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Towards a new methodological approach: A novel paradigm for covertly inducing and sampling different forms of spontaneous cognition

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Abstract

A wide range of cognitions is generated involuntarily in the human mind daily. We developed a paradigm, which covertly induces and samples spontaneous cognitions in the visual and auditory modalities, focusing on 3 key characteristics: spontaneity, repetition, and emotional valence. Sixty participants watched two visual clips while listening to music and assessed their characteristics. Post-induction, participants closed their eyes for 5 minutes and then completed a questionnaire, which indirectly samples different forms of spontaneous cognition. Induction was effective in all categories. Results indicated that different forms of spontaneous musical cognitions are experienced as longer in duration and less negative in emotional valence compared to visual cognitions. The findings are discussed in relation to spontaneous cognition methodology and experiences in different modalities. Spontaneous cognitions are multifaceted and not unitary constructs as previously considered and studied, and as such the novel induction and sampling paradigm presents a promising line of research.

Keywords: spontaneous cognition, induction paradigm, mind wandering, involuntary autobiographical memories, involuntary semantic memories, involuntary musical imagery, musical mind-pops, intrusive memories, obsessive intrusive thoughts

1. Introduction

Whilst it is tempting to assume control over our thoughts, a large proportion of human cognitions are spontaneous in nature (Killingsworth & Gilbert, 2010; Song & Wang, 2012), i.e. they are not the product of intentional generation. Since the beginning of research in this field, there has been a rapid growth in efforts to define, classify, and study a wide variety of different forms of spontaneous cognition, including task-unrelated thought (Giambra, 1989), stimulus-independent thought (Teasdale et al., 1993), mind wandering (Smallwood & Schooler, 2006), involuntary autobiographical memories (IAMs; Berntsen, 1996), involuntary semantic memories (ISMs; Kvavilashvili & Mandler, 2004) such as involuntary musical imagery (INMI; Williamson et al., 2012) and musical mind-pops (Kvavilashvili & Anthony, 2012), intrusive memories (Holmes, Brewin, & Hennessy, 2004), and obsessive intrusive thoughts (OITs; Berry & Laskey, 2012). All these terms refer to thoughts that have been recalled involuntarily and appeared unexpectedly in the mind but which can vary in sensory modality and phenomenological characteristics such as repetition and emotional valence. This variety may reflect differences in the antecedent cognitive processes such as the executive resources available, hence the importance of defining clearly the prototypical characteristics of the cognitions.

1.1 Terminology and basic features of spontaneous cognitions

A key problem in spontaneous cognition research is that terms are used interchangeably whilst, in addition, different researchers often use the same word to refer to different concepts. Here we outline the most common types of spontaneous cognition, their definitions and their core characteristics, in an attempt to simplify empirical investigation. We will begin with terms more liberal in their defining features and move on to special forms that have more restricting characteristics.

One of the most widely studied forms of spontaneous cognition is mind wandering, a term which refers to any type of thought irrelevant to the task at hand (Smallwood & Schooler, 2015). Up until recently, the onset of the experience was assumed to be involuntary or was not taken into consideration; however, it has now been recognized that the experience can be both deliberate and spontaneous (Carriere et al., 2013; Seli, Risko, Smilek, & Schacter, 2016). No other features, such as the temporal aspect (future/past), repetition, and emotional valence are important for defining this internal mental state; indeed, these features of mind wandering can vary.

Moving on to spontaneous memory, there are two main forms that have been most studied: involuntary autobiographical memories (IAMs) and involuntary semantic memories (ISMs). Kvavilashivili (2014) suggested a taxonomy for spontaneous cognitions and defined IAMs as “memories of past events that pop into mind unexpectedly without any attempt to recall them and they may refer to positive, negative, or completely neutral events”. Within this definition spontaneity, repetition, and temporal aspect (past) are crucial whilst emotional valence can vary. ISMs on the other hand, refer to spontaneous memories stripped of autobiographical and personal meaning; they can be words, images, and music, can be one-off or repeated occurrences, and can vary in emotional valence (Kvavilashvili & Mandler, 2004). The most common and studied forms of this type of memory are primarily in the auditory modality; involuntary musical imagery (INMI; Liikkanen, 2012) and musical mind-pops (Kvavilashvili & Anthony, 2012) refer to the involuntary recall of music, in the former but not the latter case over repeated occurrences. For both, emotional valence can be positive, neutral, or negative.

Intrusive memories are another type of spontaneous cognition, defined by Kvavilashvili (2014) in her taxonomy as “spontaneous involuntary memories of a mostly negative event that repeatedly intrude consciousness often against one’s will”. Thus spontaneity, repetition, and negative emotional valence are core to the definition of this experience.

Finally, the term "obsessive intrusive thoughts (OITs)" refers to spontaneous, repetitive, and unpleasant cognitions of specific content related to, for example, aggression, sex, and mistakes (Garcia-Soriano, Belloch, Morillo, & Clark, 2010). The definition of obsessive intrusive thoughts features spontaneity, repetition, and negative emotional valence as well as specific content, as crucial aspects of the experience.

The focus of our paper is on the abovementioned forms of cognition and their subtypes discussed in the preceding paragraphs in terms of their key characteristics; spontaneity, repetition, and emotional valence. In addition, we will explore a characteristic within these cognitions that is commonly overlooked, namely the corresponding sensory modality in which they are experienced.

1.2 Empirical research in spontaneous cognition

Whilst research into each of the spontaneous cognition forms noted above has progressed (Elua, Laws, & Kvavilashvili, 2012; Jakubowski et al., 2017; Konishi & Smallwood, 2016; Rasmussen, Ramsgaard, & Berntsen, 2015), advances have been based on in–depth studies of a single form of cognition in isolation, with the exception of correlational studies using retrospective self-report questionnaires (Berntsen, Rubin, & Salgado, 2015; Seli, Risko, Purdon, & Smilek, 2016). It is notable that there are only a handful of behavioural studies that directly compare the main features of spontaneous cognition forms that differ in their temporal aspect (past and future) (Cole, Staugaard, & Berntsen, 2016; Cole & Berntsen, 2016). Furthermore, no experimental methodologies currently exist that allow for within-participant comparisons of different characteristics across spontaneous cognition forms.

From the above discussion it is clear that there is a real need for the development of an experimental induction and sampling paradigm that can be used for the study of multiple forms of spontaneous cognition. Such methodological advancement will allow for the identification of similarities and differences in the mechanisms involved in spontaneous cognitions and provide insights into the extent to which they can be regarded as overlapping cognitive experiences. Next, we review the experimental paradigms which have been utilized for the induction and sampling of spontaneous cognitions.

Although the experimental procedures in spontaneous cognition induction studies vary, depending on the form under investigation and the research question, their key elements overlap. We have divided these elements along a timeline: (1) the induction stimulus associated with the encoding of the cognition, (2) the immediate (post)induction task/period, and (3) the sampling method, which in combination with the (post) induction task can be thought of as the retrieval phase of the spontaneous cognition. An additional crucial feature that is relevant to the present work is the wording of the experimental instructions. Finally, we identify induction rates and/or frequencies where reported, to explore how effective these procedures are and what could have influenced their induction. For reasons of brevity, each of these timeline components will be discussed briefly in relation to each spontaneous cognition form.

1.2.1 Mind wandering

The majority of behavioural mind wandering studies set conditions that are conducive to mind wandering, which typically involves low demanding sustained attention tasks such as the sustained attention to response task (SART) and simple go/no-go tasks, (Marcusson-Clavertz, Cardeña, & Terhune, 2016; McVay, Kane, & Kwapil, 2009; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997) or a rest period where participants do nothing and have their eyes closed (Mason et al., 2007). Mind wandering sampling most commonly occurs while the task or the resting period is taking place, via real-time subjective self-reports, either probe- or self- caught (for an extensive review see Weinstein, 2017).

In probe-caught sampling, participants are prompted, either by the experimenter or with automatic prompts like beeps, to indicate whether their mind was wandering right before or during the prompting (Marcusson-Clavertz, Cardeña, & Terhune, 2016; McVay, Kane, & Kwapil, 2009). In self-caught sampling (Schooler, Reichle, & Halpern, 2004), participants are asked to report themselves, without prompts, when their mind wandered, which requires the individual to also have an awareness of this internal state (meta-awareness; Schooler et al., 2012). In some cases, retrospective sampling post-task is preferred to avoid the drawbacks of real-time sampling, namely the interruption of the experience in the moment that it occurs and the revelation of the experimental goal (Farley, Risko, & Kingstone, 2013; Stawarczyk, Cassol, & D' Argembeau, 2013).

In terms of instructions, the majority of previously employed paradigms have explicitly stated the goal of the study, while a few have attempted to "suppress" the term "mind wandering" to avoid instruction biases (Jackson & Balota, 2012; McVay & Kane, 2013; Medea et al., 2016), which could prime as well as influence the characteristics of the experience. Finally, induction rates are usually not reported, because mind wandering is viewed as a flow of consciousness; a uniform and single state episode.

1.2.2 Involuntary Autobiographical Memories (IAMs)

A well-established experimental paradigm in IAM induction studies was developed by Schlagman and Kvavilashvili (2008). To conceal the goal of the study, participants are informed that they will participate in a "concentration experiment". As soon as the experiment starts, participants are told that they might find themselves thinking about other things unrelated to the task, such as memories, daydreaming, future goals etc., and are asked to identify such memories or thoughts that spontaneously “pop” to mind. Next, participants engage in an undemanding vigilance task where they have to identify vertical lines in a stream of horizontal lines. Similar to mind wandering studies, there is no specific induction stimulus that serves to prime the experience of a particular IAM. Rather, the vigilance task also includes word-phrases that are expected to trigger IAMs in a free-form manner resembling naturally occurring experiences.

Previous studies have used both self- and/or probe-caught methods to sample IAMs during this task (Vannucci et al., 2014; 2015) and have reported differences in the frequencies and phenomenological characteristics according to both the experimental instructions (i.e. the word ‘thought’ was used instead of ‘memory’), and between probe and self-caught methods of sampling (Vannucci et al., 2014). The mean number of induced IAMs ranges from 3.60 (Vannucci et al., 2015) to 13.58 (Vannucci et al., 2014).

1.2.3 Involuntary Semantic Memories: Involuntary Musical Imagery

Behavioral research on ISMs is sparse, except for one particular form, INMI. This relatively new field of research provides insights into spontaneous cognitions in the auditory modality. Usually, participants are not informed that the study is about INMI, but rather are told that they will rate some experimental stimuli (Hyman et al., 2013; 2015). In the laboratory context, conditions conducive to INMI are set to increase the chances of their occurrence. Participants are typically exposed to induction stimuli, such as popular music tunes, which are expected to be experienced as INMI. Subsequently, participants complete a low cognitive load task (e.g. a simple puzzle) or rest for a short period of time. Sampling of INMI occurs retrospectively, immediately post-task, where participants are explicitly asked to report any INMI occurrences during the task (Byron & Fowles, 2013; Campbell &

Margulis, 2016; Floridou et al., 2012; Hyman et al., 2013; Liikkanen, 2012a). Reported induction occurrence rates are between 65% and 75% (Floridou et al., 2012; Hyman et al., 2013).

1.2.4 Intrusive memories

The classic experimental paradigm used for inducing spontaneous, intrusive cognitions in the form of visual memories is the trauma film paradigm (Horowitz, 1969; Lazarus, 1964; for a review see: James et al., 2016). According to this paradigm, aversive video clips (e.g. human surgery, fatal road traffic accidents) are used as induction stimuli. Participants then perform a task, usually visuospatial or verbal (Deeprose et al., 2012; Green & Bavelier, 2003; Holmes, James et al., 2010), and in some cases sit with their eyes closed (Hawkins & Cougle, 2013; Wilksch & Nixon, 2010). Intrusive memory sampling is most commonly done retrospectively, immediately after the task or in the days that follow (Deeprose et al., 2012), whilst probe and self-caught methods have both been used to sample intrusive memories (Takarangi et al., 2014). In all of the reported studies, participants were provided with a definition of what an intrusive memory is either before the task or when sampling the experience. Induction rates vary depending on the measurement time point (immediately post induction or in the following days). Two studies reported mean frequency counts of 2.6 intrusive memories in a 2-minutes period (Morina, Leibold, & Ehring, 2013) and 11.78 intrusive memories during an unspecified time period (Takarangi, Strange, & Lindsay, 2014). Similar paradigms using aversive pictures (physical injury and death) have been used in IAM research (Hall & Berntsen, 2008), with a mean induction frequency rate of 2.18 IAMs across 5 days.

1.2.5 Obsessive Intrusive Thoughts

Induction paradigms for examining obsessive intrusive thoughts (OITs) follow a different approach. Commonly, participants are instructed to bring to mind a specific intrusive thought (either from their personal past or from a list of standardized items) and think about it for a short period of time (usually between 30 sec and 3 min; Olafson et al., 2014; Purdon et al., 2011; Beadel et al., 2013; Lambert et al., 2013; Magee et al., 2014; Magee & Teachman, 2012); this specific thought is considered to be the induction stimulus. Next, participants are instructed either to think freely or to actively suppress such thoughts. Self-caught sampling takes place during this period of time (between 3 and 8 minutes) for any intrusive thoughts that occur (Magee et al., 2014; Olafson et al., 2014). Frequency rates have not generally been reported in OIT induction studies although frequency of OITs is considered to be a crucial difference between clinical and non-clinical samples.

1.3 Methodological limitations and considerations

Whilst the laboratory study of spontaneous cognitions has advanced in recent years, there are a number of methodological limitations common to all induction procedures that need to be addressed. These limitations concern the suggestion and report biases as well as demand characteristics that are often inherent in the experimental instructions of induction paradigms. Currently participants are informed about the type of thought to be investigated either in advance of the study or when sampling the experience. This approach mitigates the risk of participants voluntarily recalling a memory (Barzykowski, 2014) or reporting naively understood concepts of e.g. IAMs (Vannucci et al., 2014). However, these biases arguably influence the perceived spontaneity of the experiences under investigation, their true frequency, and phenomenological characteristics; only a few studies have sought to consider these limitations (Barzykowski & Niedźwieńska 2016; Vannnucci, Batool, Palagatti, &

Mazzoni, 2014). To address these issues, when studying IAMs, Vannucci et al. (2014) asked participants to record involuntary thoughts instead of memories in one experimental condition and to provide information about their phenomenological characteristics. This allowed the researchers to later classify the reports as memories or not. In another experimental condition, they asked participants directly for involuntary memories. Their results indicated differences in frequency and phenomenological characteristics between the two conditions. Nevertheless, the characteristic of spontaneity is still mentioned to participants, which could significantly impact on the true onset of the thought and its phenomenological characteristics.

To overcome the abovementioned limitation of perceived spontaneity, Floridou, Williamson, and Stewart (2017) developed a novel, twofold covert laboratory paradigm for inducing INMI, whereby participants were not aware of the purpose of the experiment either before induction or when sampling the experience. The experiment was advertised as "films and attention"; short film trailers with prominent soundtracks were used as induction stimuli. Following this induction, participants rated the stimuli and subsequently engaged in one of four tasks of increasing cognitive load. Covert sampling of INMI was achieved post-task retrospectively by asking participants to complete a questionnaire sampling for various types of mental imagery (visual, musical, and speech) experienced during the task and rating their characteristics, including their perceived spontaneity and duration, which allowed the researchers to later reconstruct the experience. INMI induction occurrence rate was 65% during the lowest cognitive load (eyes closed), while none of the 160 participants identified the aim of the experiment, confirming the efficiency of the covert induction and sampling method.

Given the limitations of previous induction methods, covert paradigms, such as the Floridou, Williamson, and Stewart (2017) paradigm, could benefit other areas of spontaneous cognition research, which are still susceptible to suggestion and demand biases. On the other hand, this retrospective sampling method could be prone to memory biases, as participants might not accurately remember their experiences after a short period of time.

An additional concern is that because the focus of research has been on individual forms of spontaneous cognitions, their heterogeneity in terms of sensory modality has been overlooked. To date, the majority of research into spontaneous cognitions has either focused on the visual domain or has not considered wider issues regarding the sensory modality of the cognition that was experienced (e.g. visual vs auditory elements). The modality characteristics of the spontaneous cognition may reveal different behavioral and neural correlates and provide valuable insights into the nature of these cognitions, including whether their underlying mechanisms are modality-specific or modality-general.

A handful of mind wandering studies have acknowledged the importance of the heterogeneity in the experience and used multi-dimensional experience sampling (MDES; Medea et al., 2016, Smallwood et al., 2016). This technique measures various elements of mind wandering such as the temporal aspect (past, future), focus on self or other, etc. Whilst methodologically valid, this technique overlooks the auditory modality in the form of music, which is ubiquitous, or sounds and speech. When asking for words ("My thoughts were in the form of words"), it does not clarify if it is in the form of speech, which could have an auditory element instead of a visual one if it is experienced in the form of written form (Smallwood et al., 2016; Wang et al., 2018). Hence there is strong motivation to develop a paradigm that allows sensory modality comparison within each spontaneous cognition form, facilitating an understanding of how and where such phenomena are different and unique.

1.3 The current study

The first aim of the current study was to design a new, twofold experimental paradigm for the simultaneous covert induction and sampling of different spontaneous cognition forms. These include mind wandering, involuntary autobiographical memories (IAMs), involuntary semantic memories in the form of involuntary musical imagery (INMI) and musical mind-pops, intrusive memories and obsessive intrusive thoughts (OITs).

The induction paradigm we developed is an analogue of the trauma film paradigm (Horowitz, 1969; Lazarus, 1964) and the INMI induction method (Floridou et al., 2017). We used video clips depicting events most commonly experienced as OITs alongside popular music, as we were also interested to explore whether research into this type of cognition can be served by the new paradigm. Participants were unaware of the purpose of the study when priming and probing the cognitions, as stimuli were presented in the context of a study about "health and safety". Covert experience sampling occurred when participants rated retrospectively the core characteristics of the cognitions, namely spontaneity, repetition, and emotional valence. This method allowed us to reconstruct later the range of different forms of cognitions that occurred and to avoid any instruction biases.

We categorized cognitions that occurred (a) *spontaneously* as representing instances of *unintentional mind wandering* in both sensory modalities, (b) *spontaneously and repetitively* as representing occurrences of *intrusive memories* in the visual modality and *INMI* in the auditory modality, (c) *spontaneously and non-repetitively* as representing episodes of *IAMs* in the visual modality and *musical mind-pops* in the auditory modality, and (d) *spontaneously, repetitively, and negative in emotional valence* as representing *intrusive thoughts* in the visual modality and *negative INMI* in the auditory modality.

A second aim of the current study was to distinguish and compare the phenomenological characteristics of the induced spontaneous cognitions between the visual and auditory modality, both those reported in the laboratory and those experienced over a 24-hour follow-up. Comparison between two modalities is a novel aspect of our approach, as the majority of spontaneous cognitions have been studied as unimodal constructs as the sensory modality of the experience has been largely overlooked. The sensory modality could reveal crucial differences in the underlying mechanisms and the behavioural and neural correlates of the cognitions.

To summarise, this study is the first to induce and sample multiple forms of spontaneous cognition and to directly compare the visual to auditory modality with regard to various characteristics. The primary outcome will be new insights into the cognitive etiology of these experiences.

2. Method

2.1 Design

We employed a within-participants design, with the sensory modality of the cognition serving as an independent variable with two levels (visual, musical). The key dependent variables were occurrence (whether spontaneous cognition induction was effective for each participant, independently of the number of cognitions induced), frequency count (the number of cognitions per participant), estimated duration of spontaneous cognition, and emotional valence attributed to the cognition.

The study featured an experimental laboratory session where the spontaneous cognitions were sampled retrospectively and an online 24-hour follow-up experience sampling survey. In the laboratory, participants attended in groups of 1-6 and were tested simultaneously. The videos and music were presented in counterbalanced order (induction).

2.2 Participants

A convenience sample of 60 (52 female) year one undergraduate Psychology students, ranging in age from 18 to 31 years (M = 18.8, SD = 1.75) participated in exchange for course credits. Individuals were eligible to participate in the study if they declared no previous history of mental health issues (such as post-traumatic stress disorder, obsessive-compulsive disorder) and/or impaired hearing or vision.

2.3 Ethics Statement

The study received ethical approval from the Department of Psychology Ethics Committee, the University of Sheffield.

2.4 Materials

2.4.1 Stimuli

Two videos were used for the purposes of the study. Each video included the joint presentation of three visual clips and one piece of music. The visual clips used were representative of the most commonly reported obsessive intrusive thoughts (OITs), as reported on the INPIOS questionnaire (*The Obsessional Intrusive Thoughts Inventory; Spanish original version: Inventario de Pensamientos Intrusos Obsesivos;* García-Soriano, 2008) based on the findings of our work (in preparation) with a sample of non-clinical participants (n = 528; 324 women, age range 18 to 75 years, M = 41.15, SD = 14.7). Thematically the videos fell under two main categories: (a) *aggressive* thoughts (e.g. 'When in a high place (like a cliff, bridge, high building, etc.), I have had mental intrusions of jumping off a high place'), and (b) thoughts related to *doubts, mistakes, and necessity to check* (e.g. 'Even though I know it probably is not true, I have had mental intrusions of having left something on at home (e.g. kitchen, gas, heat, stove, lights, cigarette, etc.)').

The first video contained three visual clips depicting scenes related to *aggressive* thoughts: (1) a man ready to jump off a high scaffold, (2) a person preparing to cut themselves with a knife, and (3) a man jumping onto the rails in advance of a moving train. The second video included three visual clips depicting scenes related to *doubts, mistakes, and necessity to check*, in everyday life situations: (1) a woman leaves her house forgetting the stove on, (2) a woman gets out of her car and walks away without locking it, and (3) a water tap is left on. All the visual clips were presented from a first-person perspective and were accessed and downloaded from youtube.com. The videos were created using Adobe Premiere (2017) software. The duration of each was 49 seconds.

The accompanying musical tracks were selected from an online database with INMI reports (earwormery.co.uk; see Floridou et al., 2015; Jakubowski et al., 2017; Müllensiefen et al., 2014; Williamson et al., 2012; 2014) and matched the intramusical and extramusical features of the most commonly reported INMI, namely song popularity, fast tempo, and a combination of unusual interval pattern and typical global melodic contour (Jakubowski et al., 2017). One track featured a female voice (*Adele – Rolling in the Deep, 2011*) and the other a male voice (*Gotye – Somebody that I Used to Know, 2011*). The lyrics of both were about a relationship break up.

2.4.2 Questionnaires

Clip Appraisal Questionnaire. An adapted form of the "Film Appraisal Questionnaire" (Floridou et al., 2017) was used to measure any distress ("The clip made me feel distressed") and anxiety ("The clip made me feel anxious") that people experienced while watching the visual clips. Familiarity with the content of the visual clip as a thought was also assessed ("I have thought about this happening to me")[1]. Finally, music enjoyment

[1] The data from this item were collected and analysed for the purposes of another paper (in preparation).

("I liked the music in the video") and familiarity ("I have heard this music and know it well") were measured. Each of these items was assessed on a 5-point scale (1 = Strongly disagree; 5 = Strongly agree).

Mind Activity Questionnaire. An analogue version of the questionnaire used in Floridou et al. (2017) was implemented. To covertly sample the occurrence and phenomenological characteristics of any thoughts (visual, musical, or speech), we avoided providing any prompt featuring a description of spontaneous cognition forms. The questionnaire was divided into three sections, each of which was labelled according to the cognitive experience of interest; visual, musical, or speech. In each section participants were presented with identical scales to self-report on the features of the experiences relating to perceived spontaneity, repetition, and emotional valence. We also avoided using the terms "memory" or "mental imagery" and instead used "thought" as a probe relating to the visual (thoughts in the form of image) and musical (thoughts in the form of music) aspects of the clips. Speech aspects (thoughts in the form of speech) were also measured to conceal the purpose of the study as no speech stimuli were used. Given their subsequent low occurrence rate, they are not reported in this paper.

The instructions in the questionnaire were as follows: "It is perfectly normal for the mind to wander while you were sitting with your eyes closed. You may have been thinking of things on purpose or thoughts may have popped into your head outside of your control. We would like to ask you about any thoughts you might have had related to the clips you previously watched." A list containing words to describe each video was included as reminder cues, (e.g. unattended kitchen, jumping off a high place) in the visual and speech sections. In the musical section the title of the song and the name of the artist were provided. In all sections, the option to report if thoughts were not experienced was also given in addition.

For any reported thoughts, participants completed follow-up questions on: (a) the estimated duration of the thought as a percentage of time during the 5-minute rest period, (b) perceived spontaneity (1 = I deliberately generated this thought; 7 = The thought happened outside of my control), (c) repetition (Yes, No), (d) type of thought (Personally relevant or Memory of the video)[2], and (e) the emotional valence of the thought (1 = Very unpleasant; 7 = Very pleasant). Finally, participants were asked for any thoughts that they had regarding the purpose of the experiment ("Do you have any preconceived ideas as to what this experiment is about?") and, if they answered yes, they were requested to provide a short summary of what they thought.

An online adapted version of the Mind Activity Questionnaire was created to measure the same characteristics as described above with reference to the 24-hour period after the experimental session.

2.5 Procedure

The experiment was advertised via an online platform for participant recruitment as being about "the effects of health and safety in everyday life". The study advertisement included the following information: "You are invited to take part in a study about the effect of health and safety messages in videos. The study is in two parts, over 2 days, and in total will take no more than 1 hour. On Day 1, you will be invited to attend the Psychology department for up to 30 minutes. During this time you will watch and evaluate short film clips, which contain aggressive, offensive, and domestic scenes that might be considered disturbing. On Day 2, you will be sent an email to complete a short online survey at a location of your choice, which will take up to 30 minutes."

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[2] The data from this item were collected and analysed for the purposes of another paper reported elsewhere (in preparation).

Participants were tested in a lecture style manner. The experimenter was present and provided the instructions in a presentation style using PowerPoint. Upon arrival at the lecture room, participants received information verbally about the study and were also given an experimental booklet containing a consent form to sign and the questionnaires relevant to the study. Participants were informed that they could withdraw from the study at any point (including after data collection) and assured that their data would be kept confidential and anonymous. The experimental instructions avoided all mention of the true focus of the study, either in advance or during retrospective experience sampling.

The experimental session was divided into two phases. During Phase 1, participants were given the experimental booklet and told not to open it or turn the pages unless they were instructed to do so. Participants were informed that they would be shown two videos related to health and safety issues and will be asked to complete a few questions about them. Next, participants were presented with the videos along with the music. Time was allowed for participants to ask questions before or after showing the videos. At the end of each of the two videos participants were instructed to turn to the next booklet page and report their opinion by answering the “Clip Appraisal Questionnaire” for each of the three clips and the music presented in each video.

In Phase 2, participants were asked to close their eyes, sit quietly and comfortably, and let their mind wander and do what it wants to do for 5 minutes (rest period). The researcher notified participants when the 5 minutes were over and asked them to open their eyes. The aim of the rest period was to induce a diffused state of attention, the most common state in which various types of spontaneous cognition tend to occur (Ball & Little, 2006; Berntsen, 2009; Floridou et al., 2017; Schlagman, Kliegel, Schulz, & Kvavilashvili, 2009). Subsequently, participants were asked to turn to the next page and complete the Mind Activity Questionnaire. At the end of the study, participants were informed that 24 hours after the session they would receive an email invitation to complete an online survey with questions similar to the ones they completed in the laboratory. Participants were asked to complete the survey within 4 hours of receiving the email. The laboratory part of the study lasted approximately 25 minutes.

Twenty-four hours later participants received an email with a link containing the online survey, which included the Mind Activity Questionnaire and a series of other questionnaires[3]. The online part of the study took up to 30 minutes to complete. A visual representation of the procedure can be seen in Figure 1.

[3] The questionnaire data were collected and analysed for the purposes of another paper reported elsewhere (in preparation).

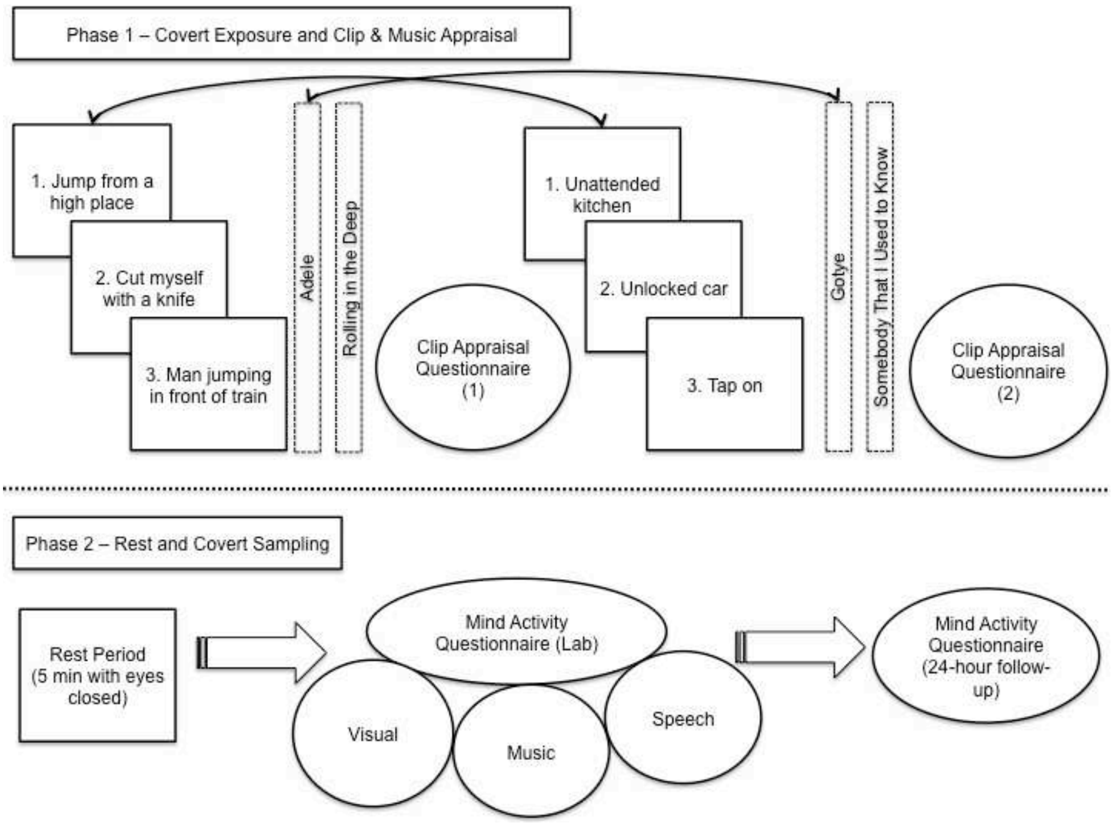

Figure 1. Visual representation of the experimental procedure and the 24-hour follow-up. In Phase 1 (covert exposure and clip & music appraisal) videos and music were presented in a counterbalanced order (represented by arrows) to the participants, who, after each exposure, completed the Clip Appraisal Questionnaire. In Phase 2, participants closed their eyes for 5 minute (rest period) and then immediately completed the Mind Activity Questionnaire, which covertly samples different types of cognitions. On the following day participants completed a 24-hour follow-up online version of the Mind Activity Questionnaire.

2.6 Statistical analysis

Participant responses across each type of thought (visual, musical, and speech) on the Mind Activity Questionnaire were coded based on three criteria (spontaneity, repetition, and emotional valence). They were divided in four categories (visual and musical) that represented the different forms of spontaneous cognition, moving from a general and liberal definition to more specific characteristics: (1) *Spontaneous* (scores ≥ 4 on the perceived spontaneity scale), (2) *Spontaneous & non-repetitive* (scores ≥4 on the perceived spontaneity scale and 'no' in self-report repetition), (3) *Spontaneous and repetitive* (scores ≥4 on the perceived spontaneity scale and 'yes' in self-report repetition), and (3) *Spontaneous, repetitive, and negative valence* (scores ≥4 on the perceived spontaneity scale, 'yes' on self-report repetition, and scores ≤ 4 on the emotional valence scale).

The *occurrence* variable (binary score) represents the experience or not of spontaneous cognition regardless of *frequency count*. A binary score was calculated for *occurrence* based on the perceived spontaneity scale in the Mind Activity Questionnaire (1 = I deliberately generated this thought; 7 = The thought happened outside of my control) and was dichotomized to 0 if the score was between 1 and 3 (voluntary retrieved) and 1 if the score was between 4 and 7 (spontaneously retrieved) according to the coding used in Floridou et al. (2017)[4]. The *frequency count* variable represents the overall count of different spontaneous cognitions reported by each participant.

3. Results

3.1 Video Clip and Music Appraisal Ratings

First, we examined the descriptive statistics as a manipulation check for the characteristics related to the video clip visuals. Results on distress and anxiety, as rated by the participants in the *aggressive* and in the *doubts, mistakes, and necessity to check* videos, can be seen in Table 1. The assessed characteristics of the music tracks used as stimuli, enjoyment, and familiarity with the music, are presented in Table 2. Among the video clips, 'jump in front of train' and 'unattended kitchen' were rated as the most distressing and

[4] Footnote. Other studies used a similar coding approach (Barzykowski & Niedzwienska, 2016; Christoff et al., 2009) but opted to exclude reports from the mid-point of the scale as this was labelled as 'undecided' or similar. In our scale the mid-point was not labelled and every point beyond 1 was considered more spontaneous in nature. We therefore coded 4 and beyond as a report that contained a degree of increasing spontaneity from a basepoint of roughly equal spontaneous and unspontaneous experience.

anxiety provoking clips of the *aggressive* and *doubts, mistakes and necessity to check* categories respectively. The two music tracks were rated comparably for enjoyment and familiarity, indicating that participants enjoyed the music and were very familiar with it. The ratings of the visual clips and the music indicate that the stimuli had the appropriate characteristics to be effective in inducing spontaneous cognitions.

Table 1. Means and standard deviations of clips resembling obsessive intrusive thoughts related to Aggression and doubts, mistakes, and necessity to check as rated in the Clip Appraisal Questionnaire. Higher scores indicate higher distress and anxiety (5-point scale).

	Aggressive					
	Jump off high place		Cut with a knife		Jump in front of a train	
	M	*SD*	*M*	*SD*	*M*	*SD*
Distress	2.78	1.13	4.10	.88	4.40	.85
Anxiety	3.65	.95	4.17	.85	4.36	.83
	Doubts, mistakes, and necessity to check					
	Unattended kitchen		Unlocked door		Tap left on	
	M	*SD*	*M*	*SD*	*M*	*SD*
Distress	3	1.32	2.38	1.01	2.20	1.12
Anxiety	3.17	1.12	2.95	1.11	2.27	1.06

Table 2. Means and standard deviations for music tracks as rated in the Clip Appraisal Questionnaire. Higher scores indicate higher enjoyment and familiarity with the music tracks (5-point scale).

	Rolling in the Deep		Somebody I Used to Know	
	M	*SD*	*M*	*SD*
Enjoyment	3.72	1.12	3.80	1.06
Familiarity	4.72	.64	4.85	.36

3.2 Induction rates and characteristics of spontaneous cognition

None of the participants identified the aim of the experiment and consequently all data were included in subsequent analyses. Table 3 shows the induction rates for each type of spontaneous cognition and their frequency count in the laboratory and at the 24-hour follow-up, for each modality (visual and musical). The highest occurrence rate in the laboratory is observed when all *spontaneous* episodes are included in the categorization both in visual and musical spontaneous cognitions, while it decreases when more stringent criteria (repetition and emotional valence) are applied to categorize the various types of cognitions. The same decreasing trend is observed in the 24-hour follow-up for both visual and musical *spontaneous* cognitions.

Although occurrence rates for *spontaneous* visual cognitions increase from the laboratory to the 24-hour follow-up for all criteria except one (*spontaneous and non-repetitive*), the occurrence rates for *spontaneous* musical cognitions decrease from the laboratory to the follow-up except for *spontaneous, repetitive, and negative valence cognitions*, for which they increase. The same trend of increase and decrease between laboratory and follow-up can be seen in the frequency counts of both visual and musical *spontaneous* cognitions.

Table 3. Induction rates and frequency count of cognitions in the visual and musical modalities, categorised according to three criteria. Sample size in the laboratory is n = 60 and the follow-up n = 54.

		1. Spontaneous		2. Spontaneous and non-repetitive		3. Spontaneous and repetitive		4. Spontaneous, repetitive, and negative valence	
Modality		Lab	Follow-up	Lab	Follow-up	Lab	Follow-up	Lab	Follow-up
Visual	Occurrence rate	51.66%	57.40%	25.93%	9.26%	36.66%	53.70%	31.66%	40.74%
	Frequency count	49	53	19	5	30	48	26	36
Auditory (Music)	Occurrence rate	68.33%	59.26%	10%	9.26%	58.33%	50%	16.66%	25.93%
	Frequency count	46	36	6	5	40	31	12	16

Note. Frequency count indicates the number of spontaneous cognitions experienced in total and was calculated based on the sum of counts for each participant for each form of thought. Occurrence rate represents the percentage of people who experienced spontaneous cognition following induction, irrespective of the number of cognitions experienced in general.

Table 4 shows the descriptive statistics for each of the key characteristics of spontaneous cognitions including frequency count, estimated duration, and emotional valence for visuals and music. The mean frequency counts in the laboratory and the 24-hours follow-up follow the same increasing and decreasing trend for spontaneous visuals, spontaneous musical respectively as described above. The estimated duration of both visual and musical spontaneous cognitions drops consistently from the laboratory to the follow-up, the decrease being much larger (almost 50%) for music. Emotional valence becomes more pleasant for visuals within 24 hours but more unpleasant for music.

Table 4. Characteristics of visual and musical cognitions (count, estimated duration, and valence), range, *M* = Mean and *SD* = Standard Deviation categorised according to three criteria (spontaneity, repetition, and emotional valence). Sample size in the laboratory is *n* = 60 and the follow-up *n* = 54.

			1. Spontaneous		2. Spontaneous and non-repetitive		3. Spontaneous and repetitive		4. Spontaneous, repetitive, and negative	
Modality			Lab	Follow-up	Lab	Follow-up	Lab	Follow-up	Lab	Follow-up
Visual	Frequency count	*M*	.82	.98	.32	.09	.50	.89	.43	.67
		SD	.91	1.03	.62	.30	.75	1.00	.72	.91
	Estimated duration	*M*	13.90	13.47	10.26	2	16.20	14.46	16.50	14.67
		SD	12.62	14.05	11.33	1.15	13.03	14.42	13.52	14.68
	Emotional Valence	*M*	2.68	3.04	3.11	3.60	2.47	2.98	1.85	1.94
		SD	2.02	2.10	2.13	2.61	1.95	2.10	1.29	1.09
Auditory (Music)	Frequency count	*M*	.76	.67	.10	.09	.68	.57	.20	.30
		SD	.60	.61	.30	.30	.63	.63	.48	.54
		M	46.74	19.30	14.17	4.60	51.63	21.68	45.42	17.88
	Estimated duration	*SD*	27.77	18.73	4.92	3.78	26.44	19.11	24.63	18.90
		M	4.94	4.22	5.67	3.80	4.83	4.29	2.83	2.81
	Emotional Valence	*SD*	1.55	1.85	.82	1.64	1.62	1.90	1.11	1.38

3.3 Comparison of visual and musical cognitions

3.3.1 Occurrence

A series of McNemar tests were employed to compare visual and musical spontaneous cognition occurrences on all four categories in the laboratory and the 24-hour follow-up. The differences between the two proportions were significantly higher for *spontaneous and repetitive* musical cognition occurrences in the laboratory compared to *spontaneous and repetitive* visual cognition occurrences, p = .02. There were no other significant differences in any other comparisons between visual and musical cognition in any of the categories: *spontaneous* in the laboratory, p = .07 and follow-up, p = 1.00; *spontaneous and non-repetitive* in the laboratory, p = .10 and the follow-up, p = 1.00; *spontaneous and repetitive* in the follow-up, p = .82; *spontaneous, repetitive, and negative emotional valence* in the laboratory, p = .09 and the follow-up, p = .15.

3.3.2 Frequency count

Poisson regression analyses determined the percentage of increase or decrease in counts for visual vs. musical spontaneous cognitions. Significantly more visual cognitions were experienced as *spontaneous and non-repetitive* in the laboratory (p = .02), *spontaneous, repetitive, and negative valence* in the laboratory (p = .03) and the 24-hour follow-up (p = .01) compared to musical cognitions. No other comparisons differences were significant.

3.3.3 Estimated duration

Wilcoxon signed-rank tests corrected for multiple comparisons demonstrated that the estimated duration of *spontaneous* musical cognitions in the laboratory (median = 45) was significantly greater than for *spontaneous* visual cognitions (median = 10), Z = -4.352, p = .02. This pattern for musical cognitions was confirmed for *spontaneous and repetitive* cognitions (musical median = 50 vs. visual median= 10; Z = -3.44, p = .05) but not for *spontaneous, repetitive, and negative valence* (musical median = 50 vs. visual median = 10; Z = -1.572, p = .12). There were not enough cases to perform the analysis for *spontaneous and non-repetitive* cognitions in the laboratory. Estimated duration was not significantly different for any type of visual and musical cognitions in the 24-hour follow-up (*spontaneous*, Z = -

.205, p = .84; *spontaneous and repetitive*, Z = -.697, p = .49; *spontaneous, repetitive, and negative*, Z = -1.75, p = .08). There were not enough cases to perform the analysis for *spontaneous and non-repetitive* cognitions.

3.3.4 Emotional Valence

Wilcoxon signed-rank tests corrected for multiple comparisons showed that emotional valence reported in the laboratory was significantly more pleasant for musical cognitions compared to visual in overall *spontaneous* (musical median = 5 vs visual median = 2; Z = -3.997, p = .03), *spontaneous and repetitive* (musical median = 5 vs visual median = 1; Z = -2.074, p = .05), and not significant for *spontaneous, repetitive, and negative valence* cognitions (musical median = 3 vs visual median = 1; Z = -1.163, p = .25). There were not enough cases to run the analysis for *spontaneous and non-repetitive.*

In the 24-hour follow-up, emotional valence was more pleasant for musical *spontaneous* cognitions (musical median = 4.5 vs visual median = 2; Z = -2.307, p = .03), musical *spontaneous and repetitive* (musical median = 5 vs visual median = 2; Z = -2.711, p = .05), and not significant for *spontaneous, repetitive, and negative valence cognitions* (musical mean rank = 3.5 vs visual mean rank = 2; Z = -.552, p = .58). There were not enough cases to perform the analysis for *spontaneous and non-repetitive* visual and musical cognitions.

4. Discussion

Spontaneous cognition research has made substantial progress however, advances have been based on studies into single forms of cognition that have been treated as a unitary construct. Up until now, no experimental methodologies allowed for direct comparison of basic characteristics across different spontaneous cognition forms. In accordance with our aims, we developed a novel, covert induction and sampling paradigm based on previous research into both visual and auditory sensory modalities that is suitable for diverse spontaneous cognition forms such as mind wandering, involuntary autobiographical memories (IAMs), involuntary semantic memories in the form of involuntary musical imagery (INMI) and musical mind-pops, intrusive memories, and obsessive intrusive thoughts (OITs). The paradigm allowed us to compare the characteristics of modalities within each cognition and ultimately, different types of cognition. We outline below the advantages of the new paradigm in terms of methodological and theoretical implications, as well as possible limitations and future avenues for exploration.

4.1 Methodological implications for spontaneous cognition research

The experimental paradigm is novel in the sense that it covertly induces and samples different forms of spontaneous cognition, avoids any instruction bias related to the spontaneity of the experience, and distinguishes and compares visual and auditory modalities. The methodological advantages of the covert experimental paradigm employed are twofold: First, the nature of the stimuli and the experimental instructions avoid both suggestion and demand characteristic biases created by direct experimental instructions, which can result in inflated induction rates and distorted phenomenological characteristics (Barzykowski, 2014; Barzykowski & Niedźwieńska, 2016; Vannucci et al., 2014). The use of specific stimuli that are later expected to be experienced as spontaneous cognition allows control in the encoding/induction phase. Moreover, using stimuli that are extreme, in the sense that they could induce obsessive intrusive thoughts and intrusive memories, enables us to induce not only these forms of cognition but also less extreme cognitions such as mind wandering and involuntary autobiographical memories.

The multidimensional experience sampling achieved with the Mind Activity Questionnaire, in combination with the experimental instructions, enhanced the covert and unbiased nature of the paradigm. Instead of giving participants a definition of cognitions and explicitly asking them if they had experienced them, we probed and gave participants the opportunity to rate characteristics such as (1) *spontaneity*, (2) *repetition*, and (3) *emotional valence*. As these are the main descriptors common to different forms of spontaneous cognition, it was possible for us to later reconstruct the cognitions we are interested in, such as mind wandering, IAMs, ISMs such as musical mind-pops and INMI, intrusive memories and obsessive intrusive thoughts. In so doing, we further avoided suggestion and demand biases in such multidimensional concepts.

Our method to prompt memory optimizes retrieval and resembles the mental reinstatement of context technique (MRC; Fisher et al., 1987), which is part of the cognitive interview used by the police for witness testimony. MRC provides physical cues to enhance information retrieval and has proved a highly effective memory recall technique, compared to the standard interview, where witnesses are asked directly, leading, and suggestive questions (Geiselman, Fisher, MacKinnon, & Holland, 1985), which could prime false memories.

As a concept, ‘spontaneity’ can be challenging to identify, especially for untrained and naïve participants. For this reason, some previous studies have tested experienced mindfulness practitioners who can be considered more efficient at identifying the onset of spontaneous cognition due to their heightened introspective abilities (Ellamil et al., 2016). Nevertheless, existing studies have showed that individuals are able to distinguish between spontaneous and deliberate mind wandering (Seli, Carriere, et al., 2014); in these studies spontaneity has been treated as a binary concept, which yielded different behavioural correlates. However, forcing judgments to one or other might be problematic for participants and a spectrum view, similar to that used by other mind wandering studies (Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016), could be more beneficial. Thus in the current study, we treated spontaneity as a continuous variable for participant report and subsequently coded it as binary prior to data analyses. The range of participant ratings of spontaneity on the scale provided reflects degrees of 'involuntary' experience, and indicates that the continuous measurement approach balances sensitivity and detectability.

Furthermore, our paradigm enables the simultaneous induction of spontaneous cognition in various modalities, in our case visual and auditory in the form of music. The paradigm could also be utilised to investigate speech and kinesthetic (motor) aspects of cognition. To-date, research in most spontaneous cognition forms has not distinguished between sensory modalities, which could be crucial in the behavioural, neural, and functional correlates of the experiences. Only research in mind wandering has started questioning the homogeneity of the experience (Smallwood & Andrews-Hanna, 2013, Wang et al., 2017) and recognising the diversity of this mental state. However, the intentionality related to the onset of the experience is still overlooked. Here, we acknowledged the richness of the internal experience and considered the complex nature of these ubiquitous episodes.

The validity of our paradigm is supported by the occurrence rates and frequency counts, which in general are comparable to those of previous studies. The basic induction rates achieved for *spontaneous and repetitive* music cognitions are comparable to those reported in INMI studies (Floridou et al., 2012; 2017, Hyman et al., 2013), a finding that demonstrates the validity of the new paradigm in relation to INMI induction. It is worth noting that our paradigm provided for the first time the opportunity to experimentally induce and study musical mind-pops, which will be beneficial in future research since so far this type of cognition has only been studied through survey and diary studies (Kvavilashvili & Anthony, 2012; Kvavilashvili & Mandler, 2004).

Comparison with induction rates reported in the obsessive intrusive thoughts literature is difficult because previous studies combine scores of frequency and duration (Beadel, Green, Hosseinbor, Teachman, 2013), do not report them at all (Lambert, Smyth, Beadel, Teachman, 2013; Magee & Teachman, 2013; Magee, Smith, Teachman, 2014; Olafson et al., 2014) or come from clinical samples (Purdon, Gifford, McCabe, & Antony, 2011). Future studies should consider reporting occurrence rates, frequency count, and estimated duration of spontaneous cognitions. The comparison of these features of spontaneous cognitions is particularly relevant to understanding OITs given that there are suggested differences between experiences in clinical and non-clinical samples. However, despite comparison between basic induction rates in the visual domain was not feasible, the important finding was that our new paradigm resulted in a reliable and consistent induction of intrusive visual cognitions in the subcategory of *spontaneous, repetitive, and negative valence* cognitions in our sample population.

A notable difference was observed between the frequency count of the intrusive cognitions reported in this study (visual, *spontaneous and repetitive*) and previous findings on intrusive memories. Previous studies report mean frequencies between 2.6 and 11.78 memories (Morina et al., 2013; Takarangi et al., 2014), while we found average frequency rates of 0.46 in the laboratory and up to 0.89 in the 24-hour follow-up period. An explanation for this discrepancy may lie in the potential for suggestion bias in previous studies, i.e. the use of explicit instructions to reflect on intrusive memory patterns may artificially inflate frequency reports, a trend previously observed in IAM studies (Barzykowski & Niedźwieńska, 2016; Vannucci et al., 2014). Another possible explanation relates to the difference in the number and duration of clips presented and in the nature of the stimuli used in our study as compared to previous intrusive memory studies. Our study included six clips lasting approximately 3 minutes in total, while previous studies used more clips, which were longer in duration; this increase in exposure may account for increased frequency counts of subsequent cognitions. In addition, while we chose scenes resembling common OITs, intrusive memory studies are likely to involve more traumatic visuals, which could also explain increased frequency reports. Finally, in previous studies participants had to classify their cognitions based on the definition that was provided to them, which could have resulted in false classification of a larger fraction of cognitions as spontaneous.

4.2 Theoretical implications

Following examination of induction rates and frequency counts, we compared visual and musical cognitions across four categories based on their core characteristics (spontaneity, repetition, and emotional valence). A notable difference observed between the two modalities was that *spontaneous and repetitive* musical cognitions (INMI) were reported by a larger proportion of participants compared to *spontaneous and repetitive* visual cognitions (intrusive memories). The originality of the current induction paradigm precludes a direct comparison with previous research, since to the best of the authors' knowledge this is the first study to directly compare induced experiences of visual and auditory spontaneous cognitions. However, research has compared experiences of the two modalities as part of retrospective reports. Kvavilashvili and Mandler (2004) and Liikkanen (2012) both reported that music is a much more prevalent type of involuntary semantic memory compared to visuals, words, and phrases. The ubiquitous nature of music in everyday life could mean that it is more easily encoded in memory and spontaneously recalled. Alternatively, individuals may be more aware of INMI due to the common externalization of the experience by humming or moving to the beat of the imagined music (Floridou, Williamson, Stewart, & Müllensiefen, 2015; Campbell & Margulis, 2015). Yet another explanation could be related to the repetition which is inherent within music, something that is more akin to the subsequent experience of repetitive musical cognitions.

When negative valence was added to the classification of the cognitions alongside spontaneity and repetition, a higher number of visual (OITs), relative to musical (negative INMI), cognitions was reported by participants in both the laboratory and 24-hour follow-up. This finding cannot be attributed to the stimuli, which in their majority were visual (6) rather than musical (2), as in this case we would expect to have observed this difference in all the comparisons across categories. Negative valence seems to facilitate the spontaneous onset of more repetitive visual cognitions compared to musical, or, alternatively, possibly make them more observable. This supposition is further supported by the frequency counts of visuals and music across categories in the laboratory and the follow-up. Whilst frequency count for visuals increases in all categories except *spontaneous and non-repetitive*, for music, frequency count decreases between the laboratory and the follow-up except in the category in comprising negative valence, where music increases, but not as much as in visuals. This finding confirms suggestions that negative INMI is not as common in the general population as is sometimes suggested, in contrast to its visual parallel, OITs. Also, that negative valence plays a key role in increased frequency of cognitions, which nevertheless affects music less than visuals.

Estimated duration for *spontaneous* and *spontaneous and repetitive* musical cognition was consistently longer than that reported in the visual modality. This difference in duration could reflect the original stimuli, since each video contained one musical track and three visual scenes. However, *spontaneous, repetitive, and negative emotional valence* musical and visual cognitions were experienced as equal in duration. An explanation for the differences in duration of cognition comes from Margulis (2014; as cited in McCullough Campbell & Margulis, 2015, p. 347) who claimed: “Musical imagery is noteworthy for the way it unfolds in time, being apprehended dynamically note-by-note rather than in some atemporal summary". In theory, the temporal and structural aspects of musical mental imagery are typically observed as unfolding in the stream of consciousness and therefore may be experienced as occurring for longer in time compared to visual cognitions, which typically have both temporal and static components.

An alternative account would be to implicate central cognitive resources. It could be argued that the inherent repetition in music could automatically refresh the phonological loop subcomponent of working memory through a reciprocal exchange between phonological store and the articulatory loop via subvocal rehearsal. This process could prevent temporal decay of music and result in it being perceived as longer in duration. Future studies should explore this further with musical stimuli which do not involve repetition and/or repeating visual stimuli in order to differentiate a stimulus lead vs. processing lead explanation for the modality duration differences.

Finally, we note the difference in emotional valence between the two cognition modalities. Whilst the contents of the visual and music stimuli had consistently negative connotations (i.e. scenes commonly experienced as obsessive intrusive thoughts and negative lyrics in the musical tunes), musical cognitions were experienced as significantly more pleasant, compared to the visual modality, when occurring as *spontaneous* and *spontaneous and repetitive*. This finding, although contrary to the popular belief that *spontaneous and repetitive* musical cognitions such as INMI are usually unpleasant, is in accordance with the results of research in this domain. In previous studies, the reported emotional valence of INMI varies from neutral to pleasant (Beaman & Williams, 2010; Floridou & Müllensiefen, 2015; Halpern & Bartlett, 2010), compared to intrusive memories, which, whilst by definition can be neutral or pleasant, are mostly considered negative (Kvavilashvili, 2014). Another explanation could be related to the paradox that sad music can evoke pleasant emotions through regulating negative moods and emotions, and providing consolation (Taruffi & Koelsch, 2014). Thus our paradigm also provides the opportunity to study differential emotional reactions and their impact on cross-modal cognitive processes.

The current study is the first empirical demonstration of modality differences in cognitions following laboratory induction; not only do these findings serve to support the external validity of the new induction paradigm, but they also support the call to consider sensory modality of spontaneous cognition in future studies of this kind.

4.3 Possible Limitations

The new paradigm has a number of potential limitations that could be modified in future developments. The retrospective thought sampling methodology might have inadvertently introduced a memory sampling bias, since it relies on the participants' ability to reliably remember and assess the content of their experience during the rest period. Accessing cognitions and evaluating their characteristics in this retrospective manner encourages participants to retrieve the cognitions in a voluntary way; hence, changing the retrieval mode of the experience may have altered the characteristics of the cognition. Instead, we could have utilized a probe- of self-sampling metholodology during the rest period, though this would involve the provision of instructions in advance of the task. This sampling method contradicts the aim of the study, to develop a covert induction and sampling paradigm, as it risks inducing participant expectation bias. In theory, ongoing reporting may also interfere with the retrieval process and reporting of cognitions, as well as with the natural stream of consciousness (Vannucci et al., 2014). Furthermore, probe- of self-sampling would have interrupted the thought and subsequently the estimated duration. These hypotheses could all be experimentally tested against the present paradigm in order to determine the most effective manner of reporting in time. In addition, whatever the sampling method, confidence ratings could be implemented to explore how certain participants are for their responses and ultimately compare the ratings between methods.

Relatedly, we acknowledge the limitation that asking participants to report the duration of thoughts relies on a subjective measure, as estimating time is a challenging human ability. Future studies could ask participants to estimate the duration of an observable task whose duration is measured by the researcher and evaluate the validity and reliability of their time estimation abilities. However, we note also the possibility that time estimation is likely to vary between an external task and an internal event.

4.4 Future developments

The present paradigm has opened promising lines of research for future research as it affords a degree of flexibility in its design that has the potential to be adapted to address many research questions. The induction paradigm could be adjusted, in terms of the exposure stimuli in order to explore the differences in phenomenological experiences reported when using clips that vary in their duration, content, and form of presentation (e.g. repeated or single, familiar or unfamiliar environments). The sampling paradigm could be adapted and additional elements that can be considered relevant to the research question can be added, for example, vividness ratings.

In addition to the comparison of different forms of spontaneous cognition, future research using the paradigm could also explore the differences between spontaneous and voluntary cognitions. Furthermore, the new paradigm gives the opportunity to explore cross and intra-modal relationships for concurrent cognition occurrences, as previous research has shown that mental imagery in the same or different modalities may be elicited simultaneously (Stillman & Kemp, 1993).

4.5 Summary and final conclusions

This paper presents a new experimental paradigm for testing multiple forms of spontaneous cognition, which allows the successful covert induction and sampling across at least two cognition modalities, visual and auditory in the form of music. The manner of reporting makes possible the identification of similarities and differences between the characteristics of spontaneous cognition in these modalities. Comparison can be drawn with the patterns reported in previous studies focusing on each of the two experiences individually. Such comparisons can inform a better understanding of the processing and effects of spontaneous cognitions in general. Adopting a form and content approach to the study of different forms of spontaneous cognition, similar to mind wandering research, could be more insightful than utilizing standard definitions.

The current paradigm offers the opportunity to conduct studies that move away from specific labelling of cognitions as part of sampling (like IAMs and OITs), a protocol which requires participants to remember each characteristic of the definition and classify their thoughts accordingly. In any case, the results have showcased that experiences assumed to be unitary constructs in this manner are actually often heterogeneous, with differences occurring within the experience. We believe that the presented paradigm offers substantial scope for application in the study of mind wandering, involuntary autobiographical memories and involuntary semantic memories in the form of involuntary musical imagery and musical mind-pops, as well as intrusive memories and obsessive intrusive thoughts. The new paradigm has opened up new and interesting routes of research in unchartered territory.

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