'Negative Valence' (IMIS) measures the subjective evaluation of the INMI experience. The reported evaluation of INMI has proven diverse in the literature, ranging from pleasant and neutral (Beaman & Williams, 2010; Halpern & Bartlett, 2011) to annoying and disturbing (Hemming, 2009; Williamson et al., 2014). This situation is likely to be a consequence of the different ways in which people have been asked about their subjective responses to INMI in the various studies. Therefore, this IMIS factor provides the potential for a more consistent picture regarding subjective responses to INMI in the future.

'Movement' (IMIS) reveals a new aspect of INMI related to embodied responses, one that has not yet been reported in the INMI literature but existed only as an implication in previous studies. Beaman and Willliams (2010) found that the chorus is the part of a song most often experienced as INMI, which usually contains a catchy "vocal hook" (Kachulis, 2005; Van Balen, Burgoyne, Bountouridis, Müllensiefen, & Veltkamp, 2015). Furthermore, Müllensiefen et al., (2014a) reported an association between 'Singing' and the length of INMI episodes. These findings contribute to the understanding of the embodied responses in the INMI experience. In addition, similar findings relating musical imagery to the sensation or

instigation of movement come from research on music listening (Werner, Swope & Heide, 2006) where a factor measuring a similar behavior has been reported ('Reactive Musical Behavior': MEQ). This result suggests potential for overlap in embodied responses to hearing real music and experiencing spontaneous INMI, a link that could be explored with both behavioral and neuroimaging studies.

'Personal Reflections' (IMIS) represents a personal quality associated with INMI. The personal quality can be related to the INMI trigger or its content, but it is important to note that 'Personal Reflections' constitutes a separate component of the INMI experience that is not directly related to its subjective evaluation (valence), as indicated by the results of the factor analysis. This finding is in accordance with studies on task-unrelated thought (Klinger & Cox, 1987; Klinger, 2008; Andrews-Hanna, 2012; Smallwood, Fitzgerald, Miles & Phillips, 2009), which found that a large amount of spontaneous thoughts centers on personal concerns and unresolved matters.

The last IMIS factor, 'Help', comprises the beneficial and constructive aspects of INMI experiences. Throughout the literature INMI has been described as (un)pleasant, annoying, and disruptive (Beaman & Williams, 2010; Halpern & Bartlett, 2011; Hemming, 2009; Williamson et al., 2014) but never as helpful. The finding that INMI can actually be perceived as a supportive experience on some occasions but disruptive on others concurs with background music studies, which have shown that music listening can have beneficial effects (Cassidy & MacDonald, 2007, Kang & Williamson,

2013; Schellenberg, Nakata, Hunter, & Tamoto, 2007) but also disruptive consequences (Avila, Furnham, & McClelland, 2012; Schellenberg, 2012) on task performance depending on the type of music (Jäncke, Brüger, Brummer, Scherrers, & Alahmadi, 2014; Judde & Rickard, 2010; Rickard, Wong & Velik, 2012), personality (Furnham & Allass, 1999) or the level of neurophysiological arousal related to music (Furnham & Strbac, 2002; Jones, West & Estell, 2006). This result is also in accordance with studies on task-unrelated thought that demonstrated beneficial (Baird, Smallwood, & Schooler, 2010; Franklin, Mrazek, et al., 2013) but also disruptive effects of the experience (Cheyne, Solman, Carriere & Smilek, 2009; Mrazek, Smallwood & Schooler, 2012; Smallwood et al., 2004a). The factor 'Help' (IMIS) could therefore potentially reflect similarities in the attributes of unfocused music listening, INMI, and task-unrelated thought.

Strong associations were observed between INMI and task-unrelated thought. For example, all the IMIS factors and INMI frequency were associated with measures of mind-wandering (IPI), daydreaming (IPI), and musical behaviors (Gold-MSI, MEQ). This result concurs with previous findings that captured analogous relationships with self-report measures of musical and general activities (Hyman et al., 2013; Liikkanen, 2012a; Müllensiefen et al., 2014a; Williamson et al., 2012), thereby linking task-unrelated thought and music behaviors with the INMI experience.

In summary, IMIS is a novel, reliable and validated instrument that allows for systematic measurement of multiple and distinct aspects of the INMI

experience. The scale will be of use to researchers who aim to understand the origins of the INMI experience, as well as the commonalities and differences between INMI and other forms of spontaneous cognition, in terms of phenomenology and possible function.

Chapter 5. Involuntary Musical Imagination: An Interview Study About Novel Involuntary Musical Imagery

Abstract

The previous chapters explored the relationship between INMI and various aspects of spontaneous cognition. This last chapter focuses on the relationship between INMI and creative cognition which, as described in the Introduction, is assumed to stand between goal-directed and spontaneous thought. So far this thesis has focused on familiar INMI, while this chapter explores for the first time novel INMI, i.e. involuntary, repeated musical imagery, which to the best of the individual's knowledge has never heard before. To study this phenomenon, a semi-structured interview was conducted with 6 composers. Based on grounded theory two models were developed, one regarding the phenomenology of novel INMI and the other about how this experience is translated to an external outcome relating to composition. Results from this study confirm previous findings on familiar INMI, creative, and spontaneous cognition and extend our understanding of this unique type of creative musical imagery.

5.1 Introduction

Musical imagery is a crucial part in the creative process of musicians, but so far this relationship is understudied. The vast majority of research on creative cognition has focused on visual imagery (Campos & Gonzalez, 1995; Forisha, 1981) and, although it has improved our understanding of the creative aspects of mental imagery, it has a distinct visual bias. The small number of studies conducted on musical imagery has mostly focused on how the latter may improve musical performance (Brodsky, Henik, Rubinstein, & Zorman, 1999; Mellet et al., 1998; Kosslyn et al., 2001) and on its relationship to perception in professional musical life (Bailes, 2002). To the best of my knowledge there are no studies focusing specifically on spontaneous, novel musical imagery, which repeats in the mind of the composer i.e. “novel INMI”.

In the literature there are widespread reports of ‘novel’ INMI which can be defined as INMI involving music that an individual believes is unfamiliar meaning that to their best of their knowledge they have never heard before (Bailes, 2007; Liikkanen, 2012a; Wammes & Barušs, 2009; Williamson & Jilka, 2013). Nevertheless it is more common to experience familiar rather than unfamiliar or novel music as INMI (Liikkannen, 2012a; Hyman et al., 2013; 2015) and research that aims to induce INMI has mostly used familiar music (Hyman et al., 2013; Floridou et al., 2012; Liikkanen, 2012b).

How might novel INMI arise? Wammes and Barušs (2009) reported 2 items related to the experience of novel musical imagery based on the “Musical Imagery Questionnaire” they developed, one related to waking states and

one to dreams. These items loaded in the Unconscious factor of MIQ, something that the authors attributed to the individual being unaware of the INMI source. A more explanatory conclusion about where novel inner music comes from is given by Williamson and Jilka (2013), who found that, over time, extemporizations may be added to familiar INMI, which could explain novel INMI occurrence as arising from a memory but developing into a new musical form.

Novel INMI is associated more with musicians than non-musicians (Liikkanen, 2012a) and is assumed to be part of creative cognition. Famous musicians such as Beethoven, Schuman, and Mozart reported "hearing" novel music in their "mind's ear", which they used in their compositions (Agnew, 1922). However, whether these episodes of "hearing" music were repeated or not, so that they could be characterized as INMI, is unknown. So far the only information relates to the existence of individuals who experience novel INMI and where the latter may come from, but no further details are known.

Previous studies have shed light on the links between spontaneous and creative cognition. Reported similarities between these two phenomena relate to the reduced cognitive control required for both (Fink & Neubauer, 2006; Razumnikova, 2007), the brain networks (such as the default mode and memory networks) activated in both (Jung-Beeman et al., 2004; Kounios et al., 2006) and the patterns of biochemicals released (Chamberlain, Muller, Blackwell, Robbins, & Sahakian, 2006; Heilman, Nadeau, & Beversdorf,

2003). Since the relationship between spontaneous cognition and INMI has been already established in the previous chapters, a logical next step is to investigate novel INMI and its relationship to creative cognition, which is assumed to stand between spontaneous and goal directed thought. In this study, novel INMI will be explored in two stages based on the creative cognition approach (Finke et al., 1992; Ward et al., 1999): (1) the experience of the generation of a novel idea, in this case the novel INMI occurrence, and (2) the appropriateness of the creative product, in this case the externalization of the novel INMI as music.

5.2 The Present Study

This study has been motivated by the lack of information about novel INMI in the literature, in a first attempt to bridge this gap. The aims of the present study were (1) to describe the phenomenological aspects of the novel INMI experience and how it contributes to the generative phase of creative thought and (2) to explore how the internal experience is translated to an external experience, i.e. music. This study is based on interviews with 6 music composers. It was hypothesized that the experience of INMI will be more prevalent among composers compared to the general population since musical imagination is a crucial aspect of their activity.

A semi-structured interview was the preferred method since it overcomes many of the limitations of a survey by permitting a personal and adaptable form of data collection in the investigation of a previous unexplored phenomenon. Because the study was not driven by specific hypotheses and

was exploratory in nature, seeking new information, data were analysed using Grounded Theory in view of the advantages that this method provides for under-studied topics such as novel INMI, and also because of the method's suitability for looking for regular patterns within the data in order to develop emergent theories (Bryant, 2002; Glaser, 1978, 1992, 1998, 2001; Martin & Turner, 1986).

5.3 Method

5.3.1 Participants

A total of 6 individuals took part in the interview, ranging in age from 20 to 35 (*M = 25, SD = 3.6*). F1, F2, and F3 were female and M1, M2, and M3 were male. Three participants (M1, M2, and F2) stated that they experience novel INMI infrequently (1-3 times a week) and the other three (M3, F1, and F3) very often (several times a week-several times a day). All participants except F1 were students of Goldsmiths, University of London and all but F2 were studying music. F1 is a professional musician and F2 is an undergraduate psychology student who also works as a composer. Their scores in the Musical Training factor of the Goldsmiths Musical Sophistication Index (Gold-MSI; Müllensiefen et al., 2014b) were between 39 and 49[3], indicating a highly musical sample.

Four participants (F3, M1, M2, and M3) replied to an advertisement, distributed at Goldsmiths, looking for people who had experienced novel

[3] Note. Estimated population mean is 26.52 based on a sample of 147,633 participants who took part in a large online survey by BBC Lab UK (Müllensiefen et al., 2013b)

tunes repeatedly in their mind. F1 and F2 replied to an email sent directly by the researcher asking them if they experience novel INMI. All but one participant received monetary compensation.

5.3.2 Ethics Statement

The study protocol was approved by the Ethics Committee of Goldsmiths, University of London, UK. All participants gave written informed consent for their participation in the study.

5.3.3 Material

The initial step was the development of the questions (Appendix 5.1). The main body of the interview was in two parts. In the first part, participants gave general information about the music they compose and experience as INMI.

The second part of the interview focused on their novel INMI experiences. The first questions were related to the experience of the generation of the new idea and were related to: (1) the frequency of novel INMI (How often do you experience novel INMI?) to see how regular it is, (2) the activities they are engaged in when they experience it (Can you give me some examples of what kind of activities you're engaged in when you get novel INMI?) to explore the cognitive capacity the moment of the occurrence, (3) the sense of familiarity with the tune (Do you have a sense of something familiar but not known is experienced when you experience the novel INMI in your head?) to investigate the idea that extemporizations may be added to familiar tunes, (4) the feelings they have when they experience it (How would you describe the

emotions that you feel or the mood you're in when experiencing that phenomenon, the moment of insight?), (5) the form the novel INMI usually takes (What kind of musical structure is the novel INMI usually? e.g. only melody? Only chord sequence? Sounds? Full song?), and finally (6) the role of repetition (Is the element of repetition useful in any kind of way? How would you describe it?). The remaining questions were about the externalisation of novel INMI into music and were about (1) the way they capture them (Can you describe to me how you capture them? E.g. i-phone app, instrument) and (2) the level of difficulty in externalising the novel INMI (Are there times when what you have in mind can't be actually recorded/played?).

The interview schedule was the same for all participants, however because of the semi-structured nature of the interview, additional questions arose for each interviewee depending on the flow of the conversation. The questionnaires employed included (1) the IMIS (Involuntary Musical Imagery Scale; Floridou et al., 2015, see Chapter 4), measuring a range of emotions, behaviors and evaluations towards INMI ("Negative Valence", "Movement", "Personal Reflections" and "Help") as well as INMI frequency and length and (2) the Goldsmiths Musical Sophistication Index (Gold-MSI; Müllensiefen et al., 2014b), measuring all 5 factors ("Musical Training", "Active Engagement", "Perceptual Abilities", "Singing Abilities", and "Emotions").

5.3.4 The Interview

Two researchers conducted each interview session. The interview started

with an introduction about who the researcher was and some general information about INMI and novel INMI. To confirm that the participants had understood the latter concepts, they were asked to describe back to the interviewer the difference between INMI and novel INMI and to give examples of each. The interview continued once a clear definition was understood. Then they were asked for permission to film/record the interview and to transcribe it later rather than keeping notes during its course.

One researcher was responsible for leading the discussion and the other was filming the interview and waited until the end to ask any additional questions which arose as a result of the interview. At the end of each interview participants completed the IMIS (Floridou et al., 2015) and the Gold-MSI (Müllensiefen et al., 2014b). Interviews lasted between 40 and 90 min and were recorded and filmed.

5.3.5 The Analysis

The first step in the analysis of the interview data was to transcribe the audio recordings of each participant to text. Transcriptions were divided in two parts. The first part included the answers related to influences on composition, composition techniques, and familiar INMI. The second part, which was considered as the body of the interview, included the answers on novel INMI. The text was coded by two researchers, using the Grounded Theory analysis method, which was based in work of Charmaz (2008) and a series of studies by Williamson (Williamson et al., 2012; Williamson & Jilka,

2013; Williamson et al., 2014) who has investigated different aspects of familiar INMI.

The analysis followed three stages (Glaser & Strauss, 1967; Strauss & Corbin, 1990): (a) open coding, which involved reading transcripts line-by-line and identifying and coding the concepts found in the data into “themes”, (b) axial coding (i.e., organizing the concepts and making them more abstract), and (c) selective coding (i.e., focusing on the main ideas, developing the story, and finalizing the grounded theory)

According to this method, and to guarantee consistency across the large amount of data, first, one researcher conducted the initial open line-by-line marking of the text and created codes, classifying the answers to each question of the interview, to summarize the large amount of data in a few words (Charmaz, 2008). The remaining stages of the analysis were shared between the researchers and aimed at achieving consensus so as to minimize individual biases in interpretation. They worked with the codes independently, but at the same time and location, looking for emerging themes and subthemes on novel INMI phenomenology. Dominant themes were based on the interview questions and were presented with one or a few words, while subdominant themes were representing the range of categories answering each question and were also summarized in a few words. In some of the subthemes further subcategories were also developed. In the second stage, the two researchers compared the themes they generated and the links they had developed, explaining and justifying them according to the

data. In case of any disagreement, the researchers mostly consulted a dictionary (as this was mostly a language issue since both of the researchers are bilingual) or an external subjective observer or tried to find literature which supported one theme against the other. In the final stage, researchers combined the themes they generated; they revised them after a week and developed the final theory and models based on memos they were sharing throughout the analysis (Charmaz, 2008), finally coming up with the visual representations shown in the Results section (Figures 5.1 and 5.2).

5.4 Results

The results are presented in 2 sections: First, General “INMI information” that comes from questionnaires and an additional question from the interview, and second the results from the main body of the interview focusing on “Novel INMI phenomenology” and presented as (a) internal experience and (b) external experience.

5.4.1 General INMI Information

All participants had experienced INMI and were able to identify it and its difference from novel INMI when asked by giving examples for both of the phenomena to the researcher. The Involuntary Musical Imagery Scale (IMIS) scores, information about frequency and length of familiar INMI as well as the frequency of personal compositions experienced as INMI for each participant are shown in Table 5.1.

Table 5.1

Participants' IMIS (Involuntary Musical Imagery Scale) Scores, Frequency and Length of Familiar Music, and Frequency of Personal Compositions Experienced as INMI.

	Participants					
Measure	M1	M2	M3	F1	F2	F3
IMIS						
Negative Valence	7	8	21	7	8	10
Movement	9	5	15	12	13	11
Personal Reflections	7	6	5	5	9	9
Help	6	6	2	5	5	8
INMI						
Frequency	Once a week	Several times a week	Several times a week	Several times a day	Several times a week	Several times a day
Length: Section	5-10 sec	>1 min	5-10 sec	5-10 sec	<2 sec	5-10 sec
Length: Episode	1-3 hours	½ - 1 hour	½ - 1 hour	1-3 hours	1-3 hours	10-30 min
Personal compositions as INMI	Not very often	Often	Sometimes	Sometimes	Everyday	Quite often

5.4.2 Novel INMI Phenomenology

5.4.2.1 Internal Experience

The first model presents 5 dominant themes centered around the basic theme of novel INMI and shows phenomenological aspects that characterise the onset of the experience and qualities of the inner music and of the subjective experience. Below dominant themes will be presented in bold italics and subdominant themes in italics. Dominant themes represent the interview questions related to different aspects of the experience and are numbered as follows: (1) ***Mental and Physical States****, (2)* ***Feeling****, (3)*

Familiarity**, (4) **Form,** and (5) **Repetition**.* Subdominant themes represent the main categories answering each question and in some cases they include subcategories (e.g. ***Form). For each subtheme an example will be given from a participants' statement. A model of the dominant themes and their relationship to subdominant themes can be seen in Figure 5.1.

1) Mental and Physical States – Situations when Novel INMI Occurred

The activities which the participants were engaged in when novel INMI occurred were related to a range of ***Mental and Physical States***. Three subdominant themes emerged: *Low Attention States, Self-Conscious, and Repetitive Movement.*

In the case of *Low Attention States*, 3 participants reported that novel INMI occurred when they were not fully engaged in the activity they were doing:

> M3 – "When I'm doing something in which I have to be rationally engaged it doesn't happen. If I have some degree of automation, it will start."

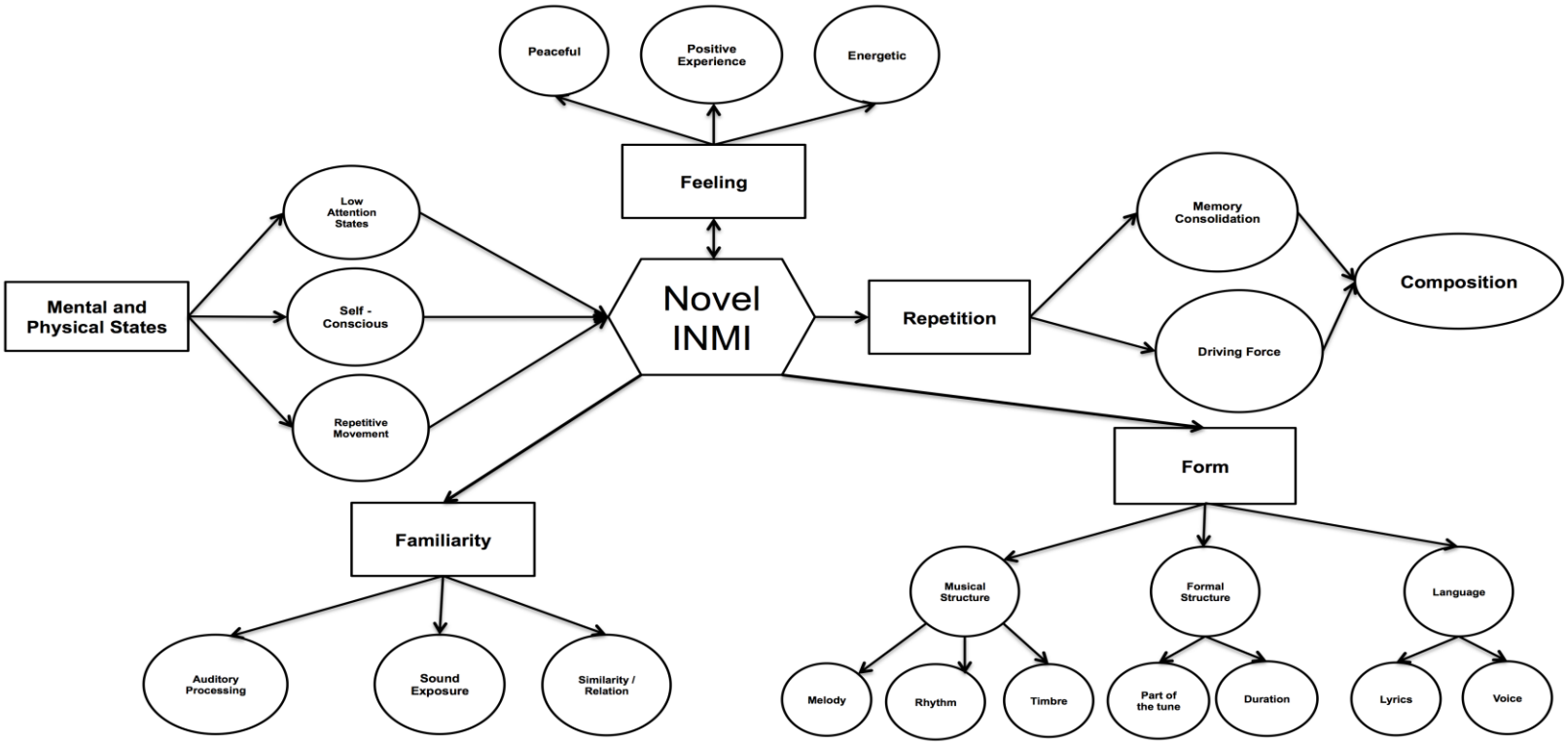

Figure 5.1. Visual representation of the phenomenological aspects of the novel INMI experience. Dominant themes are represented by squares, subdominant with circles and basic themes of novel INMI with diamonds. Single directional arrows indicate hierarchical links while bidirectional arrows illustrate reciprocal relationships.

In most cases participants described situations in which they were also *Self-Conscious*, i.e. feeling they were connected with themselves:

M2 – “I think it is more like connecting to your inner self. It is more like having the space to.”

M3 – “It’s to do with your capacity, at the moment your mental availability to put lots of effort and focus at the right moment. If you have it maybe you can do lots of complicated things. And grab it and put it down.”

Another subtheme which emerged was that of activities, specifically relating to *Repetitive Movement,* where the participants describe that the onset of the novel INMI is associated to activities characterised by moving in a repetitive way:

F3 – “When I went away, I would be constantly having these things going around in my head, because I was in my own a lot, and I was walking, or swimming or doing something quite repetitive.”

2) Feeling – How the Novel INMI Experience Would Make Them Feel

Participants were asked to identify the ***Feeling*** they experienced once the novel INMI occurred. In some of the cases, instead of describing their ***Feeling*** at the moment the novel INMI occurred, they reported how the

Feeling of the novel INMI would affect them and make them feel. Within this dominant theme three subthemes are identified.

All participants except one ascribed a positive evaluation towards the novel INMI, labeled as a *Positive Experience*:

F2 – “It is a very positive experience. I think it is just a quite wonderful thing you can have. You have these sounds in term of sounds and constructing as well, which is in both senses both of novel and a normal INMI”

The other ***Feeling***-related subtheme participants described was that of being *Peaceful*:

M1 – “It’s like a little glimpse of stillness really even if I don’t know if I can stay still…”

At the other end of the arousal continuum, the subtheme of being in an *Energetic* mood emerged:

M3 – “In the majority of times because I’m walking it just feels great. It’s really, a very strong driving power. I’ll start probably walking like a lunatic but well that’s another thing.”

Another theme, which can be seen in the model as represented by the bidirectional arrow connecting *Novel INMI* and ***Feeling***, was that of an interaction between the emotion which the novel INMI conveyed and how it was making the participants feel. The opposite relationship was also reported, where the mood of the participant at the moment the novel INMI occurred would affect the mood of the novel INMI:

F3 – “But, saying that, maybe the melodies that come in to my head, these little things are, dependent, you know they change depending on my mood, like it might be like a nice little happy thing that goes around around around if I am in a particularly good mood.”

M1 – “I feel each thing as a mood. Hmmm each different melody has its own mood and I’m.”

3) ***Familiarity* – Whether the Novel INMI Experience can be Identified as Familiar.**

One of the key aspects of novel INMI is that the endogenous musical pattern experienced is original. When participants were asked about elements of familiarity in the novel INMI, all but one (see M1 below) identified a familiar sense.

M3 – “So yeah familiarity. I feel it when I have the newest idea of mine. It feels like it’s part of something already. Like it’s part of a piece I haven’t done yet but I already know it’s going to be, how is it going to be.”

M1 – “Yeah, it’s very new. It can be. Ohh it’s definitely, it’s always new. It’s never like a twist on something else. It’s always something completely fresh and friendly.”

A subdominant theme on how the sense of ***Familiarity*** is explained is that of previous *Sound Exposure*:

F2 - “It would be something that you heard before I guess so yeah. Belonging feeling. But I wouldn´t be able to articulate or identify it”

In one case a sense of *Similarity/Relation* was identified which contributed to ***Familiarity***:

M3 - “So everything that comes to my head that is sticky enough to stay has strong relations with everything of that I know. A completely unrelated thing would never be an earworm to me”

In other cases more detail was given regarding *Auditory Processing* following *Sound Exposure*:

M2 - “I mean it is like an aural reanalysis, analysis of your perceptions…. It´s our perception brings the data inside, and the brain processes it.”

4) Form – Reports on the Parameters Which Describe the Novel INMI

All participants predominantly reported the *Musical Structure* of the Novel INMI, resulting in three subcategories, namely *Melody, Rhythm, and Timbre.*

M1 – “Ok so they normally come to me as a melody line. Pretty much just the melody.”

F3 – “Yeah, so I´ve had like a beat, like literally just like beat, but I am really bad. The thing about beats is that I cannot do beats, like if I get a beat in my head, I have no idea how to like put that down.”

*F3 – “*And I´ve had it with cello, I had cello melodies, like the cello was playing that I could hear it playing over and over again, and it was like someone turning down the volume when it went away, and then turning it up again”

Technical aspects of the tune, such as the specific *Part of the tune* that was experienced and the *Length* of the novel INMI, comprised the subdominant theme of *Formal Structure*:

F1 – “Usually a refrain. The refrain will come in first and then you build something around it. But it’s usually the refrain. The catchiest part of the song comes to the mind first.”

F3 – “Em, and they are very short, and they will be really short and then I start singing it to myself and I just stay, yeah.”

A final subdominant theme within ***Form*** was that of *Language.* Participants reported a linguistic aspect describing their novel INMI either related to *Lyrics* or *Voice*:

F3 – “I guess, probably just hear when it´s novel, it´s usually just like me sing it to myself in my head”

F2 – “But that would be lots of string sounds and nice conflowing rhythms, and there has been a voice sometimes.”

5) ***Repetition*** – Reports on how repetition within the novel INMI is perceived and why it is useful

All participants but one stated that repetition is beneficial for *Memory Consolidation* purposes:

M2 – “So like, because it´s looped you don´t forget it. And this is, this might be one of the reasons why it is looped because your brain knows that you will forget it, otherwise. And I do forget my earworms if they don´t loop. But it´s not voluntary, it just happens.”

Two participants reported that repetition had a *Driving Force* effect on them.

M1 – “The more repeatable an earworm is, the more it drives you to compose and get it out of you”

5.4.2.2 Musical Outcome

At this point I focus on how novel INMI is translated from an internal to an external experience as a musical outcome and to the accuracy of the externalization, whether in the capturing method or in the composition. The model in Figure 5.2 represents this process.

1) Capture – the Means Used to Capture Novel INMI

The most prevalent way of capturing novel INMI is by recording it on the *Phone.*

M2 – “Yeah, with an iPhone it´s so much easier with technology. Yeah, I use an iPhone these days.”

Another subtheme observed was that of *Manuscript paper.*

M1 – “I have a cute little book. I’ll just show you to know what I mean. And it’s just a manuscript paper.”

Another subdominant theme within the theme of ***Capture*** was the use of *Musical Instrument.*

F3 – “Sometimes I’ll play on the piano and just try remember it by playing on the piano and might not even write it down, but try to remember it on the piano”

2) ***Accuracy*** – On what the accuracy of the external version of novel INMI depends

All participants reported that how similar the final composition of the tune which included the novel INMI is to the inner experience varied depending on various factors.

F1 – “Sometimes these melodies that must just stay the same. That’s what it was there, that’s the seed of the song and it must stay in your head. And anything could change around it, but that needs to stay because that was the point of the song.”

One of the factors affecting the ***Accuracy*** of the composition is the *Musical skills* of the individual.

M2 – “Of course, when something is made with my own instrument which is voice or guitar, I know exactly how I wanted to sound and because I am so experienced in that instrument I can actually, I can, the approximation is much better.”

Another participant reported that ***Accuracy*** depends on the *Complexity* of the novel INMI:

M2 – “Now, if it´s something minimal, with few instruments of course it´s easier, ok. The more the instruments the more the harmony creates, shades of sounds that are not easy to reproduce at all, at all..”

The way participants capture the novel INMI also affected the accuracy of the outcome such as *Singing* and writing down on *Manuscript paper*:

M3 – “Sometimes I try to just realise it with my voice which already completely changes it. Singing, singing…It’s the most immediate thing. Even if it’s rhythmical stuff.”

M1 – “It works for me (manuscript paper). I tend, I tend not to use the iPhone too much ummm. I have recorded things down. I used the voice memo application as well but umm I tend not to do that because I don’t have such a replicable representation.”

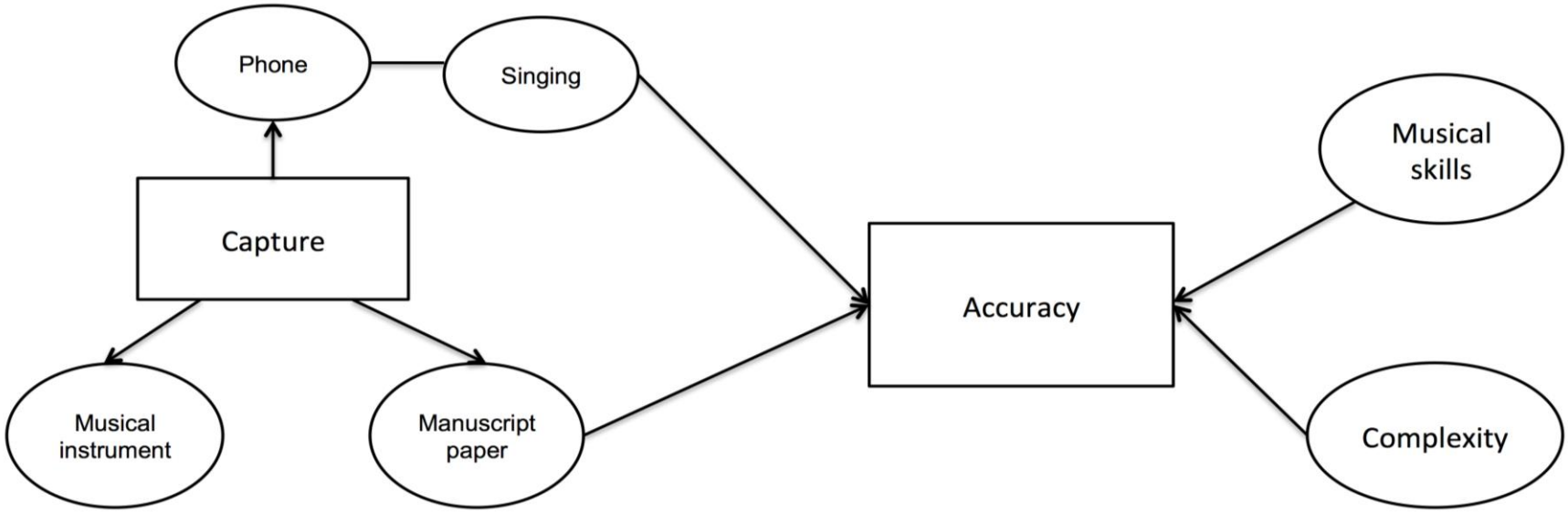

Figure 5.2. Visual representation of how novel INMI is externalized into music. Dominant themes are represented by squares and subdominant with circles. Single directional arrows indicate hierarchical links while bidirectional arrows illustrate reciprocal relationships and straight lines represent associations.

5.5 Discussion

The experience of novel Involuntary Musical Imagery has been reported in previous INMI studies (Bailes, 2007; Liikkanen, 2012a; Wammes & Barušs, 2009; Williamson & Jilka, 2013), however no further investigations have been conducted to shed light on its phenomenological aspects. The current chapter presents the first interview study to investigate novel INMI as experienced by composers. The study focuses on two key aspects of the novel INMI experience: the phenomenological aspects and how this internal experience is translated to an external experience. The composers who participated in the study were highly musical as indicated by their Gold-MSI score in "Musical Training" and half of them experienced novel INMI infrequently while the rest more often.

Novel INMI Phenomenology: Internal Experience

The first model which was developed from the interview data revealed important information about the phenomenological aspects of the novel INMI experience. The activities that an individual is engaged in when novel INMI occurs where grouped in an abstract dominant theme, that of Mental and Physical State, which was further subdivided in three subdominant themes, those of Low Attention States, Self Conscious, and Repetitive Movement.

Previous literature as well as studies presented in this thesis, regarding activities enabling INMI onset, have highlighted the importance of those described by low attention states and concurrent cognitive load (See Chapters 2 and 3, Hyman et al., 2013; Liikkanen, 2012a; Williamson et al.,

2012). Findings from the current study are in concordance with this notion as described in the *Low Attention States* activities. Whether familiar or novel, INMI onset is favoured by such situations. Similar findings come from the mind-wandering literature where the onset of episodes is associated with less cognitive load and engagement (McVay & Kane, 2010; Smallwood & Schooler, 2006). This is also in concordance with literature on creative thought, where defocused attention is a key aspect enabling its onset (Gabora, 2002, 2003; Heilman, Nadeau, & Beversdorf, 2003; Howard-Jones & Murray, 2003; Mendelsohn & Mendelsohn, 1976).

Low attention states are not the only prerequisite for novel INMI occurrence. A new finding of the present study is that being *Self-Conscious,* i.e. focused on inner experiences (Fenigstein, Scheier & Buss, 1975), hence being in a better position to observe the novel INMI the moment it occurs, was a vital characteristic for almost all the study participants. Findings from neuroimaging studies on creative thought have identified activation not only of the default mode network, which is associated with spontaneous cognition, but also of networks which require more control and focused attention (Carlsson, Wendt, & Risberg, 2000), a finding which may be explained by such a dual process, with external attention being decreased while internal focus is increased. This process is similar to mind-wandering episodes where the internal stream is insulated from external distraction and is termed as «perceptual/attentional decoupling» (Smallwood, 2013a; Smallwood & Schooler, 2006). Similarly here, activities are found which are associated to spontaneous cognition but also to internal cognitive states. Future studies

should examine whether there are differences in private self-consciousness scores, as measured by Self-Consciousness Scale-Revised (SCSR; Scheier & Carver, 1985), between people who experience novel INMI and those who do not.

Previous research on INMI has shown that repetitive activities are associated with INMI occurrence (Williamson et al., 2012). This could be explained by the low attention states describing practiced and repetitive activities. The *Repetitive Movement* subtheme describes a repetitive activity similar to that reported by previous studies but also showcases the importance of movement. In Chapter 3, the IMIS factor “Movement” revealed the tendency of individuals to move to the beat when experiencing INMI from familiar music. However in the present study the relationship is in the opposite direction, with novel INMI occurring when individuals perform repetitive movements. A finding in support of this theme comes from the literature on creativity, which has been described as fluid thinking because of its similarity to the movement of fluids and their flexibility and ease of movement (Hofstadter, 1995; Sternberg, 1985). Greater generation of fluid creative thinking has been associated to fluid movement (Slepian & Ambady, 2012; Leung et al., 2012). These findings highlight an important relationship between movement and creative ideas like novel INMI, indicating a relationship between motor experiences and cognitive processes. This finding falls under the embodied cognition topic, where states of the body modify states of the mind and more specifically embodied creativity and embodied musical creativity, phenomena which at the moment are

understudied. This relationship could be investigated further with empirical studies.

Contrary to popular belief, familiar INMI is mostly evaluated as pleasant (Beaman & Williams, 2010; Halpern & Bartlett, 2011; Williamson & Jilka, 2013). The results reported here agree with this by presenting novel INMI as a positive experience. Beyond describing the experience itself, participants also reported how they felt at the moment novel INMI occurred. They described two widely different types of feeling, namely being peaceful or, in some cases, energetic. This finding is in concordance with the finding, described in Chapter 2, that mind-wandering causes mood changes which result in the same two extremes of feeling, i.e. of feeling peaceful or energetic. Different feelings, depending on the situation could be associated with a more associative and creative mood. Another interesting finding relates to the description by participants of an interaction between the mood of the tune and the mood the participants were in. It is possible that novel INMI may act as a means of emotional self-regulation, something that has been previously suggested for familiar INMI (Jakubowski et al., 2015) as well as for music (Thoma, Scholz, Ehlert, & Nater, 2012.), although the opposite is also possible, with the feelings of the individual giving rise to the feeling of the tune.

Although novel INMI represents an original experience, most of the participants reported a sense of *Familiarity.* They attributed this to having been exposed in the past to sounds which their brain processed,

decomposed, and then composed into novel material. However, although novel INMI felt familiar because of its similarity and relation to previous heard material, as well as because of the participants being able to identify relations, the participants were not able to identify where the novel INMI originated. This is in line with the suggestion of Liikkanen (2004) that "new imagined music may not be unexpected incident but a natural outcome of the way our brain processes information." Similarly, Williamson and Jilka (2013) suggested that novel INMI could be the result of "subconscious musical extemporization", adding the idea that novel INMI is not a virgin idea but the result of additions to familiar INMI over time.

The *Musical Structure* of novel INMI reflects similarities to familiar INMI but also to voluntary musical imagery, where the *Melody*, *Rhythm*, and *Timbre* are the most prevalent experienced musical features (Bailes, 2007; Halpern, 2007). Findings about the *Formal Structure* and *Language* of novel INMI also agree with familiar INMI literature where short length, chorus (Beaman & Williams, 2010; Hyman et al., 2013), and lyrics (Byron & Fowles, 2013; Halpern & Bartlett, 2011; Hyman et al., 2013, 2015) or own voice (Williamson & Jilka, 2013) characterise the INMI experience. Future research should employ experience sampling methodology (both probe and self-caught) to investigate these characteristics at the moment the experience occurs and to explore their relationship to the musical training and engagement of the individual.

One of the two defining INMI characteristics, *Repetition,* seems to be

important for the consolidation of the novel INMI in memory (*Memory Consolidation*), which in turn leads to composition. Mountain (2001) also observed a similar process in composers, although in a voluntary manner: “By mentally "playing back" the auditory image repeatedly to oneself, it can become "engraved" more firmly into memory” (p. 276). The subtheme of *Driving Force*, which leads to *Composition,* could mediate memory consolidation, since items, words, and images that elicit high arousal can be better remembered (Bradley, 1992; Burke, Heuer & Reisberg, 1992; Butter, 1970), however it is noted that the same effect has not been found for music. *Positive experience*, which although not captured in the *Repetition* theme but in the *Feeling,* could play an additional role in the consolidation of the novel INMI, as previous studies have shown in relation to music and positive feelings (Eschrich, Münte, & Altenmüller, 2008). Repetition and arousal seem to play an important role in the development of a strong memory for novel INMI which will last and lead to composition. Future behavioral studies should explore this finding by presenting originally composed tunes to participants and investigating the number of repetitions (externally and internally) required for a new tune to be consolidated in memory and the level of arousal and valence elicited by the music in their ability to create an INMI.

Novel INMI Phenomenology: External Experience

The most common way to capture novel INMI is by phone and particularly by *Singing* it and recording it. One disadvantage elucidated by singing was that it distorted the *Accuracy* of the novel INMI participants had in their mind. A similar finding comes from Williamson and Jilka (2013) who, while finding

that familiar INMI are similar to the original music in terms of form, also reported that singing affected the fidelity between the two by altering the original voice in the tune to their participants'. In contrast, writing down on *Manuscript Paper* resulted in the outcome of the externalisation being closer to the original form. The lack of general *Accuracy* could be explained by the fact that, although repetition helps in memory consolidation, novel INMI are not strongly embedded in memory like familiar INMI and are not easily reproduced in their initial form.

Accuracy was a more dominant theme with regard to the outcome of the composition in comparison to the novel INMI. *Musical skills* of the composer and Complexity of the novel INMI seem to be key elements in how veridical the composition will be to the novel INMI. According to Mountain (2001), "The extent to which the original stimulus is manifest in the final composition is almost exclusively dependent on the intentions (and skills) of the composer, though naturally some stimuli are more transferable into the musical domain than others." (p.10). This qualitative mismatch corresponds to what Bailes and Bishop (2012) call translation from a musical image to sound and the composers' skills as fluency.

5.6 Limitations of the Present Study

A number of limitations of the study are acknowledged. First, two of the participants were not native English speakers. Although they were fluent in English, their comprehension of critical information could have been hindered. Future studies should take this complication into consideration and

recruit a more homogenous sample. Secondly, the interview focused on composers to increase the probability of finding individuals who experience novel INMI. This does not mean that individuals who are not composers, or do not have musical training, do not experience novel INMI. Future research should take into consideration both types of subjects.

5.7 Conclusion

The present chapter introduced the first interview study of novel INMI, focusing on its phenomenology as an internal translated into an external experience. The results of this study highlight the parallels between novel and familiar INMI and creative thought in terms of mental and physical states related to the genesis of both, the feeling associated with their occurrence, and their structure. They also reveal new insights regarding repetition and its relationship to memory consolidation, which may be the first functionality identified in the INMI phenomenon. Finally they show how fragile novel INMI is when externalised into music.

The results presented in this chapter lead to testable hypotheses for future studies that will help us understand better why novel INMI and familiar INMI occur, but also highlight our creative capacity manifested in everyday life, which could be exploited in music education.

Chapter 6. General Discussion

The four studies presented in this thesis investigated the relationship between Involuntary Musical Imagery and spontaneous as well as creative cognition. INMI was studied in relation to other forms of spontaneous cognition and connections were identified between novel INMI and creative cognition. In this section, the key results from each study will be summarised and discussed in relation to each other and in relation to (a) spontaneous cognition, (b) creative cognition, (c) music perception, (d) voluntary auditory imagery, and (e) INMI literature. In addition, issues related to INMI terminology and the length of the experience will be discussed. The methods and analyses used in the different studies discussed in this thesis vary, something that adds to the value of this work by contributing to the interpretation and integration of the results from different perspectives. For this reason methodological advantages and limitations will also be discussed. Finally, the general limitations, possible applications, and future directions of INMI-related research will be presented, followed by the concluding remarks.

6.1 Summary of Main Results

Study 1 in this thesis (Chapter 2) was conducted to investigate the relationship of INMI to the cognitive process of mind-wandering. An experience sampling methodology (probe-caught) was implemented, where participants reported on-going INMI and mind-wandering episodes (if any) at the moment they were contacted, as well as additional information such as the time of the day, the activity they were engaged in, what triggered any INMI episode reported, how much they enjoyed their INMI, and their mood at

the time. This resulted in a highly informative dataset made up of 1374 reports. A Bayesian networks analysis identified the interplay of factors associated with the INMI experience and revealed causal relationships between them. The main finding pointed to mind-wandering, the process of generating thoughts in relation or not to the current activity, preceding and causing INMI. Time of the day caused the activity the individual was engaged in and finally the latter, mostly when described by low attention states, caused mind-wandering. Mood was caused by mind-wandering rather than INMI occurrence and the type of INMI trigger affected the subsequent subjective evaluation of INMI. A difference in the reported INMI frequency between experience sampling reports and retrospective reports in the same individuals revealed the advantages of the first method over the second.

Following the establishment and elucidation of a relationship between the cognitive states preceding INMI as reported by self-report measures, Chapter 3 reported the effect of cognitive load on INMI occurrence and length as has been previously done with other types of spontaneous cognition, aiming to shed light in a behavioral context on the cognitive states which precede INMI occurrence. A comparison of INMI occurrence rates (following musical exposure) and length (how long INMI lasted) between a baseline condition (no task) and 3 tasks representing low, medium and high cognitive load showed that, as cognitive load increased, INMI occurrence and length decreased, thus supporting the hypothesis that INMI occurrence is linked to spare cognitive capacity, as holds for other types of spontaneous cognition. Besides the empirical findings of this study, a novel paradigm for inducing

and indirectly probing INMI was introduced which facilitated the experimental procedure.

The development of the IMIS in the context of Study 3 (Chapter 4) first enabled the creation of an enhanced self-report inventory measuring individual differences in the INMI experience. The four IMIS factors revealed new facets associated to the INMI experience, while three extra items improved the measurement of INMI frequency and length of the section of music experienced as INMI as well as the INMI episode. Second, the existence of such a measurement instrument enabled the investigation of individual differences in the INMI experience and the exploration of associations with other forms of spontaneous cognition and processes such as mind-wandering, daydreaming, and cognitive intrusions, as well as with other similar constructs such as voluntary auditory imagery and musical background and behaviors. Based on the items the “Help” and “Personal Reflections” factors pertained to and in terms of what they represent, it revealed similarities of INMI with other spontaneous thoughts. The magnitude of the correlations between all IMIS factors with other measures of spontaneous cognition pointed to certain associations and similarities between INMI and other spontaneous thoughts. Finally, the “Movement” factor revealed critical similarities between INMI and music perception related to corporeal articulations.

Finally in Chapter 5, for the first time in INMI research, novel INMI was explored along with its relationship to creative cognition with a semi-structured interview with 6 composers. As a result, two models were developed, one regarding the phenomenology of the inner experience and the other related to the way in which the latter is translated to an external outcome. Activities and feelings at the time of the occurrence, as well as the form of the experienced novel INMI, revealed similarities with familiar INMI, voluntary musical imagery, and other forms of creative cognition, thus supporting the idea that creative cognition in the form of novel INMI lies between voluntary and involuntary processes. Furthermore, the role of repetition was elucidated, adding to ideas about the functions of novel and subsequently familiar INMI related to memory consolidation.

6.2 The Relationship of INMI with Spontaneous Cognition

Spontaneous cognitions, in several different forms, are universal human experiences, occupying a significant portion of our waking thought (Kane et al., 2007; Killingsworth & Gilbert, 2010; Klinger & Cox, 1987; Kvavilashvili & Mandler, 2004; Singer, 1966). The majority of previous studies on spontaneous cognition investigated it as a general process and did not distinguish between its different modalities, while only few studies have focused on specific types and characteristics (Berntsen, 1996; Delamillieure et al. 2010, Gorgolewski et al. 2014; Kvavilashvili & Mandler, 2004). The work described in this thesis investigated a specific type of spontaneous cognition (INMI) which is ubiquitous and distinct, and explored it in relation to other forms of spontaneous cognition in terms of cognitive states preceding it

and individual differences in order to shed light on the distinct types of such a complex and multimodal phenomenon.

Study 1 (Chapter 2) revealed a crucial relationship between mind-wandering and INMI, with the former causing the latter. A similar finding comes from retrospective reports (Williamson et al., 2012), where situations described by low attention states were reported to induce mind-wandering episodes, which in turn enabled INMI episodes. Spontaneous memories such as Involuntary Autobiographical Memories and Involuntary Semantic Memories are very common during minimally demanding tasks (Berntsen 1998; Berntsen & Jacobsen, 2008; Kane et al., 2007; Killingsworth & Gildbert, 2010; Kvavilashvili & Mandler, 2004; Mace, 2006; Singer, 1966). In accordance with these findings, mind-wandering was caused more by low attention states activities, and in turn caused INMI. It appears that activities described by low attention induce a mind-wandering state which, depending on recent encounters, subsequently triggers and activates the relevant type of spontaneous cognition. This knowledge will be of value for future research wishing to disentangle the various types of spontaneous thought.

In Chapter 4, first IMIS was developed and then it was used to investigate associations with other forms of spontaneous cognitions using different measures. It was proved particularly challenging to identify validated instruments which quantify specific forms of spontaneous cognitions rather than processes. Three subscales of the Imaginal Process Inventory (IPI) were used: the “Daydreaming frequency”, “Mind-wandering”, and “Auditory

Images in Daydreams", along three subscales of the Cognitive Intrusion Questionnaire (CIQ), namely "Emotions", "Intensity", and "Effectiveness". INMI frequency, length (episode), and the majority of IMIS factors were associated with all the IPI subscales, while CIQ factors showed strongest correlations with the more affective IMIS factors such as "Negative Valence" and "Personal Reflections". All these associations indicate an overlap of INMI aspects with other forms of spontaneous cognition and suggest that individuals who are prone to one type of spontaneous thought are likely to be prone also to the other. Future studies should use the recently developed Involuntary Autobiographical Memories Inventory (Berntsen et al., 2015) and the Frequency of Involuntary Thoughts Scale (Hyman et al., 2015) to explore the relationships of INMI with other more specific types of spontaneous thought rather than processes.

In the previous studies an association and overlap of different aspects of INMI and other forms of spontaneous cognition, as measured by experience sampling and retrospective reports, was established. In Chapter 3, a laboratory study investigated the effect of gradually increased cognitive load on INMI retrieval and length. If INMI is similar to other forms of spontaneous cognitions, then the more cognitive resources available the more and longer INMI should occur. The development of a novel, covert paradigm to induce and capture INMI allowed the confirmation of the hypothesis that INMI occurrence and length depend on spare cognitive capacity, which is in accordance with other findings related to the process of spontaneous cognition (Mason et al., 2007; Teasdale et al., 1993; Teasdale et al., 1995).

Another interesting finding in relation to INMI to other forms of spontaneous cognition is that the factors “Personal Reflections” and “Help”, based on the items they include and what these represent, highlight commonalities to spontaneous thoughts in terms of their content, triggers, and beneficial aspects. Similarly to other forms of spontaneous thought, the content and triggers of INMI as expressed by the “Personal Reflections” factor are associated with personal concerns and unresolved matters (Andrews-Hanna, 2012; Baars, 2010; Klinger, 2008; Klinger & Cox, 1987-1988; Smallwood et al., 2009). Furthermore, like other forms of spontaneous cognition (Baird et al., 2010; Franklin et al., 2013), the INMI experience can have beneficial effects in task performance.

The abovementioned findings provided a basis for comparing INMI characteristics to those of other forms of spontaneous cognition and highlighted their overlap in certain aspects. INMI proved a useful tool for gaining a better understanding on specific types of spontaneous memory.

6.3 Novel INMI and Creative Cognition

The second aim of the present thesis was to explore, for the first time in INMI research, novel INMI, from the point of view of the creative cognition approach (Finke et al., 1992; Ward et al., 1999) which emphasizes two key features of the creative product: (a) novelty and (b) usefulness. An interview study with 6 composers made it possible to gain access to the phenomenology of novel INMI as an internal experience and as a useful

product. Based on grounded theory analysis, the results obtained confirmed previous findings regarding familiar INMI as well as voluntary musical imagery, in agreement with findings from creative thought literature.

The main findings of this study outline the mental and physical states associated with the occurrence of novel INMI. Two mental states were identified: (a) low attention states, confirming previous findings on familiar INMI (Williamson et al., 2012; Floridou & Müllensiefen, 2015, see Chapter 2) as well as findings on creative thought according to which defocused attention is one of the key factors facilitating creative thought (Gabora, 2002, 2003; Heilman et al., 2003; Howard-Jones & Murray, 2003; Mendelsohn & Mendelsohn, 1976); (b) self-conscious, a state where individuals are more in contact with themselves and more aware of their inner thoughts. This finding is in accordance to the perceptual decoupling state (Schooler et al., 2011), in which attention turns from processing external perceptual information to internal cognition and is linked to creative thought (Baird et al., 2012; Christoff et al., 2008)

An additional important finding concerns the role of repetition in the novel INMI experience. This gives a first provisional answer regarding the function of INMI in general, which is related to memory consolidation. This finding will be discussed further in section 6.4.2.

This first study on novel INMI sheds light on the phenomenology of the experience. Further work is needed in order to explore how prevalent the

phenomenon is in the general population as well as the associations between the frequency of novel INMI and measures of creativity.

6.4 The Relationship of INMI to Other Domains

Although the main aims of this thesis are related to spontaneous and creative cognition, a number of additional interesting findings regarding different INMI aspects, especially in relation to (a) music perception and (b) voluntary auditory imagery, were also obtained and will be discussed in detail below.

6.4.1 INMI and Music Perception

While (musical) memory and (music) perception are essentially different processes, “hearing with our mind’s ear” (at least for voluntarily recalled music) shows similarities with music perception in relation to brain activations and the processes involved. In the present thesis the similarities and overlap between INMI and perceived music has been demonstrated in two ways. The first is with the identification of the IMIS factor “Movement” and the second with the IMIS factor “Help”.

In Chapter 4, one of the IMIS factors identified was labeled “Movement” because the items it pertained to relate to embodied responses when experiencing INMI. Items such as: “The rhythms of my earworms match my movements”, “The way I move is in sync with my earworms” and “When I get an earworm I move to the beat of the imagined music” illustrate the connection between rhythm, beat, movement, and inner music in the form of INMI. A series of correlations revealed that “Movement” was associated with

the “Reactive Musical Behavior” factor (from the Music Experience Questionnaire), measuring similar embodied responses when listening to music. This finding is of critical importance since it demonstrates the similarity of inner to real music in the ability of both to evoke embodied responses and for this reason it will be discussed in some detail below.

The synergy of perceived music and movement have been long known and discussed. From dance to military marches, from lullabies to sports, and from Aristotle (Schoen-Nazzaro, 1978; Susemihl & Hicks, 1894) and Hume (Hume, Selby-Bigge, & Nidditch, 1975) to Nietzsche (Came, 2014), all human cultures emphasise and talk about this cross-modal relationship, while in some cultures these two terms are even inseparable. Music has been shown to be an effective means of eliciting body movement (Keller & Rieger, 2009). As revealed in a large-scale study on the semantic description of music (Lessafre et al., 2008), 95% (n=663) of people move spontaneously when they listen to music.

A fundamental feature of music, which is associated with movement, is rhythm, and more specifically the beat. Neuroimaging studies have demonstrated the relationship between rhythm and groove perception and movement as found in motor areas (premotor cortex, basal ganglia, and the cerebellum) activated in the brain of musicians and non-musicians when overt movement is inhibited (Chen, Penhune, & Zatorre, 2008; Janata & Grafton, 2003; Grahn & Brett, 2007; Grahn & Rowe, 2009; Stupacher, Hove, Novembre, Schütz-Bosbach, & Keller, 2013). These findings demonstrate

that music serves as a great example of perception-action coupling (Janata & Grafton, 2003), eliciting motor responses manifested both in behavior and in brain activations.

Given the relationship between voluntary musical imagery and brain activation in motor areas (Halpern & Zatorre, 1999; Zatorre et al., 1996), the motor responses which occur while experiencing INMI, and the findings about the considerable overlap in the electrical brain activations when listening to and when imaging music (observed with a range of brain imaging methods such as electroencephalography, magnetoencephalography, event-related potential and functional Magnetic Resonance Imaging) (Halpern & Zatorre, 1999; Herholz et al., 2008; Herholz et al., 2012; Kraemer et al., 2005; Schaefer et al., 2011, 2013; Vlek et al., 2011), it is hypothesized that the same brain areas will be active when INMI is experienced. Future brain imaging studies will shed light on this hypothesis. If this is confirmed, it will imply that INMI (and voluntary musical imagery) have the potential to contribute to therapeutic methods in diseases associated with motor responses such as Parkinson's, or in stroke rehabilitation, in a parallel way to how music is used. The unintentional nature of INMI can prove challenging in relation to the use of INMI as a direct therapeutic tool, however it may be possible to exploit INMI in parallel with voluntary musical imagery and music as a supportive unintentional enhancement tool.

The link between inner music and bodily responses is supported by another finding. The factors "Movement" (IMIS) and "Reactive Musical Behavior"

(Music Experience Questionnaire) both correlate with INMI frequency. Floridou et al. (2012) identified a similar relationship using a survey tool which included v0.9 of Gold-MSI (Müllensiefen et al., 2011). The latter contains a factor measuring bodily responses (Body), such as moving to the beat of perceived music and singing and/or humming when listening to music (or not). It was found that individuals who scored higher on the “Body” factor experience INMI more frequently. This finding has been supported by the results of a subsequent behavioral study (Campbell & Margulis, 2015), according to which participants engaged in overt motor involvement in the form of humming, singing, tapping or moving while listening the stimuli tunes subsequently experienced significantly more INMI than when engaged in imagined motor involvement or passive listening.

An additional finding of interest is that Gold-MSI factor “Singing Abilities” correlates with INMI length and also INMI frequency, which agrees with the findings of Müllensiefen et al. (2014a) who identified a connection between singing (Self-rated Singing Ability and Extend of Sing-along Behavior) and INMI length. Taken together, these findings highlight the links between INMI and action responses including movement and singing, and can be interpreted in terms of brain areas activated when tapping and singing to the music overlapping with areas associated with voluntary musical imagery (Halpern & Zatorre, 1999; Hickok et al., 2003; Kleber et al., 2007; Kraemer et al., 2005; Zatorre & Halpern, 2005), which in turn suggests that increased activation in one domain could stimulate activity in the other.

The relationship between INMI, movement, and singing can be linked to the framework of embodied cognition (Lakoff & Johnson, 1980) and more specifically to the notion that off-line cognition is body based (Wilson, 2002). A more specific context, which this relationship fits better, is that of embodied music cognition. Leman (2007) said about embodied music cognition: “The human body is the natural mediator between experience and physical reality; Music-driven movements of the listener are seen as corporeal articulations that reveal a mirroring (in movement) of the perceived sonic moving forms. Through this mirroring, it is assumed that musical expression can be captured more fully, experienced, and understood.” And he continues, “Spontaneous movements [to music] may be closely related to predictions of local bursts of energy in the musical audio stream, in particular to the beat and the rhythm patterns” (p. 96).

Until today the paradigm of embodied music cognition has overlooked the example of inner music probably because of the lack of studies exploring the relationship between the two. Given the overview presented above and the similarities noted between music and inner music, the relationship of INMI with corporeal articulations adds to the understanding of the embodied music cognition paradigm. It is possible that, when people experience INMI and move in any way (head nodding, foot tapping, and whole body movement), this might enhance the meaning they give to the particular tune. It is recognised that this view is based on observational studies and that to confirm it there is need for more studies exploring the specific connection between INMI and movement by looking at individuals who move and those

that do not when experiencing INMI and the meaning they ascribe to the music experienced as INMI.

The link between the experience of inner music and spontaneous movement may also have implications for another mental domain, that of emotion. It is well known that music can elicit strong emotions in people (Juslin & Sloboda, 2001) and movement is one of the ways through which such emotions can be expressed (Pollick, Paterson, Bruderlin, & Samford, 2001). Corporeal articulations in music, such as foot tapping and whistling or humming, could represent more naturalistic emotional cues in an everyday setting of a layperson. As has been proposed by Koelsch (2014), “Music can evoke changes in the major reaction components of emotion, including others that of action tendencies such as dancing, singing, playing an instrument, foot tapping and clapping, even if only covertly” (p. 170). Additionally, Zatorre, Chen, and Penhune (2007) have suggested that music-induced emotion could provide the link between listening and moving. This hypothesis (Zatorre, Chen, & Penhune, 2007) could explain why in Study 1 (Chapter 2) mood was caused by mind-wandering rather than INMI. Motor responses, which could have played a role in mood, were not measured in that study since IMIS had not been developed yet.

The existence of a link between the experience of inner music and movement could explain the contradiction with the findings of Jakubowski et al. (2015), who found a relationship between INMI tempo and affective states. The participants in that study were instructed to tap to the INMI beat,

which as the researchers also point out might have increased the salience of INMI tempo. However it is possible that the guided interaction of the participants with their INMI might have enhanced their affective states. Future studies should take this complication into consideration and investigate any possible differences in the affective states experienced when INMI occurs between people who move to the beat of INMI and those who do not.

Future studies exploring how INMI can induce spontaneous movement should also take into consideration and measure the factors that can affect the various degrees of music-induced movements such as personality (Luck, Saarikallio, & Toiviainen, 2009), the combination of personality and musical genre (Luck, Saarikallio, Burger, Thompson, & Toiviainen, 2010), specific musical features (Burger, Thompson, Saarikallio, Luck, & Toiviainen, 2013), body morphology (Dahl, Huron, Brod, & Altenmüller, 2014), perceived emotion (Burger, Saarikallio, Luck, Thompson, & Toiviainen, 2013) and familiarity and enjoyment of the music (Janata, Tomic, & Haberman, 2012). Findings from such studies will elucidate the role of individual differences in the variation of induced movement and its relationship to INMI frequency.

Another aspect which points to similar attributes of INMI to music listening and perception is that of the beneficial effects the experience can have on task performance. The identification of the factor “Help” in IMIS in terms of providing focus and general help in completing tasks resembles the effects of perceived music on attention and performance of various tasks. The existing

literature on music listening and its effects on performance is mixed with regard to the conclusion regarding the role of various factors such as the type of music (Jäncke et al., 2014; Judde & Rickard, 2010; Rickard et al., 2012), personality (Furnham & Allass, 1999), or the level of neurophysiological arousal related to music (Furnham & Strbac, 2002; Jones et al., 2006).

Smith (1969) proposed that music can reduce the tension and boredom which could be associated with routine work, while Fox and Embry (1972) found that music can increase arousal and alertness during a repetitive task, something that can raise performance levels. In addition, Daoussis and McKelvie (1986) proposed that familiarity with background music can influence task performance. Routine work, repetitive tasks, and familiarity with the music are common factors associated with INMI occurrence. Hence the experience of familiar INMI in such routine and repetitive situations may also have benefits on task performance, as indicated by the observed importance of factor “Help”. Future work should further explore this relationship, and more specifically personality factors such as “Extraversion”, which has been found to be associated with better task performance while listening to music. Similarly Extraversion could predict higher scores in the factor “Help”, which will shed light on individual differences in possible constructive uses of INMI.

6.4.2 INMI and Voluntary Auditory Imagery

Involuntary Musical Imagery is a ramification of a wider imagery concept, namely that of auditory imagery which refers to voluntary and involuntary imagery of music, language, and environmental sounds, in the absence of a direct external stimulus. A large part of the imagery literature has focused on auditory imagery, and specifically on voluntary musical imagery, the counterpart of INMI. Findings discussed in this section point to the resemblance of involuntary to voluntary auditory imagery, including musical imagery, as well as to the fundamental differences between the two.

Voluntary auditory imagery abilities in a range of sounds such as musical, verbal and environmental, were measured with the Bucknell Auditory Imagery Scale (Halpern, 2015) in relation to IMIS in Chapter 4. The only two significant relationships between the two measures were between BAIS Vividness and IMIS “Movement” as well as INMI frequency. The lack of correlations with the rest of the IMIS factors and INMI characteristics indicates that there may be fundamental differences between the two scales as well as between the two types of imagery. Such differences could be related to the more personal qualities measured by IMIS and the more technical factors of BAIS, as well as reflect functional differences between the two types of imagery.

An additional finding about the relationship of INMI to voluntary auditory imagery comes from the characteristics of the tunes experienced as novel INMI. These were divided into three main subthemes: musical (melody,

rhythm, and timbre), formal (part of the tune and length), and linguistic (lyrics and voice). All these findings about novel, involuntary musical imagery agree with findings from studies on both voluntary (Halpern, 1988; Halpern et al., 2004; Zatorre & Halpern, 1993; Zatorre et al., 1996) and involuntary (Bailes, 2007, 2015; Hyman et al., 2015) musical imagery with regard to the features better recalled from memory when experiencing both. They also underline the similarities between the two types of imagery and the possibility that their differences might lie in their onset and function.

Taken together, all the findings presented in the preceding sections illustrate the overlap between INMI and spontaneous cognition, creative cognition, music perception, and voluntary musical imagery. Figure 6.1 shows the intersection between these domains and illustrates how INMI can be used to explore the relationship between them.

6.5 General Findings and Issues Related to INMI

In this section I will discuss the most important findings in relation to different aspects of INMI which emerged from the studies presented in this thesis. I will touch upon some relevant issues and put forward suggestions regarding INMI terminology and length, which I believe must be clarified to allow future work to be consistent and more coherent than research to date.

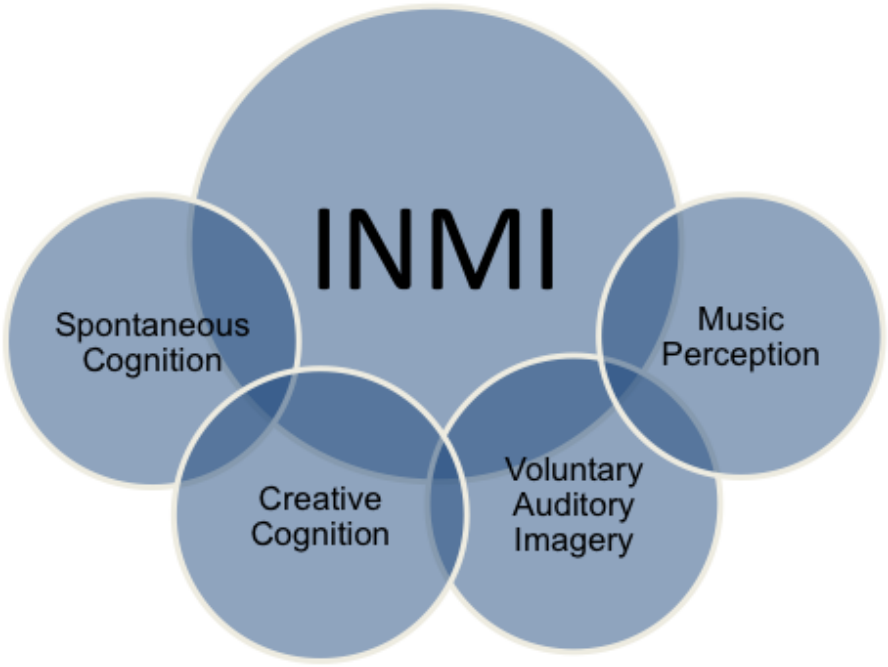

Figure 6.1. A visual representation of the intersection of INMI with other domains such as spontaneous cognition, creative cognition, voluntary musical imagery and music perception and the interrelations between the latter four.

6.5.1 What Factors Contribute to Positive or Negative INMI Evaluation?

Literature findings regarding the evaluation of INMI are mixed (Beaman & Williams, 2010; Halpern & Bartlett, 2011; Hemming, 2009; Liikkannen, 2012a; Williamson et al., 2014). This may be so because of the varying ways individuals were asked about how to rate the pleasantness of their INMI in the different studies, or because of the various factors affecting the subjective evaluation of INMI. In Study 1, participants were asked to rate their INMI each time they experienced it on an 11-point Likert scale. In total the average INMI pleasantness was rated as slightly pleasant, confirming some of the previous findings (Beaman & Williams, 2010; Halpern & Bartlett, 2011).

The Bayesian networks analysis revealed INMI pleasantness is induced by what triggered INMI. INMI resulting from a memory association, recent exposure to music, an association with a sound or a recent or upcoming event, all caused higher pleasantness rates. As explained in the discussion of Study 1, this could be because people are usually exposed to music they like (North & Hargreaves, 2003; North et al., 2004), hence when they subsequently experience it as INMI they draw pleasure from it. However, when individuals are unaware of what the INMI trigger was, experience the same tune more than once throughout the day, or experience their default INMI (a specific tune which returns frequently to their mind), then they register lower pleasantness rates. The last two triggers mentioned above imply that a repetitive INMI may result in a negative experience. This finding is in accordance with results from Study 3 where one of the IMIS factors, namely “Negative Valence”, correlated to the Length of the INMI episode, indicating that the number of repetitions can increase the unpleasantness of INMI.

Another finding in this thesis could shed light on the reason why INMI appears to be evaluated as negative by some people and why it is even reported as such in a handful of studies (Williamson et al., 2014). In Study 3 the IMIS factor “Negative Valence” was correlated only to the length of the INMI episode amongst the various INMI characteristics (frequency and length of section). This finding indicates that in individuals who experience longer INMI episodes (referring to the period a particular tune is experienced as

INMI, regardless of whether it is intermitted or continuous), INMI is associated with a more negative subjective evaluation. Similarly, in Study 1, individuals who reported experiencing the same INMI throughout the day, as well individuals who experience their default INMI (recurrent INMI), reported low pleasantness, something that can be attributed to the repetition of the experienced INMI. On the other hand, individuals who experience novel INMI (Study 4) characterize it as a positive experience, possibly because of the original quality associated with it, i.e. the newer and less repetitive the INMI is the more enjoyable it is. Taken together these findings indicate that various factors are associated with the evaluation of INMI, with repetition being linked with unpleasantness.

6.5.2 What is the Role of Repetition in INMI?

A key element of INMI, in addition to its spontaneity, is repetition. In the general psychological literature, spontaneous repetitive thoughts have been associated to rumination and are considered as a feature of a depressive mood (Smallwood et al., 2007). However, spontaneous repetitive thoughts can also be positive and contribute to a positive mood (Cohn, Frederickson, Brown, Mikels, & Conway, 2009). Baars (2010) suggests, “Spontaneous repetition of conscious thoughts, even if they are unwanted and intrusive, may play an important adaptive role.” (p. 2). This suggestion could also apply to the case of INMI. Almost 90% of people experience INMI at least once a week and 33.2% several times a day. In addition, most of the INMI studies have found, contrary to popular belief, that the experience is mostly evaluated as pleasant.

Could INMI have an adaptive role linked to their repetitive character? In Study 4, a subtheme identified within the repetition theme was that of memory consolidation. Interview participants described repetition of novel INMI as beneficial in terms of memorising. Novel INMI serves as a great example of a first time occurrence INMI, which makes its characteristics more identifiable. Further behavioral testing with novel tunes is required to explore the possible role of "unfamiliar" INMI in memory consolidation, in terms of how many times the tune needs to be listened to and how many times it has been repeated in the mind. Taken together, the findings about repetition indicate a beneficial effect of INMI but also point out other, negative aspects, which are associated with the length of the repetition and individual characteristics.

6.5.3 Issues Related to INMI Terminology and Length

At this point, I would like to make two suggestions regarding (a) INMI terminology and (b) the length of an INMI episode. Throughout this thesis, as well as in previous literature, the phenomenon under investigation is referred to as either "an earworm" or INMI. Here I would like to suggest a slightly different terminology, which I believe depicts the experience in a more accurate way. The term involuntary musical imagery (INMI) is too broad to cover only one phenomenon, that of "earworms" (see also Williams, 2015[4]). Other phenomena, such as musical mind-pops (Kvavilashvili & Anthony,

[4] This suggestion was made before I became aware of William's (2015) paper, which was published when the current thesis was being written. A similar suggestion was also made in my MSc thesis in 2011 (Floridou, 2011).

2012), musical obsessions (Taylor et al., 2014), and musical hallucinations (Kumar et al., 2014), also fall under the term involuntary musical imagery since they are involuntary in terms of onset. I propose the use of the term Involuntary Musical Imagery Repetition (INMIR) to describe the «earworm» phenomenon, a term that captures both its involuntary onset and its repetitive quality.

The definition for INMIR would be along the lines of what has been used previously but with the emphasis on the involuntary and repetitive nature. This would be as follows: “the internal experience of a short section of music that comes into the mind without effort (it is involuntary, i.e., it comes without any intention to retrieve or remember the music) and then repeats (immediately repeating at least once, on a loop, i.e., without consciously trying to replay the musical image) in the absence of an external, direct stimulus from the physical environment and any pathological condition”. The reason I do not propose the use of the term «earworm» instead, as suggested by Williams (2015), is because it has a negative connotation. According to popular belief, having an earworm is an unpleasant experience (contrary to what research shows).

The term INMI may still be used to describe a group of phenomena such as 1) INMIR 2) musical mind-pops, 3) musical obsessions, and 4) musical hallucinations. Figure 6.2 shows a visual representation of the umbrella term INMI and what it covers, including INMIR.

For consistency, the term INMI will be kept for the rest of thesis and until a general consensus is achieved in the research community investigating repeated inner music.

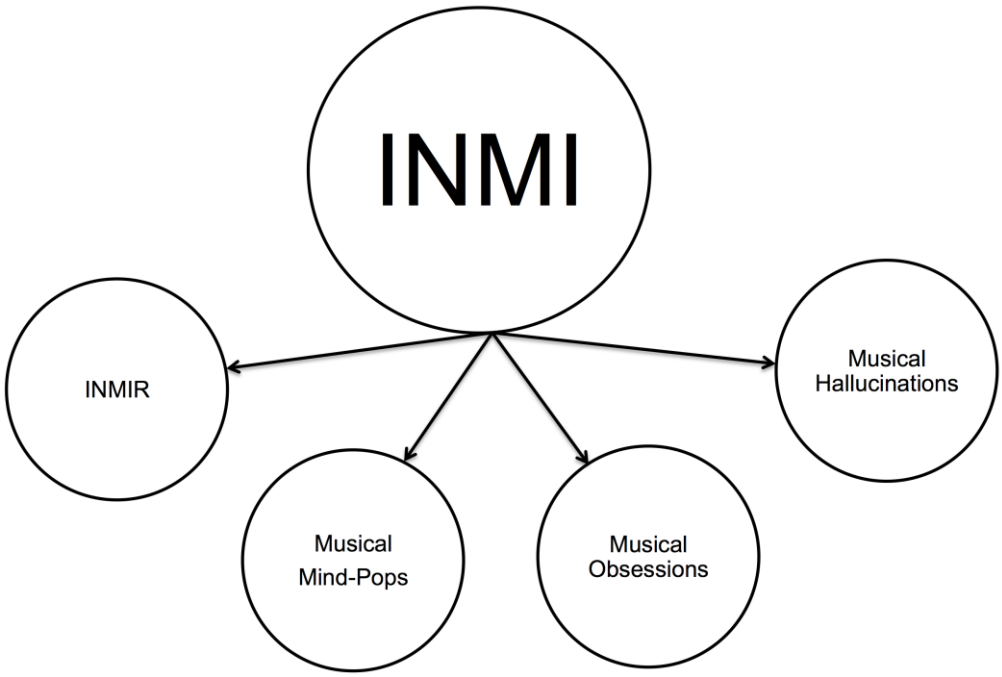

Figure 6.2. Visual representation of the suggested umbrella term INMI (Involuntary Musical Imagery) and its subcategories, INMIR, Musical Mind-Pops, Musical Obsessions and Musical Hallucinations.

The second suggestion concerns the length of INMI. The average life expectancy of INMI varies. Reports about the length of INMI episodes indicate they can last from a few minutes to hours (Halpern & Bartlett, 2011) or up to two days (Beaman & Williams, 2010; Hyman et al., 2013). I propose that if INMI persists more than one week and up to a month or longer, then it should be considered and treated as a musical obsession. Taylor et al.,

(2014) conducted a comprehensive review of published papers from 96 cases of people with musical obsessions and reported that their length ranged from months to years of intermittent or continuous INMI episodes. In the last few years, in the email address my research group holds dedicated to INMI, we have received tens of emails from people who suffer from constant tunes in their mind and are looking for help. I believe that drawing a line between the two phenomena is necessary to avoid confusion that could potentially confound the results of future studies, and will also help people who suffer from musical obsessions and not INMI.

6.6 Methodological Issues: Advantages and Limitations

The studies in the current thesis employed a variety of methodologies for the investigation of INMI, which allowed an evaluation of advantages and limitations of each method.

One of the main findings of this thesis regarding methodology (Chapter 2) relates to the advantage of experience sampling methodology with regard to the reliability it offers in comparison with retrospective reports when researching a phenomenon such as INMI, which is transient by nature. Researchers looking into other types of involuntary memories have highlighted the need for experiences to be recorded at the moment they happen (Berntsen, 2009) and have underlined the need for cautious interpretation of retrospective assessments which may underestimate the frequency of involuntary memories (Kvavilashvili & Mandler, 2004; Rasmussen & Berntsen, 2011; Takarangi, Strange, & Lindsay, 2014). Future

studies should, where possible, combine retrospective self-reports and experience sampling reports for maximum accuracy and clarity, which can be achieved with smartphone technology. This was one of the limitations faced when developing the IMIS, since it was based on retrospective reports regarding INMI frequency, length and other aspects, however such a limitation had to be accepted because conducting an experience sampling study with 2646 individuals (sample size that was used for the development of IMIS) would be extremely challenging.

The use of Bayesian networks in Study 1, for the first time in this type of research, provided useful insights on the interplay of external and internal events, confirming previous associations and, more importantly, revealing new connections and suggesting new explanations regarding the INMI experience. Future studies should make use of this powerful analysis technique and further explore its potential for this kind of research.

The development of a scale measuring four main facets of INMI constitutes an important step forward for INMI research, providing a new tool which will minimize the time needed to collect the necessary data and also allows the exploration of individual differences in relation to INMI and various other phenomena. IMIS has so far been employed in the evaluation of the association of its factors with neural correlates (Farrugia et al., 2015) as well as autistic traits (Castell, 2015) and it is anticipated that it will be of use to other researchers as well as health practitioners working with musical hallucinations and obsessions.

Two behavioral paradigms were developed and used in Study 3, which have the potential to accelerate INMI research in the future. First, an induction paradigm making use of film trailers accompanied by music, introduced a covert paradigm for INMI research. This proved to serve as an efficient INMI trigger under conditions where participants cannot guess the purpose of the experiment, something which might influence the data. Second, the use of the "Mind Activity Questionnaire" for indirect INMI probing was critical to support the covert nature of the paradigm just mentioned and to sample and differentiate between two types of musical imagery (voluntary and involuntary), which is essential when sampling for INMI. This is expected to be of use to INMI researchers who aim to compare the two types of imagery in terms of control as well as different types of imagery in terms of content.

Finally, the use of a semi-structured interview for investigating the phenomenological aspects of a previously unexplored phenomenon (i.e. novel INMI) showed the flexibility of this method and its utility for identifying aspects which cannot be captured by surveys.

6.7 General Limitations in the Thesis

The studies presented in this thesis have a number of potential limitations. Self-reports as used in Studies 1, 2, and 3 could reflect response biases, such as social desirability bias where participants respond in a favourable manner, having in mind how they are perceived by other people, by either over reporting or under reporting behaviors, thoughts and skills (Fisher,

1993). Future research should take this into consideration and include measures of social desirability, such as the Social Desirability Scale (SDS; Crowne & Marlowe, 1960), along with the questionnaires of interest.

The lack of any measure of other types of involuntary memories, such as involuntary autobiographical memories and involuntary semantic memories, as well as intrusive thoughts, prevented the direct comparison of such phenomena with INMI. Future studies should take this into consideration and use the recently developed measures for involuntary autobiographical memories and intrusive thoughts (Berntsen et al., 2015; Hyman et al., 2015).

6.8 Future Directions

The studies described in this thesis raise a number of questions that require further investigation. Future work along these lines should take into account the advantages and limitations of the methodologies highlighted above, as well as of the general limitations of the studies. This section will focus on possible future avenues in INMI research based on the findings described above.

Given the relationship identified between INMI frequency and various musical behaviors, and having in mind the absence, according to results to-date, of a relationship between personality measures and INMI frequency, a next step would be to implement the Gold-MSI battery of listening tests in INMI studies. This battery of tests, measures various musical abilities such as “Melodic Memory”, “Beat Perception”, “Sound Similarity Judgments”, and “Beat

tapping Abilities" and it will help to clarify the fine differences between self-report measures of musicality and musical abilities as measured by the test of batteries, and highlight the musical behaviors associated with INMI frequency and characteristics.

Another interesting next step would be the exploration of the relationship between age and INMI as well as other types of spontaneous cognition such as involuntary memories. It would be noteworthy to look at children and older adults and explore differences in the formation and decline of memory with ageing.

The exploration of novel INMI has just started. Future work could implement creativity tests and explore the experience of novel INMI and creative individuals in general rather than only in composers and musically directed people.

Finally, given the successful application of covert INMI induction paradigms and the overcoming of methodological challenges in the context of the studies described here, brain imaging studies including EEG and fMRI should be initiated to investigate the neural correlates of INMI and pinpoint areas and networks associated to its occurrence and characteristics.

6.9 Possible Applications

In view of the findings in this thesis, some possible applications for INMI beyond academic research are proposed. The identification of the ability of

INMI to induce spontaneous movement similar to that induced by real music implies a potential unintentional aid, along with voluntary musical imagery, in clinical applications for the rehabilitation of stroke patients and individuals with motor disorders such as Parkinson disease. If INMI activates similar brain areas associated to movement as music, a finding, which has been shown already with voluntary musical imagery, then this could imply positive supportive effects of INMI in movement rehabilitation. Future studies using music or voluntary musical imagery in rehabilitation should also take into account and measure INMI effects as well.

A further possible application, stemming from the results of this thesis, relates to IMIS. In addition to being used in research to study individual differences in relation to other phenomena, IMIS could be used as a screening and monitoring tool for clinicians and practitioners seeking to help people who suffer as a result of their INMI. The compact version of IMIS, which only takes 5 min to complete, could provide clinicians with a quick assessment tool to evaluate the severity of the situation and serve as a valid and reliable instrument across time.

Finally, the finding related to the memory consolidation effect of repetition in novel INMI, which could generalise to familiar INMI, highlights the powerful potential of INMI for memory enhancement, which could be harnessed in educational environments as a mnemonic tool for facilitating the learning of new languages or skills.

6.10 Concluding Remarks

INMI is a ubiquitous experience, yet research has only recently started to explore the various factors associated with its occurrence, mainly because of the challenges which studying such a spontaneous phenomenon presents. The work described here is the first empirical thesis exclusively focused on the INMI experience where a wide range of methodologies and approaches have been used to shed light on the phenomenon. Novel methods were introduced, in terms of analysis, behavioral work, and material, which will facilitate future INMI research.

The findings of the work described here contribute to the understanding of the relationship between INMI and spontaneous as well as creative cognition, and confirm and extend previous findings regarding INMI characteristics and their relationship to music perception and voluntary auditory imagery.

More specifically, these findings highlight the potential functions of INMI related to memory consolidation and everyday creativity. Furthermore, the common overt behavioral manifestations between INMI and music demonstrate the supportive therapeutic effects of INMI and constitute the first recognised type of spontaneous cognition which can induce action as manifested in corporeal articulations. Overall, these studies demonstrate that INMI is a special type of spontaneous cognition which not only highlights the power of musical memory and its potential in learning and therapy but also provides an improved understanding of our inner mental life and inner world.

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Appendices

Appendix 1: Experience Sampling Study Materials

Appendix 1.1 Experience Sampling Form

Date: Time when message was received: am/pm Time when form was filled: am/pm

A. At the time of the beep (when the text message came in)

1) I was experiencing an earworm(s) YES/NO

2) My mind had wandered to something other than what I was doing. YES/NO

If NO, go to question 10; if YES, how would you rate the following statements? (1=not at all, 4 moderately, 7=very much)

3) I was aware my mind was wandering in the moments before the beep	1 2 3 4 5 6 7
4) I allowed my thoughts to wander on purpose	1 2 3 4 5 6 7
5) I was thinking about personal concerns or things I need to do	1 2 3 4 5 6 7
6) I was daydreaming or fantasizing about something	1 2 3 4 5 6 7
7) I was worrying about something	1 2 3 4 5 6 7
8) I was remembering something	1 2 3 4 5 6 7
9) My mind was occupied only by the earworm	1 2 3 4 5 6 7

10) What were you doing? (PLEASE UNDERLINE)

Housework, getting dressed, in the bath, travelling, working, studying, reading a book, shopping, exercising, socializing, listening to music, other (please specify) _____

11) How would you rate the way you were feeling (tick in the Table below)?

	Very	Quite	Somewhat	Neither	Somewhat	Quite	Very	
Alert								Drowsy
Happy								Sad
Tense								Relaxed
Interested								Bored
Energetic								Tired
Lonely								Connected

If you're not experiencing an earworm (if you replied NO to question 1) then do not answer section B.

B.

12) Can you name the title and the artist of your earworm tune?
YES/NO

Title _____ Artist _____

13) How would you rate the pleasantness of the earworm? 0-10 (0=not at all pleasant, 10= love it)
_____

14) Can you give a possible explanation of how the earworm was triggered?

☐I heard it recently (Please specify by circling: private music (e.g. home/car), public music (e.g. restaurant, shop), radio, live music, ringtone, contagion, learning, other_____)

❐ I saw a person that reminded me of it ❐ I heard a sound that reminded me of it

☐A word that I saw or heard was somehow connected with the earworm

☐An recent or upcoming event made me think of it ☐A dream that I had is connected with the tune

☐It expresses my current thoughts at this moment/period

☐Other (please specify) _____

Appendix 2. Conditional Probabilities of all Bayesian Networks

2.1 Conditional probabilities of the First Network (INMI & Mind-wandering Network)

Table A.1

Conditional Probabilities of INMI and Mind-wandering

INMI	Mind-wandering	
	0 (No)	1 (Yes)
0 (No)	.56	.20
1 (Yes)	.44	.80

Table A.2

Conditional Probabilities of Activity and Time of the Day

Activity	Time of the Day		
	8:00am-1:00pm	1:01-6:00pm	6:01-11:00pm
1. Working	.28	.32	.04
2. Socializing	.06	.10	.16
3. Grooming	.26	.16	.20
4. Audio/Visual	.07	.09	.21
5. Travelling	.09	.10	.08
6. Physical movement	.06	.07	.05
7. Low Cognitive Load	.06	.02	.06
8. Computer/Leisure	.06	.08	.09
9. High cognitive load	.05	.05	.10

Table A.3

Conditional Probabilities of Mood and Mind-wandering

Mood	Mind-wandering	
	0 (No)	1 (Yes)
1.Drowsy, Lonely, Tired, Bored	.36	.49
2. Relaxed, (Happy)	.26	.20
3. Sad, Tense	.20	.20
4. Alert, Happy, Interested, Energetic, Connected	.17	.11

2.2 Conditional Probabilities of the Second Network (INMI Episodes Network)

Table A.4

Conditional Probabilities of Activity and Mind-wandering

Activity	Mind-wandering	
	0 (No)	1 (Yes)
1. Working	.70	.30
2. Socializing	.75	.25
3. Grooming	.58	.42
4. Audio/Visual	.64	.36
5. Travelling	.54	.46
6. Physical Movement	.60	.40
7. Low Cognitive Load	.37	.63
8. Computer/Leisure	.68	.32
9. High Cognitive Load	.74	.26

Table A.5

Conditional Probabilities of Activity and Time of the Day

Activity	Time of the Day		
	8:00am-1:00pm	1:01-6:00pm	6:01-11:00pm
1. Working	.26	.33	.02
2. Socializing	.049	.06	.10
3. Grooming	.28	.20	.28
4. Audio/Visual	.06	.05	.10
5. Travelling	.10	.14	.12
6. Physical Movement	.06	.08	.06
7. Low Cognitive Load	.08	.03	.09
8. Computer/Leisure	.06	.06	.09
9. High Cognitive Load	.05	.05	.13

Table A.6

Conditional Probabilities of Mood and Mind-wandering

	Mind-wandering	
Mood	0 (No)	1 (Yes)
1. Drowsy, Lonely, Tired, Bored	.39	.52
2. Relaxed, (Happy)	.25	.18
3. Sad, Tense	.20	.20
4. Alert, Happy, Interested, Energetic, Connected	.16	.11

Table A.7

Conditional Probabilities of INMI Trigger and Pleasantness

INMI Trigger	Pleasantness		
	0-4	5-7	8-10
Music Exposure	.36	.23	.41
Association; Person	.49	.23	.29
Association; Sound	.40	.10	.50
Association; Word/Image	.44	.22	.33
Recent/Upcoming Event	.47	.18	.35
Thoughts/ Dreams	.39	.40	.22
No Idea	.15	.47	.38
Same INMI	.64	.22	.13
Default INMI	.61	.26	.13
Memory	.17	.17	.67

2.3 Conditional Probabilities of the Third Network (Mind-wandering Episodes Network)

Table A.8

Conditional Probabilities of Activity and Time of the Day

Activity	Time of the Day		
	8:00am-1:00pm	1:01-6:00pm	6:01-11:00pm
1. Working	.19	.28	.03
2. Socializing	.04	.04	.05
3. Grooming	.32	.20	.36
4. Audio/Visual	.03	.08	.14
5. Travelling	.11	.21	.10
6. Physical Movement	.07	.09	.06
7. Low Cognitive Load	.13	.03	.10
8. Computer/Leisure	.06	.06	.08
9. High Cognitive Load	.03	.02	.08

Table A.9

Conditional Probabilities of Mind-wandering; Allowance and Mind-wandering; Allowance

Mind-wandering; Allowance	Mind-wandering; Awareness	
	1-4	5-7
1-3	.70	.39
4-7	.30	.61

Table A.10

Conditional Probabilities of Mind-wandering; Daydreaming and Mind-wandering; Personal Concerns

Mind-wandering; Daydreaming	Mind-wandering; Personal Concerns	
	1-4	5-7
1-2	.46	.79
3-7	.54	.21

Table A.11

Conditional Probabilities of Mind-wandering; Worries and Mind-wandering; Personal Concerns

Mind-wandering: Worries	Mind-wandering: Personal Concerns	
	1-4	5-7
1	.62	.40
2-7	.38	.60

Table A.12

Conditional Probabilities of Mind-wandering: Only INMI and INMI

Mind-wandering: Only INMI	INMI	
	0 (No)	1 (Yes)
1	.99	.52
2-7	.01	.48

Appendix 3: Film Appraisal, Mind Activity, Direct Paradigm and 24 hours Follow-up Questionnaires

3.1 Film Appraisal Questionnaire

Rate the film clips

Please circle a number from the following scale for each statement:

1) Strongly agree
2) Moderately agree
3) Neither agree nor disagree
4) Moderately disagree
5) Strongly disagree

Please focus on the **film clip content** rather than the quality of the recording.

Film 1

The film clip was very engaging	1	2	3	4	5
The film clip was very emotional	1	2	3	4	5
I liked the music in the film clip	1	2	3	4	5
I liked the visuals in the film clip	1	2	3	4	5
I have seen this film and know it well	1	2	3	4	5
I have heard this music and know it well	1	2	3	4	5

Film 2

The film clip was very engaging	1	2	3	4	5
The film clip was very emotional	1	2	3	4	5
I liked the music in the film clip	1	2	3	4	5
I liked the visuals in the film clip	1	2	3	4	5
I have seen this film and know it well	1	2	3	4	5
I have heard this music and know it well	1	2	3	4	5

APPENDIX 3.2 Mind Activity Questionnaire

Profile of Mental Activity

It is perfectly normal for the mind to wander while your eyes are closed. You may have been thinking of things on purpose or thoughts may have popped into your head outside of your control.

1) Did your mind wander to any aspect of the film clips during the period of silence/when you were playing the dot game? (please circle Yes or No)

YES NO

If "NO", then please skip to the next page and **Question 2**

If "YES", then please fill out the following sections to tell us which aspects of the film clips entered your thoughts

Visual mental imagery (V) - "thoughts in the form of images"

- Percentage of time on visual imagery .....%

- What images did you see (if any)? Please provide a brief description.

  .....

  .....

  .....

- Rate the level of control over these thoughts from 1 (I deliberately generated this imagery) to 7- (the imagery happened outside of my control)

1 2 3 4 5 6 7

Language mental imagery (L) - "Imagined speech"

- Percentage of time on speech imagery .....%

- What speech did you hear (if any)? Please provide a brief description including name of speaker if you know them (including if it was your own voice).

.....

.....

- Rate the level of control you had over the imagery from 1 (I deliberately generated this imagery) to 7- (the imagery happened outside of my control)

1 2 3 4 5 6 7

Musical mental imagery (M) - “Imagined melody, song and/or a rhythm”

- Percentage of time on musical imagery .....%

- What music did you hear (if any)? Please identify or describe the music if the title/ artist is unknown to you.

.....

.....

.....

- Rate the level of control you had over the imagery from 1 (I deliberately generated this imagery) to 7- (the imagery happened outside of my control)

1 2 3 4 5 6 7

Question 2

Do you have any preconceived ideas as to what this experiment is about? (please tick one answer)

_____ No, I have not considered the purpose of the experiment other than what I was told

_____ Yes, I have thought about the purpose of the experiment

If you ticked YES above then please provide a summary of your thoughts

"I think the experiment was about
.....
.....

.....
.....
.....

Follow up request

We would like to be able to contact you by email in around 24 hours time to ask you a small number of follow-up questions, similar to those which you have answered today. You are under no obligation to respond but we would really appreciate your help to complete our study.

We will never pass on your email address and your responses would remain completely confidential at all times.

If you would like to volunteer to help with the follow up then please write your email here

.....
.....

Appendix 3.3 Direct Paradigm Questionnaire

Did you experience any earworms during the period of silence?
An “earworm” (or Involuntary Musical Imagery) is a short section of music that comes into your mind without effort (it is involuntary; without any intention to retrieve or recall the music) and then repeats by itself (immediately repeated at least once, on a loop, without you consciously trying to replay the music).

YES NO

If “YES”, then please fill out the following section to tell us more information about the music that entered your mind.

- Percentage of time during the silence period that you experienced an earworm/earworms .....%

- What music did you experience as an earworm/earworms? Please identify the tune or do your best to describe the music if the title/ artist is unknown to you

.....

.....

.....

Follow up request

We would like to be able to contact you by email in around 24 hours time to ask you a small number of follow-up questions, similar to those which you have answered today. You are under no obligation to respond but we would really appreciate your help to complete our study.

We will never pass on your email address and your responses would remain completely confidential at all times.

If you would like to volunteer to help with the follow up then please write your email here

.....
.....

Appendix 3.4 Twenty-four Hour "Mind Activity Questionnaire"

"It is perfectly normal for your mind to have wandered back to the film clips that you saw yesterday. You may have been thinking about the film clips on purpose or thoughts about them may have popped into your head outside of your control. In this questionnaire we are interested in any mental imagery (thoughts) that you have experienced in relation to the film clips, since seeing them yesterday. Have you thought about the content of the film trailers over the last 24 hours? (i.e. the sights or the sounds)"

In the last 24 hours have you experienced any thoughts containing visual mental imagery in relation to the film clips?

Yes No

What images did you see? Please provide a brief description.

.....
.....

Rate the level of control over these thoughts from 1 (I deliberately generated this imagery) to 7 (the imagery happened outside my control).

1 2 3 4 5 6 7

How frequently would you estimate that your mind wandered to this visual imagery? From 1 (very infrequently) to 7 (very frequently).

1 2 3 4 5 6 7

In the last 24 hours have you experienced any thoughts containing musical mental imagery in relation to the film clips?

Yes No

What music did you hear? Please identify or describe the music if the title/artist is unknown to you.

.....
.....

Rate the level of control over these thoughts from 1 (I deliberately generated this imagery) to 7 (the imagery happened outside my control).

1 2 3 4 5 6 7

How frequently would you estimate that your mind wandered to this musical imagery? From 1 (very infrequently) to 7 (very frequently).

1 2 3 4 5 6 7

In the last 24 hours have you experienced any thoughts containing speech mental imagery in relation to the film clips?

Yes No

What speech did you hear? Please provide a brief description including name of the speaker if you know them (including if it was your own voice).

.....
.....

Rate the level of control over these thoughts from 1 (I deliberately generated this imagery) to 7 (the imagery happened outside my control).

1 2 3 4 5 6 7

How frequently would you estimate that your mind wandered to this speech imagery? From 1 (very infrequently) to 7 (very frequently).

1 2 3 4 5 6 7

Have you had any additional thoughts or ideas about the nature or aim of this study? If yes, then please describe; if no, then type "no".

Appendix 4: The Involuntary Musical Imagery Scale Materials

Table A.13

Initial Hypothesized IMIS (Version 1) Items, Dimensions and Response Scales.

Dimensions, Scales, and Items of the initial IMIS
Intensity/Frequency (Frequency scale*)
1. I experience earworms
2. If I have an earworm it appears only once throughout the day
3. I get earworms soon after waking up
4. I get earworms at the end of the day
5. I get the same earworm coming back again and again
Disturbance (Frequency scale)
6. I try hard to get rid of my earworms
7. I find it difficult to get rid of my earworms
8. I find my earworms help me focus on the task that I'm doing
9. Earworms help me when I'm trying to get things done

10. When I have an earworm I find it easy to focus my attention

11. It worries me when I have an earworm stuck in my head

12. I find my earworms irritating

13. My earworms prevent me from sleeping

14. Earworms prevent me from falling asleep

15. My earworms agitate me

Trigger sensitivity (Frequency Scale)

16. I'm unaware of what caused an earworm

17. I try to work out what might have triggered my earworms

18. Hearing music triggers my earworms

19. My earworms result from unresolved matters

20. Personal issues trigger my earworms

21. Earworms happen when I'm absorbed in what I'm doing

22. My earworms are triggered when I think about past events

23. I get earworms when I’m doing physical activities such as exercise, walking, or cycling

24. I get earworms when I’m doing engaging mental activities such as reading or writing

25. I get earworms when I’m doing routine activities such as housework, cleaning, or brushing my teeth

26. Words that I hear or read trigger my earworms

27. Earworms happen when I'm not particularly focused on what I'm doing

28. My earworms are triggered when I think about future events

Psycho-physiological match (Frequency Scale)

29. My earworms don't necessarily match my mood

30. My earworms have a connection to what I’m currently doing

31. The content of my earworms mirrors my state of worry or concern

32. The rhythms of my earworms match my movements

33. The way I move is in sync with my earworms

34. I get fewer earworms when I'm stressed

35. The speed of my earworms doesn't relate to how fast I move

Vividness (Frequency Scale)

36. My earworms are not as vivid as hearing real music

37. The speed of my earworm matches the speed of the original music

38. If my earworm contains lyrics then the singing voice I hear sounds like my own voice (rather than the original singer)

39. If my earworm contains many instruments I'm not able to hear them all at the same time

40. The lyrics in my earworms are not accurate

41. If my earworm contains an instrument (e.g., a trumpet) then it sounds very much like the original

42. If my earworm contains singing then the voice/s sounds very much like the original version

43. If my earworm is a song I experience only the tune without the words

Induced emotions: Valence (Frequency Scale)

44. The experience of earworms is not pleasant

45. I don't like the music I have as earworms

46. I like my earworms

47. I find my earworms boring

48. My earworms get more annoying the longer they stick in my head

49. Earworms are ‘welcome guests’ in my head

50. I wish I could stop my earworms

51. My earworms energize me

52. My earworms bring back past emotional associations

Approach vs withdraw (Frequency Scale)

53. My typical reaction to an earworm is to do nothing

54. When I get an earworm I try to block it

55. When I get an earworm I try to manipulate it in my head (e.g., make it play to the end, fill in musical details)

56. When I get an earworm I mention it to other people around me

57. My reaction to an earworm is to focus my mind on another task or activity

58. I try to distract myself from an earworm by doing something physical

59. When I get an earworm I move to the beat of the imagined music

60. My reaction to an earworm is to listen to/ sing/ hum/play the imagined music

Familiarity (Frequency Scale)

61. My earworms contain music that I have never heard before

62. The earworms I get are from styles of music to which I would not normally choose to listen

Time, length

63. On average, my earworm (the section of music that is stuck) lasts
1) Less than 5 seconds 2) Between 5 and 10 seconds 3) Between 10 and 30 seconds
4) Between 30 seconds and one minute 5) More than 1 minute 6) I don't know 7) N/A

64. Compared to the complete original music my earworm (the section of music that is stuck) is
1) Very much shorter 2) Somewhat shorter 3) A little shorter
4) About the same length 5) Longer 6) I don't know 7) N/A

65. On average, one earworm episode (a period of time where one particular tune gets stuck) lasts
1) Less than 10 minutes 2) Between 10 minutes and half an hour 3) Between half an hour and 1 hour
4) Between 1 and 3 hours 5) More than 3 hours 6) I don't know 7) N/A

66. On a day when I get a particular earworm I tend to notice it
1) Only once that day 2) Two or three times that day 3) More than five times that day
4) More than ten times that day 5) Almost continuously during the day 6) I don't know 7) N/A

67. My most recurring earworm has visited for
1) Days 2) A week or so 3) Two weeks or more
4) A month or more 5) Over a year 6) I don't know 7) N/A

68. In my life, there have been times when I've had earworms more frequently and times when they were less frequent
1) Strongly Disagree 2) Moderately Disagree 3) Neither Agree nor Disagree
4) Moderately Agree 5) Strongly Agree 6) I don't know 7) N/A

* Frequency Scale
1) Always 2) Most of the time 3) Sometimes 4) Not very often 5) Never

Appendix 5: Interview Materials

Appendix 5.1 Interview schedule

Thank you for agreeing to take part in this interview.

I am a PhD student at the Music, Mind and Brain group at Goldsmiths, University of London. The topic of my thesis is involuntary musical imagery (INMI) or as it is colloquially known, earworms. These are short sections of music, which come to the mind unintended and then repeat themselves without conscious control.

So far research has focused on INMI that come from memory. In some of these studies we found some people experience novel INMI. What I mean with novel INMI is the sections of music that come to the mind unintended and then repeat and to the best of the individual's knowledge, have never been heard before. Through reports from questionnaires we know that there is a small percentage of people who experience novel INMI but we don't know details about the phenomenon. In our initial communication you stated that you've experienced novel INMI in the past as part of your life as a composer. With your help we are aiming to see in depth and understand more about this experience.

Throughout the interview I will refer to INMI and novel INMI. Do you understand the difference between them? Can you tell me?

The interview is divided in two parts. The first focuses on general INMI and the second part of the interview in novel INMI.

Before starting the interview do I have your permission to film/record the interview? This is because I can then listen to what you are saying instead of having to write everything down, and I can also analyse the interview in greater detail.

All data will be securely stored and kept confidential and anonymous

1st part: General

[Interviewer: The following questions are related how you compose music and also a bit about your general INMI experiences. Try to recall previous experiences of yours and observations and not voluntarily recall a tune after each question.]

1) Do you experience your own compositions as INMI? If so, how often?

2nd part: Novel INMI

[Interviewer: The following questions are related to the times that you experience novel tunes in your head. I would like you to think about the times that you noticed that you were experiencing a new composition in your head, either you later wrote it down/composed it or not]

2) How often do you experience novel INMI?

3) Can you give me some examples of what kind of activities you're engaged in when you get novel INMI?

4) Do you have a sense of something familiar but not known is experienced when you experience the novel INMI in your head?

5) How would you describe the emotions that you feel or the mood you are in when experiencing that phenomenon, the moment of insight?

6) What kind of musical structure is the novel INMI usually? (e.g. only melody, only chord sequence?, sounds? full song etc.)

7) Is the element of repetition useful in any kind of way? How would you describe it?

8) Can you describe to me how you capture them? E.g. iphone app, instrument

9) Are there times when what you have in mind (the novel INMI) can't be actually recorded/played?