# Open University of Cyprus

**Faculty of Pure and Applied Sciences**


**Postgraduate (Master's) Programme of Study *Cognitive Systems***

## Postgraduate (Master's) Dissertation

# Intersections Between Emotion and Visual Mental Imagery


**Laura-Ana Schönegger**

**Supervisor**

**Marios Avraamides**

**June 2022**

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The present Postgraduate (Master's) Dissertation was submitted in partial fulfillment of the requirements for the postgraduate degree in Cognitive Systems
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Summary

Mental imagery is the ability to conjure sensory information in the absence of a corresponding stimulus in the immediate environment. Closely connected to the concept of visual imagination, visual mental imagery (popularly referred to as 'the mind's eye') has been studied from a psychological, neuroscientific, cognitive literary perspective; the ensuing model has been successfully translated to artificial intelligence and machine learning applications. The dissertation at hand follows a multidisciplinary approach in reviewing the existing knowledge surrounding the topic of visual mental imagery, and aims to expand this research in a novel direction. Namely, the dissertation addresses the impact various positive and negative emotions may have on the ease with which mental imagery is conjured while reading fictional text, and the quality of this imagery. As a secondary purpose, this dissertation presents criticism to existing standards of measurements, to the reliance of current testing on the term 'vividness', and offers an alternative combination of terms to more accurately measure imagery quality (emotional intensity, detail, saturation, sharpness and latency).

How emotion affects visual mental imagery is a question yet to be explored. Therefore, insight must be gained from interactions between emotion and other cognitive functions which are closely related to mental imagery. Perception has much in common with mental imagery from a phenomenological, structural and functional perspective, and thus could be considered a great predictor. Neuroimaging studies show that cortical areas associated with memory, as well as the default mode network, are active in visual mental imagery exercises. From a cognitive literary perspective, some narratological studies examine what traits in a text cause it to evoke potent imagery. All these explorations coalesce into a within-subjects experiment design

whereby participants are presented with four texts, equalised for narrative factors, each evoking one of the following emotions: joy, affection (or empathy), sadness and fear. Multiple ANOVA analyses of the resulting data showed higher saturation scores in positive, but not in negative, emotions. Other variables remained below statistical significance. When data resulting from emotive vs. non-emotive reading was compared, emotion was seen to amplify saturation and sharpness, and greatly amplify intensity. However, it did not affect the level of detail or latency.


Περίληψη

Η φανταστική αναπαράσταση είναι η ικανότητα δημιουργίας αισθητηριακής πληροφορίας εν την απουσία του σχετικού ερεθίσματος στο άμεσο περιβάλλον. Συνδεδεμένη στενά με την έννοια της οπτικής φαντασίας, η φανταστική οπτική αναπαράσταση (ευρέως αναφερόμενη ως το "μάτι του μυαλού") εξετάζεται από την πλευρά της ψυχολογίας, της νευροεπιστήμης και της γνωστικής λογοτεχνικής μελέτης· το μοντέλο που προκύπτει με επιτυχία μεταφέρεται στις εφαρμογές της τεχνητής νοημοσύνης και της μηχανικής μάθησης. Η παρουσιαζόμενη διατριβή προσεγγίζει διεπιστημονικά την επισκόπηση των υπαρχόντων γνώσεων γύρω από το θέμα της φανταστικής οπτικής αναπαράστασης και στοχεύει να επεκτείνει αυτή την έρευνα προς μια νέα κατεύθυνση. Πιο συγκεκριμένα, η διατριβή εξετάζει την επίδραση που ενδέχεται να έχουν ποικίλα θετικά ή αρνητικά συναισθήματα πάνω στην ευκολία με την οποία δημιουργείται η φανταστική αναπαράσταση κατά τη διάρκεια της ανάγνωσης ενός μυθοπλαστικού κειμένου, καθώς, επίσης, και την ποιότητα μιας τέτοιας αναπαράστασης. Δευτερευόντως, ο σκοπός της διατριβής είναι να παρουσιάσει μια κριτική των υφιστάμενων προτύπων μέτρησης, καθώς και της εξάρτησης των τρεχουσών δοκιμών από τον όρο "εντονότητα", και προτείνει έναν εναλλακτικό συνδυασμό όρων με στόχο την πιο ακριβή μέτρηση της ποιότητας μιας αναπαράστασης (η συναισθηματική ένταση, η λεπτομέρεια, ο κορεσμός, η ευκρίνεια και η ταχύτητα δημιουργίας).

Το πως επηρεάζει το συναίσθημα μια φανταστική οπτική αναπαράσταση είναι ένα ερώτημα που ακόμη χρίζει διερεύνησης. Επομένως, οι γνώσεις πρέπει να αντληθούν από την διάδραση του συναισθήματος με άλλες γνωστικές λειτουργίες που συνδέονται στενά με την

φανταστική αναπαράσταση. Η αντίληψη έχει πολλά κοινά με την φανταστική αναπαράσταση από την φαινομενολογική, την δομική και την λειτουργική άποψη, και, επομένως, θα μπορούσε να θεωρηθεί ως ένας καλός παράγοντας πρόβλεψης. Νευροαπεικονιστικές μελέτες δείχνουν ότι οι περιοχές του φλοιού που σχετίζονται με την μνήμη, καθώς και το δίκτυο προεπιλεγμένης λειτουργίας συμμετέχουν ενεργά στην εξάσκηση της φανταστικής οπτικής αναπαράστασης. Από την γνωστική λογοτεχνική πλευρά, μερικές αφηγηματολογικές μελέτες ερευνούν ποια στοιχεία ενός κειμένου το κάνουν να προκαλεί μια δυνατή αναπαράσταση. Όλες οι εν λόγω μελέτες ενώνονται σε ένα θεματικό πείραμα κατά τη διάρκεια του οποίου στους συμμετέχοντες δίνονται τέσσερα κείμενα, ισορροπημένα σε σχέση με το αφήγημα, με το καθένα να προκαλεί ένα από τα εξής συναισθήματα: χαρά, τρυφερότητα (ή συμπόνοια), θλίψη και φόβο. Πολυάριθμες αναλύσεις διακύμανσης των δεδομένων του πειράματος έδειξαν υψηλότερο βαθμό κορεσμού στην περίπτωση των θετικών συναισθημάτων σε αντίθεση με την περίπτωση των αρνητικών. Άλλες μεταβλητές παρέμειναν κάτω από την στατιστική σημαντικότητα. Όταν αντιπαραβλήθηκαν τα δεδομένα που προέκυψαν από την συναισθηματικά φορτισμένη και την συναισθηματικά μη φορτισμένη ανάγνωση, διαπιστώθηκε ότι το συναίσθημα ενισχύει τον κορεσμό, την ευκρίνεια και, ιδιαίτερα, την ένταση. Παρ’ όλα αυτά, δεν επηρεάζει το επίπεδο της λεπτομέρειας ή την ταχύτητα δημιουργίας.

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# Chapter 1
# Introduction

*"Imagination is not a state: it is the human existence itself." William Blake, 1948*

## 1.1 Imagination and Mental Imagery

The human ability for mental imagery (that is, the ability to conjure sensations, images, smells, sounds and tastes in their absence from the immediate environment) (Bence, 2018), has bound philosophers, artists and scientists in common inquiry. Closely entwined with the concept of imagination, mental imagery is generally considered to play a significant role in various cognitive processes related to memory, prediction, planification and decision-making (Buckner et al., 2008). It has also been strongly associated with introspection, daydreaming and creative exploration (Aldworth, 2018); and proposed as one for the core methods for organising thoughts and expressing ideas internally (Pearson & Kosslyn, 2015). As far back as Aristotle, mental imagery has been thought to rely on perception and memory, on images which have already been experienced by the individual. This idea is echoed by scientists of mental imagery and visualisation (the process of experiencing mental imagery during reading), who propose the existence of schemata, or automated mental imagery (D'Angiulli, 2013). It is yet unknown whether the human mind is capable of conjuring entirely unique imagery, or if all imagery is a recombination and manipulation of stimuli once perceived and stored in memory. However, most modern theories lean towards the latter.

For the understanding of the dissertation at hand, it is important that a clear distinction be made between imagination, and mental imagery. The latter, as described above, is a cognitive process explored in numerous studies of psychology, psychiatry, neuroscience, even artificial intelligence and machine learning. The former, however, is a more abstract, as of yet not entirely understood concept - largely accepted to be the foundational process for invention, and all manner of creative production, but thus far unclear from a scientific, functional perspective. Since the beginnings of documented human history, as far back as the first tools and cave drawings, imagination has been a pervasive aspect of human existence, allowing generations to advance, to share experience, knowledge, emotions and ideas through creative output. The human ability to imagine or predict the outcome of an action or situation, our propensity for dreaming up ideals which become our goals, our main strategy for creating progress, is vital.

Notably, while humans can hardly exist without imagination, imagination has been shown to exist without mental imagery (Zeman, 2010; WowRightMeow, 2018). We know from studies of aphantasia that individuals who are unable to mentally imagine in one or all senses nevertheless maintain not only their 'imagination' (not in the sensorial but in the metacognitive denotation), but also their ability to be creative. Numerous successful artists have, in recent years, been diagnosed with aphantasia (Zeman, 2015), and have reported no detriment to their craft. Imagination, as consciousness itself, has eluded scientific dissection and understanding; mental imagery, on the other hand, is much more accessible to the scientific method. As a topic of research, however, mental imagery has largely been approached from a utilitarian perspective, as an underlying process for greater cognitive functions, or training tool for developing understanding and critical thinking (Kenny, 2010). This approach, while valuable, only addresses part of the picture.

## 1.2 A Case for an Interdisciplinary Approach

In a special issue of the Cortex scientific journal, Aldworth (2018) makes a case for an interdisciplinary approach to visual mental imagery, uniting cognitive science with visual art. She puts together a questionnaire which touches upon the phenomenology of visual imagery as used for professional purposes by artists working in architecture, film, illustration and multimedia, the extent to which they rely on it to complete their tasks, but also the role it plays in their daily lives. The participants admit to using visual imagery to a large extent, from orienting themselves in a city by imagining their route, to sitting back and 'daydreaming' a work of art before touching paint on canvas. One of the often described practices is 'feeding' their visual imagination with information either from memory or external sources (images, text, music) and allowing images to form freely from this basis. As the medium brings its contribution (one can imagine watercolour on paper spreading in unexpected patterns), this original image is constantly updated. The goal may be purely visual, or the creation may be driven by the desire to impart a certain feeling. The scientific practice of defining visual mental imagery as recall and recombination of stimuli which have been, at one point, perceived, and the measure of one's ability to imagine by asking them to rotate shapes in their mind's eye, or bring forth sunsets, appears reductive to anyone who relies on mental imagery in the process of creation. The use of mental imagery in any modality is so tightly entwined with the artistic personality and lifestyle: it is not a tool, but a greater part of the self.

With this in mind, the dissertation at hand will rely on an interdisciplinary approach spanning cognitive psychology, neuroscience and cognitive literary science in an attempt to capture the multi-faceted nature of visual mental imagery By far the most work to date has been done in the field of cognitive psychology. The efforts carried by cognitive psychologists have led to formalising the measurement of imagery strength to a certain degree of success in tests such as the Vividness of Visual Imagery Questionnaire (VVIQ) (Marks, 1973), and to successfully separating the cognitive processes needed for object or situational visual mental imagery, from those required in performing spatial manipulation tasks, such as rotating a piece of geometry by a discrete number of degrees (Kosslyn 1980, 2005). More recently, neuroimaging techniques have brought an important contribution to understanding the neural substrate associated with mental imagery, and have indeed revealed overlap with memory and perception. The emerging field of cognitive literature, spearheaded by Troscianko and Kuzmičová, has tied the reading of emotion-evoking narrative with the act of conjuring mental imagery in a process termed 'visualisation'. These studies offer insight into the process of spontaneous imagining (in the sense that the reader does not set out to recreate the narrative visually, but seems to do so anyway, prompted by the narrative structure and emotions it provokes), and what influences this process from a narratological standpoint. And lastly, the field of artificial intelligence has recently brought visual mental imagery into its repertoire in a number of ways, from adding it as a task-independent process in spatial manipulation AI, to training artificial neural networks to decode neural activity from the visual cortex and re-encode it as images, effectively ‘reading’ participants’ visual mental imagery. However, while the effect of mental imagery on emotion has been explored in a number of clinical studies, the converse has not yet been investigated. The dissertation at hand aims to address this gap in knowledge by means of a psychological experiment designed to assess the strength (as defined by a number of parameters which will be introduced later in this dissertation, namely Level of Detail, Level of Intensity, Sharpness, Saturation and Latency) of visual mental imagery in participants as a range of emotions is induced through written literary text.

# Chapter 2

# Models of Perception

*"This is what fascinates me most in existence: the peculiar necessity of imagining what is, in fact, real." Philip Gourevitch*

Studies of perception are numerous; from them, a few models of perceptions have emerged as more reliable than others. Namely, that perception relies on visual representation, propositional representation, or emerges from the interactions of the individual with the environment (enactive perception). While perception is not the topic of this dissertation, studies of enactive perception, and research of the intersections between perception and emotion, could inform equivalent research in visual mental imagery.

## 2.1. Mental Imagery and Perception

Mental imagery is distinct from perceptual processing in that it occurs in the absence of corresponding sensory stimulation. (Bence, 2018). However, while the corresponding sensory stimulus must be absent from the immediate environment in order for the experience to qualify as imagery, multimodal mental imagery theory supports the idea that imagery in one of the senses must happen in the presence of external stimulation of one of the other senses. For example, an image may be conjured while listening to a song or smelling a particular smell, thus including an element of perception (Kuzmičová, 2012; Bence, 2018). Neurologically, one can distinguish visual mental imagery from visual processing by checking the correspondence between the activation of the retinal cells and the neural excitation in other parts of the perceptual system along the visual pathway, since the primary visual cortex is organised in a retinotopic manner. It is the case of visual mental imagery when such correspondence is not apparent. In other words, it is possible to conjure mental imagery while also actively perceiving an image, and, using neuroimaging techniques, it is possible to tell whether the visual cortex activation denotes mental imagery or perception (Pearson, 2019).

## 2.2 Visual, Propositional and Enactive Perception

Much of the psychological and neuroscientific research surrounding perception and visual mental imagery to date is centred around 'the imagery debate' which Stephen Kosslyn and Zenon Pylyshin had engaged in for almost four decades before finally resolving in 2015 (Pearson & Kosslyn, 2015). In a series of psychological experiments where participants were asked to mentally conjure simple visual forms and manipulate them, later on while the participants' blood oxygenation levels in the brain were monitored by an fMRI, Stephen Kosslyn argued that the brain represented, or encoded, information in the form of images. At the same time, Zenon Pylyshyn argued, sometimes using the same data which Stephen Kosslyn had acquired in his experiments, that representation is made propositionally, with visual imagery being a secondary mechanism triggered by association of the linguistic information with visual information (1973). In 2015, both scientists admitted that the data, by then aided by multiple neuroimaging studies, points towards a representational model which does not entirely match either the two paradigms.

Other models exist, and while they are not as popular as the depictive and propositional models, they have been shown to have merit in the context of visual mental imagery. Namely, the enactivist model of perception is supported by both Troscianko and Kuzmičová in their visualisation studies (Troscianko, 2013; Kuzmičová, 2014). The enactive perception model proposes a type of perception emergent from interaction with the environment. It is the individual's response to the stimuli, and not their observation thereof, which creates the experience of perception. The traditional representational models of Kosslyn and Pylyshyn do not account for perceptive consciousness, for the 'experience of seeing', argue Alva Noë and Kevin O'Reagan (2002). The idea of 'knowledge-free' perception, or visual encoding which happens independently of memory and other cognitive mechanisms, appears in Pylyshyn's model as well (2003), but not in the absence of a representational model, as Noe and O'Reagan propose.

The enactive approach may not provide a complete model for perception, but it, nevertheless, creates a theoretical basis for some of the phenomena observed with visualisation. For example, sensorimotor adaptation during visual mental imagery, change blindness, boundary extension which are documented in perception, are also noted with visual mental imagery conjured during reading. In her paper on the enactive reading of Kafka, Troscianko (2013) attributes some of Kafka's success as a writer to his use of enactive cues, the use of first person narrative, the evocative descriptions of emotion and the character's sensorimotor response triggering the reader's own physical reaction. The idea that narrative, and specifically that visualisation, triggers a physical response is supported by sensorimotor studies (Pearson, 2019). In recent years, studies of visual mental imagery have included groups of visual aphants (individuals with no visual mental imagery, a term first employed by Konigsmark et al., 2021) for comparison. In one of these studies (Wicken, Keogh & Pearson, 2021), a group of individuals who experienced visual mental imagery, and a group of aphants, were asked to read a highly emotive text designed to induce fear or anxiety. Electrodermal activity measurements showed a significant difference in the two groups' response: while the control group presented elevated activity levels at key moments in the narrative, the aphants had, on average, an even, low-level response throughout the reading (Wicken et al., 2021). At the same time, Troscianko offers in support of enactive mental imagery the reported qualities of this function. For example, the observation that a strong emotional response associated with visualisation does not always correlate with a high level of detail, suggests that it may not be passive observation, but rather an enactive element which triggers the emotion (2013). Numerous studies which address visual mental imagery describe it as a 'weak form of perception' (Pearson, 2019; Kosslyn, 2005). Pearson uses this analogy to describe its functional characteristics, whereas Kosslyn refers to its visual phenomenology. Mental imagery is less saturated, less detailed and less sharp when compared to perception.

However, Troscianko argues that the main reason why perception is considered detailed and sharp, is because the image can be continuously renewed as long as the object of perception is available in the environment (2013). Natural vision selectivity and the impression that the perceived image is complete and detailed are emphasised in a number of studies: from change blindness experiments (Simons & Levin, 1997) to Gestalt principles which underlie our tendency to look for patterns and to see 'the bigger picture' more readily than its individual elements, to Intraub and Richardson's Boundary Extension experiments which suggest a heavy reliance on the 'idea' of an image rather than its exact depiction (when asked to recreate a series of images from memory, participants extended them mentally such that objects therein would appear complete) (1989). From a phenomenological perspective, Troscianko argues mental imagery, even in the visual modality, is more akin to language than it is to perception in that is is "inexplicitly noncommittal" (a term first employed by Ned Block in 1981). In text, as in visualisation, we may choose to direct our attention towards a specific part of the image, and ignore the rest. The rest, then, neither is nor isn't; it simply remains unexplored as long as it is irrelevant. It is the choice of the author of a text, as it is the choice of the person conjuring a mental image, to fill in other parts of the image. By contrast, a painter doesn't have this option: what is in view must be depicted, or otherwise a choice must be made to allow parts of the image to be incomplete (but this will become immediately apparent in a way that is not true with textual description) (Troscianko, 2013).

## 2.3. Perception as Prediction

In 1999, following the publication of a landmark computational study conducted by Rajesh Rao and Dana Ballard, predictive processing became the leading hypothesis to explain a number of cognitive processes, starting with visual perception. According to this theory, perception functions bidirectionally, with input moving from the sensory organs imto the visual cortex (from the retina, to the lateral geniculate nucleus of the thalamus, then to V1 through to V6), while predictions move from higher visual cortical areas to lower ones. For example, V2 passes down a prediction to its immediately downstream counterpart, V1. Any discrepancy between the stimulus which has reached V1 from the environment, and the prediction which V2 made, is passed to V3 together with the stimulus information which V1 had relayed. V3, in the meantime, had output a prediction, which will now be updated with the new information passed up from V2, and so on. This theory is supported by computational algorithms which successfully model the process, starting with Rao and Ballard's and replicated in several other studies across the years (Bar et al., 2006; Alink et al., 2010). If the process of perception is predictive, then it could be argued that it relies on visual mental imagery, and thus that imagery plays an important role in defining our expectations with respect to our environment. In a study consisting of a control group and a group of individuals with aphantasia, Keogh and Pearson show that phantom vision (i.e. reporting having visually perceived information which is not, in fact, present, in this case after being shown a series of optical illusions) only occurs in the former, but not in the latter group (2020). Similarly, binocular rivalry studies have shown that individuals who experience visual mental imagery will prime their response to the task by conjuring one of the two patterns from which they are asked to choose. However, the same priming effect was not observed in aphants, whose choice was consistently around 50%, or chance level (Pearson, 2014).

## 2.4 Perception and Emotion

The strong relationship which seems to exist between perception and visual mental imagery, from a neurological, functional and phenomenological standpoint, underlines the importance of visual mental imagery in everyday life. In a meta-analytic study published in 2011, Zadra and Clore recounted a number of experiments where emotion was observed to affect perception in various ways. Fear was shown to impact low-level visual processes: shown the image of a man with a fearful expression before stimuli in an orientation discrimination task, and randomly the image of the same man with a neutral facial expression, one study noted that perception was enhanced by the fear-referrencing cue (Carrasco et al., 2006). Stress narrowed attention, and consequently perception, while yet other studies showed positive emotion broadened perception (Derryberry & Tucker, 1994). These results were achieved by alternately inducing happy and sad moods in the participants by having them recount an event in their lives. Following this, the participants would be shown an initial geometric figure, and subsequently two more (in the image below, the three squares at the top would be shown first and the two images below would follow). The participants would be asked to match the first image with the one they believe to be closest from the other two. A 'narrow' response would be the four squares, because at a first glance they share geometrical characteristics. However, a 'global' response would take into consideration the arrangement of the figures, and consequently reveal that the triangles are more similar to the initial cue.

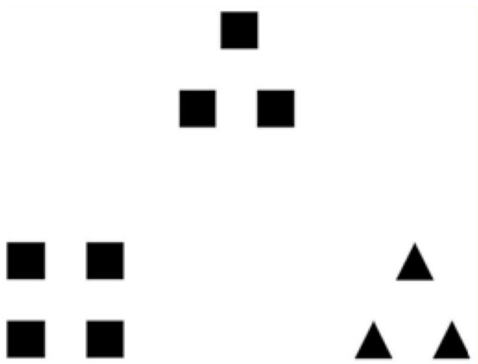


**Image 1.** Derryberry & Tucker study on broadened perception, image presented to participants.

Other studies mentioned by Zadra and Clore (2011) measured reaction times and reached a similar conclusion. Studies of optical illusions, specifically of the Ebbinghaus Illusion, have revealed that individuals who are experiencing sadness are less susceptible to such optical tricks. Moreover, in a study of semantic priming, participants were less affected by cues consisting of either similar or dissimilar meaning to the subsequent stimuli if they were experiencing sadness, suggesting that the impact of emotion extends to conceptual processes. We might expect that visual mental imagery will be modulated by emotion in a similar manner to perception, by prompting orientation towards a stimulus charged with negative emotion, and 'narrowing' in the same conditions. Presumably, the level of emotional intensity associated with imagery conjured under the effect of sadness or fear will be higher than neutral, or even positive trials. However, it is unclear what impact negative emotion might have on the level of detail, sharpness or saturation of the imagery. It is likely that one, if not all, will correlate positively with positive emotion.

# Chapter 3
# Imagery and Memory

Memory does not depend on the ability to conjure visual mental imagery. However, the emotion associated with autobiographical memory appears to do so to a great degree.

## 3.1. Encoding and Decoding Memories

For a long time, visual mental imagery has been assumed to play an important role in all cognitive processes associated with memory, not least due to the aforementioned 'imagery debate' (Kosslyn, 1980). However, attempts at developing tests of either cognitive process which would predict the other all failed (McAvinue & Robertson, 2007). More recently, studies showed that recall in aphants happened with the same capacity and accuracy as in control groups, as the individuals successfully adopted strategies that did not rely on the visual aspect of the event (Keogh & Pearson, 2014; Keogh et al., 2021). However, several studies have shown that the emotional dimenson of memory is less potent in individuals who do not experience visual mental imagery compared to those who do, and increases as a function of visual mental imagery intensity or vividness (D'Argembeau & Van der Linden, 2006). One EEG study found that high-frequency gamma-band activity (50-150Hz) in the inferior temporal gyrus increased with visual, but not verbal, working memory load, whereas the fusiform gyrus exhibited the opposite effect, activating only in the case of verbal working memory tasks (Hamame et al., 2011). This finding points towards a specific working memory neural substrate associated with visual information, and the subsequent possibility to decode memories based on the pattern of neural activation.

It would appear that the visual encoding and manipulation of memories may persist even if the ability to experience visual mental imagery is lost. A 2010 study engaged a participant who had lost their visual imagery ability due to physiological trauma in a number of spatial manipulation and memory tasks (Zeman et al., 2010). The study revealed an unimpaired ability to perform spatial rotation and manipulation (a result supported by Pearson's studies on aphant groups), despite greatly diminished activation in the posterior cortical regions involved with vision. Furthermore, reaction time was not impacted by the distance or degrees required by the manipulation, as is generally observed in these tests (Kosslyn et al., 1978). Stronger activation in the prefrontal cortex to the one observed in participants with typical mental imagery was observed, suggesting greater reliance on the executive function. In visual recall tasks the participant reported no visual imagery experience, but had no difficulty in recounting visual details, and weak activation in the visual cortex was noted. The team theorised that visual information may be stored in memory prior to the loss of imagery function, and may unconsciously persist in non-congenital aphantasia. (Zeman et al., 2010).

## 3.2. Autobiographical Memory

Visual mental imagery has been shown to have a particularly strong influence on autobiographical memory, in terms of both fluency of memory recall and the density of sensory detail (D'Argembeau & Van der Linden, 2006). The reported phenomenology is supported by stronger neural activation in the visual cortex during recall (Gilboa et al, 2004) and also by stronger resting state connectivity between brain areas associated with memory (medial temporal) and visual areas in the occipital lobe (Sheldon et al., 2016). While there have been studies linking autobiographical memory impairment with a deficiency in mental imagery, this is not necessarily the case, and aphantasia is not routinely correlated with memory deficiency (Greenberg & Knowlton, 2014). However, the nature of those memories which are stored seems to be different in those who can and those who cannot conjure associated visual mental imagery. Specifically, the timing of those memories recalled: aphants report memories as being accessed 'all at once', without a temporal dimension, or the film-like unfolding that an imager might describe (Quiet Mind Inside b, 2020). They may also have difficulty recalling events when they are described visually, but would have no issues when they are given details about the actions or the people involved (Quiet Mind Inside a, 2020).

Of particular interest to the present dissertation is the interaction between visual mental imagery, memory and emotion: a number of aphants describe emotional detachment from the past, and being able to overcome trauma, such as the death of a loved one, quicker than their peers. This most likely has to do with the lack of intrusive imagery, and a lack of visual component to recreate the experience through which they suffered (Wired UK, 2021). This theory is supported by Greenberg and Knowlton study on autobiographical memory. In 2014, the team conducted experiments with participants who relied mostly on visual imagery, a group who relied on verbal information storage and recall, and a group who experienced no visual mental imagery. Their findings suggested that, not only does visual mental imagery play a role in storing and recalling autobiographical memory, auditory information cannot replace this role: the aphants experienced difficulty in recalling the auditory aspect of events, as well, despite not having a history of lack of auditory mental imagery. The same effect was observed, where memories were recalled all at once in the case of aphants, whereas imagers (both verbal and visual-style participants) described 'reliving' their memories sequentially. D'Argembeau and Van der Linden reported similar findings, and additionally tested the participant's style and ability to imagine the future. They found that the sensory, contextual and emotional details of future predictions matched that of recalled events, and correlated positively with the intensity of visual imagery experienced by individuals (2006). Further observations in the same study linked a history of emotional suppression with reduced capacity for visual mental imagery, both in the case of recall and while imagining the future. A study which tested a group of participants with hyperphantasia against a control group and a group of participants with aphantasia, showed differences in performance for autobiographical memory and future-related imagination, with hyperphants performing significantly better, and being more emotionally engaged than their peers (Milton et al., 2021).

These observations seem to support the claim that the intensity of the experienced imagery correlates positively with emotional intensity, while accessing past events in memory or while predicting an imagined future. In a previous chapter (see 2.2. Visual, Propositional and Enactive Perception) an experiment was described, whereby emotional response, measured as electrodermal activity, to fear-inducing narratives was shown to be almost non-existent in a group of individuals with aphantasia. The same response recorded in the control group showed great spikes in activity at key moments in the narrative (Wicken et al., 2021). These findings should be taken into consideration in the design of the upcoming experiment. For example, in deciding on the method for inducing emotion: namely, visual (photographic) cues are likely to produce a similar effect across a wide sample, whereas autobiographical memory (recounting an event) may evoke stronger emotions as a function of visual mental imagery capabilities.

# Chapter 4

# The Neuroscientific Approach

Neuroimaging research points towards different neural correlates between the precision of visual mental imagery, and the intensity thereof. The current standard for measuring visual mental imagery (the Vividness of Visual Imagery Questionnaire (VVIQ)) does not take these differences into account.

## 4.1. Neural Correlates of Visual Mental Imagery

Owing to the emergence of modern neuroimaging techniques such as the fMRI (functional magnetic resonance imaging) and PET (positron emission tomography) in the 1990s, the study of visual mental imagery was able to partially escape the introspective testing methods and adopt an empirical approach. The findings supported some of the psychological observations and models which preceded them: notably, the overlap of neural activation during perception and imagery supports the relationship that has been consistently drawn between the two. Due to the same imagery debate which dominated research between 1970 and 2000, much of the neuroimaging literature is dedicated to neural correlates between visual perception and imagery. More recent studies leverage the differences in latency and vividness in the study of neural mechanisms for visual mental imagery as a distinct process.

A meta-analytic study conducted in 2018 identified 634 foci of activation based on measurements from 464 participants (Fulford et al., 2018). The activation was prominent in the superior parietal lobule, with greater activation in the left hemisphere, in the inferior premotor areas and the inferior frontal sulcus, areas associated with semantic processing. The team also noted bilateral activation in several areas associated with the integration of eye movements and visual information, including the supplementary and cingulate eye fields (SCEFs) and the frontal eye fields (FEFs), supporting an enactive element in the process of visual mental imagery. Temporal lobe activation was restricted to area PH and regions of the fusiform gyrus, adjacent to the fusiform face complex (FFC). Pearson (2019) also noted activation of the prefrontal cortex during various mental imagery tasks, ranging from conjuring, to manipulation, and complex imagination. He speculates that this area may play a more general executive role, rather than perform a specific imagery-related function. This claim would be supported by Zeman et al.'s study in 2010 where greater PFC activation was noted in aphantasia than in controls. In the case of spatial imagery specifically, some studies show hippocampal activation (Bartolomeo, 2002; Pearson, 2019).

The sequence of activation for visual mental imagery has been noted to be in reverse to that of perception. The information that would be processed first in the occipital lobe, then propagated to multimodal cortices involved in the executive function in the frontal lobe, and memory-related areas in the medial temporal lobe is, in the case of visual mental imagery, first accessed in the latter, then propagated to the former (Pearson, 2019). At the same time, greater activation has been noted for anterior parietal areas during the processes of conjuring and maintaining visual imagery as compared to perception (Milton et al, 2021), and the volume of the prefrontal cortex has been positively correlated with imagery vividness (Bergmann et al, 2016).

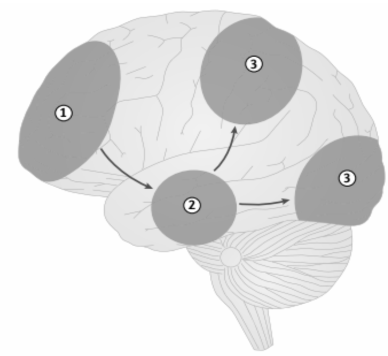



**Image 2.** Pearson's (2019) model of top-down or voluntary imagery: the process starts from the executive area in the prefrontal cortex (1), moving in a reverse sequence to that of perception through the medial temporal areas associated with memory storage (2), and ultimately to the visual cortex in the occipital lobe and sensory areas (3). Additional areas such as the hippocampus, middle temporal areas and parietal lobes may be activated depending on the nature of the imagery (movement or spatial information).

As mentioned earlier in this dissertation (see 2.1 Mental Imagery and Perception), we can distinguish visual mental imagery from visual processing by checking the correspondence between the activation of the retinal cells and the neural excitation in other parts of the perceptual system along the visual pathway (retina to V1 via the lateral geniculate nucleus LGN in the thalamus; outputs from V1 activate other parts of the visual cortex and are also fed forward to a range of extrastriate areas V2, V3, V4/V8, V3a, V5/MT), since the primary visual cortex is organised in a retinotopic manner (Pearson, 2019). In the case of perception, the primary visual cortex or V1 comes into play for low-level depictive features, and its engagement appears to be dependent on task (unlike engagement of higher visual areas, V2 onward, which are engaged in visual mental imagery in a manner comparative to visual perception) (Pearson et al., 2015). Using fMRI and transcranial magnetic phosphene data, resting activity and excitability levels in the early visual cortex (V1-V3) was shown to negatively correlate with sensory imagery strength (Keogh et al., 2020). Electrically inducing lower excitability in the visual cortex using tDCS also correlated with more intense visual imagery, supporting the claim that visual cortex excitability plays a causative role in visual mental imagery (2020). Additional negative correlations have been observed between the surface area of the primary visual cortex (V1) and sensory imagery. However, V1 surface area correlated positively with imagery precision in the same study (Bergmann et al., 2016).

Visual mental imagery has also been explored in clinical studies of schizophrenia and post-traumatic stress disorder (PTSD) among other conditions marked by particularly emotionally intense, disruptive and involuntary mental imagery. Neuroimaging studies of these conditions have noted a reduced size in the primary visual cortex, as much as 25% in schizophrenia compared to healthy controls (Pearson, 2019). The size of the prefrontal cortex was also observed to predict the size of V1, with an increase in the former correlating with decrease in the latter (Song et al., 2011). Although V1 typically activates during visual imagery, even when participants have their eyes closed, consistent with influential depictive theories of visual imagery (Winlove et al., 2017), there is evidence to suggest that early visual cortex activation is not necessary for visual mental imagery: brain lesion studies effected on participants whose occipital lobe, and specifically the retinotopic visual cortex areas, were damaged, nevertheless reported visual mental imagery abilities, although in some cases these were impaired (Bartolomeo, 2002; Bridge et al., 2012). On the other hand, extensive left temporal damage seems to accompany imagery deficits for object form and colour (Bartolomeo, 2002). This suggests that the parallel between perception and visual mental imagery may not be as complete as their phenomenology might imply. Considering all of the above, it would seem that a reduced V1-V2 area may be indicative of stronger visual mental imagery experience. Unfortunately, this study does not make use of fMRI in order to include this information.

In a meta-analytic study published in 2019 which takes into account the above-mentioned observations, Pearson uses the metaphor of a blackboard to outline the way he believes these qualities to interact. In this metaphor, the contrast of white chalk on the blackboard is the top-down signal, its strength determining how sharp and intense the subsequent imagery will be. The clarity of the board, i.e. the level of noise which exists on the visual cortex at a given time, also plays a role in imagery quality. Therefore, more intense imagery is thought to be experienced by individuals whose visual cortex neurons are highly excitable, whose excitability levels correlate negatively with the level of resting activity (in other words, whose 'blackboard' is less noisy), and who experience stronger top-down signalling. In light of these observations, it appears imperative that a distinction be made between LoD (level of detail) and LoI (level of intensity) at a theoretical level (when used in the context of psychological testing, for example), as they appear to rely on distinct cortical features (surface area and excitability levels).

## 4.2. Voluntary and Involuntary Imagery, and the Role of the DMN

A large network of areas have been noted to activate during exercises of visual mental imagery: frontoparietal regions also associated with executive attentional control and the control of eye movements; areas involved in memory, with overlap with the default mode network; primary visual cortices and the fusiform face area (Pearson, 2019). Elsewhere in this dissertation (3.2 Autobiographical Memory) it was mentioned that intense visualisation correlated with stronger resting state connectivity between the medial temporal lobes, associated with memory, and visual areas in the occipital lobe (Sheldon et al., 2016). Greater connectivity has also been observed between prefrontal cortices and the visual network in hyperphants as compared to aphants (Milton et al., 2021). The Default Mode Network, or DMN, is the set of interconnected areas of the brain recently identified as consistently active when the brain is not engaged in a particular task. It connects spatially remote areas of the brain, and includes the precuneus, the posterior cingulate cortex and retrosplenial regions, which together form the posteromedial cortices, and other regions associated with autobiography, self-awareness, daydreaming, remembering the past and anticipating the future (Buckner et al., 2008). Studies have noted individual differences in area size for the DMN, which seems to be more developed or larger in people who perform creative professions, such as musicians or visual artists. It is unclear whether this difference is as a result of creative activity, or if natural size is what predisposes people to a higher level of creativity in the first place (Kuhn, 2014).

Neuroimaging studies of creative processes such as during musical (Jazz and Rap) improvisation sessions have shown decreased activity in the dorso-lateral prefrontal cortex (DL-PFC) associated with the executive function, and increased activity in the medial prefrontal cortex and default-mode network areas (Limb & Braun, 2008; Liu et al., 2012). Studies of attention from a psychological perspective have also correlated leaky attention (the inability to entirely and successfully block distractors, resulting in performance impacted by conflict between relevant and irrelevant stimuli) with creativity, and even more generally with creative people. At the same time, creative individuals have been shown to display effective conflict resolution, i.e. effective selective attention. Early studies associate creativity with unfocused or defocused attention (Eysenc, 1995) or support the idea of leaky selective attention (Mendelsohn et al., 1964/1972). Rawlings (1985) found that creative individuals performed less accurately when presented with a dichotic listening task. These findings are in line with a series of experiments conducted by Mendelsohn: participants given a list of 25 words to memorise (distractors) were made to listen to another 25 words (targets). They were then asked to come up with the solution to an anagram task which required the combination of both lists of words to complete. Participants with higher creative abilities had better accuracy scores, supporting the theory that creativity correlates with leaky types of attention, or the inability to effectively select only relevant stimuli (Mendelsohn and Griswold, 1964). A similar experiment conducted by Mendelsohn and Londholm (1972) was a recall test of likewise distracting and target words played simultaneously, which also resulted in higher accuracy for creative participants.

Intense visual mental imagery has been associated with intrusiveness. Imagery is considered intrusive when conjured involuntarily, and especially if such imagery is emotionally disturbing or if it distracts from, or disrupts ongoing activity. This phenomenon is also referred to 'anomalies of the imagination' (Ramussen et al., 2010). From a neuroscientific perspective, it is interesting to note that involuntary imagery, for example in the case of schizophrenia, as well as involuntary but non-disturbing imagery such as is used in creative endeavours, correlates with stronger activation in the DMN, weaker executive function and smaller V1 and V2 cortical areas. This would suggest that weaker perception, or less reliance on perceptive mechanisms, may correlate with stronger mental imagery, and greater reliance on prediction (as per the 'perception as prediction' theory). Almost two centuries before this information became available, Samuel Taylor Coleridge put forth the idea of primary and secondary imagination (published in the "Biographia Literaria'' in 1817). According to Coleridge and Wordsworth (romantic poets and literary theorists), primary imagination is the involuntary (Pearson would refer to it as bottom-up) process which accesses images in memory. These, they proposed, may be past sensory precepts which left a strong impression on the imagery, and are thus evocative and emotionally charged. While Coleridge considered this ability common to all humans, we now know this not to be the case. Secondary imagination is more akin to top-down imagery in a modern paradigm - based on the evocation of primary imagination, secondary imagination brings narrative, semantic meaning and aesthetic polish to raw imagery. The product of secondary imagination is the product of contemplation and deep artistic sensibility, and is therefore deemed more difficult to master than its primary counterpart. A third type of imagery is proposed, but considered to be beneath the nomenclature of 'imagination' - it is therefore termed 'fancy', and refers to a common ability of manipulating and recombining sensory information from memory. The visual task of, for example, imagining a breakfast table (as is the case in Galton's Questionnaire, 1870), then manipulating the objects which are on it, would most likely fall into this category.

While Coleridge's idea does not fall within the realm of science, the intuition that creative work relies on a schema of past precepts, and at the same time on involuntary activity (the 'muse'), later on induced voluntarily, maintained and manipulated, seems to have retained its merit in light of more recent scientific discoveries. When Coleridge and Wordsworth first proposed the existence of three types of imagination, they were aided in their creative work by opioids. More recently, psychedelics have been shown to disrupt the prediction mechanism of perception and have been associated with highly creative, and emotionally heightened, states (Schartner et al., 2017), suggesting a strong connection between processes in visual mental imagery which rely on higher areas in the visual cortex, the DMN, and emotion. It becomes apparent that there is a need to understand these interactions, not only in the way mental imagery impacts emotion, but in the way emotion impacts mental imagery, involuntary mental imagery, and the creative process in general.

# Chapter 5

# Visualisation, Storytelling, Emotion

While a clear model for emotion as a general concept has yet to emerge, a number of 'core' emotions have been identified, which are considered to make up the foundation for all experience. This distinction is based on the various neurotransmitters involved, some of which have been shown to be released during specific reading experiences.

## 5.1. The Neuroscience of Storytelling

There are two main theories governing the neuroscientific study of emotion: firstly, there is the locationist approach, which most studies adopt either overtly or on whose assumptions they rely. This model supports the idea that different emotions correspond to specific brain regions (a few suggest that a series of networks, or activation sequences, can, instead, be more strongly correlated), and do so consistently between individuals. Within this branch, some scientists adopt a developmental approach, whereby emotions may be divided into "first order", inherent to all human beings and even to other mammals, and "emotion schemas", which develop from first order emotions, and are more specific to an individual and their circumstances. A natural approach assigns all emotions to a single category, that of basic and inherited, and therefore common and inalienable from human nature.

A second main branch corresponds to the constructionist approach, whereby emotions are emergent properties of other established cognitive processes. More specifically, when an individual is presented with specific stimuli, a similar mechanism to that of perception (i.e. integrating the new information into the existing knowledge of the world via predictive processes) takes place, resulting in an emotional reaction which is specific to the stimuli and situation at hand. In order for emotion, or even perception, to take place, this model relies on the theoretical existence of "psychological primitives", or mental processes which cannot be further broken down, and which make up the basis of all complex cognitive functions (Lindquist et al., 2012).

Neuroscientific research in storytelling distinguishes between a number of neurotransmitters and hormones associated with emotions, and the narrative structures which induce them. Dopamine is associated with focus, motivation and memory. It is released during reading when encountering suspense, and since suspense is one of the core narratological elements, all storytelling is associated with dopamine production. Oxytocin is, as well, present with storytelling regardless of genre, as it is associated with empathy and narratives which create a connection between the reader and characters (Peterson, 2017). This neurotransmitter is likely to play a role in what Kuzmičová terms 'perceptual mimesis', and subsequent reader engagement and intense visual mental imagery (2012). Endorphins activate the body's opiate receptors and are associated with a feeling of wellness, creativity, greater focus and relaxation. In narratives, this hormone is induced with laughter and comedic techniques. On the other hand, not all biochemical responses to stories are beneficial. Cortisol and adrenaline are released during stressful reading, for example during a violent or frightening scene. They result in intolerance, irritability, impaired creativity, impaired memory, and have been associated with negative outlook and poor decision-making (Philips, 2017). Emotional correlates of visual imagery, which are explored below, have addressed emotions as a single entity. Troscianko, Kuzmičová and Brosch speak of emotional attachment and its impact on the vividness of visual mental imagery. However, treating all emotions equally means disregarding their varied effect on the biochemistry and psychology of the reader or conjurer. As noted in a previous chapter (see 2.4 Perception and Emotion), negative emotions impact perception in a different manner than do positive emotions, and may impact visual imagery in a similar way.

## 5.2 Emotional Correlates of Visual Imagery

When linking emotion to visual mental imagery, the prevalent scientific approach comes from clinical studies of schizophrenia, post-traumatic stress disorder, obsessive-compulsive disorder and bipolar personality disorder, among others. Such conditions are marked by intrusive, involuntary and affect-laden visual mental imagery, oftentimes noted for their extremely disruptive and detrimental nature. The consensus seems to be that imagery, in this context, has the effect of exacerbating the individual's mood, by forcing them to relive a disturbing past experience, or creating fear for a negative event in an imagined future (Pearson et al., 2015; Pearson, 2019; Ramussen et al., 2019; Berg et al, 2020; Konigsmark et al., 2021). It can be an immersive experience, and an unwanted one in cases where imagery is conjured independently of the person's conscious intention, and sometimes entirely against it (as is the case with post-traumatic stress and intrusive imagery associated with concern for an imagined future, for example in obsessive-compulsive and bipolar disorders (Berg et al., 2020), or with disruptive, macabre imagery in schizophrenia (Ramussen et al., 2019). A separate study led by the same authors (Ramussen et al., 2019) defines anomalous imagination as clear and detailed, with a robust spatial character (the person can explore the image at different locations and depths without the image losing spatial stability), repetitive (described as 'a movie which repeats itself'), and which do not respond to the person's control. They may have sudden onset and no obvious external triggers.

From a cognitive literary perspective, several authors note that emotional engagement is correlated with the intensity of resulting visualisations. Emotional attachment to the character and/or situation emerges as one of the main factors responsible for increase in visual mental imagery vividness (Brosch, 2018), as is being privy to the emotional responses of the characters, either as an observant or in a first-person perspective (Kuzmičová, 2012; see also Troscianko, 2014; Iser, Moore & Schwitzgebel, 2018). The 'eyes' of the character are paramount, Kuzmicova (2012) argues: what makes the description compelling is the emotion imbued by the character who perceives it, whereby the reader falls into "perceptual mimesis", copying the feelings and reactions of the perceiving character. The idea that a description made by a neutral narrator is less potent than one seen through the eyes of a subjective character is supported by several authors (Auyoung, 2015; Esrock, 1994; Scarry, 1996). Brosch links this to the notion of joint attention, a fundamental social ability that allows infants to share someone else's visual perspective even before language development (Mundy & Newell, 2007:269). Brosch (2018) proposes that a heightened emotional experience is directly influenced by the vividness of the imagery that is brought into awareness, possibly drawing this conclusion from studies of intrusive imagery similar to those mentioned in the previous paragraph. The proposal made in the dissertation at hand is that this is one, but not the only, process which drives this phenomenon: the emotion evoked by the story is likewise responsible for the parameters of the ensuing visualisation.

## 5.3 Narratology and Vividness

Narratology is a branch of literary studies, part of the Russian Formalist movement, concerned with analysing the structure, logic and principles (themes, symbols etc) of a story. Cognitive literary studies have, from a narratological perspective, revealed a number of factors which are thought to have an effect on the engagement of the reader, and subsequently on their visual mental imagery. Firstly, vividness decreases with effort: if the narration calls attention to itself (for example, by employing elaborate sentence structure or vocabulary that is difficult to decode), and the reader is forced to expend cognitive resources in order to follow it, this shifts the focus from visual representation to verbal processing and disrupts what is referred to as "presence effect" (Kuzmicova, 2014) (i.e. the experience of immersing oneself in a story). Likewise, shifting narratological perspective requires the reader to adapt their point of view, delaying visualisation or disrupting it, a process referred to as "fictional recentering". (Bortolussi & Dixon, 2003). This happens as the reader inserts themselves into the story and imagines the depicted world from their position occupying one of the characters (Brosch, 2018; Bortolussi & Dixon, 2003). The shift from movement to static description, or from action to object, has also been correlated with increased vividness in mental imagery (Brosch, 2018). From a neuroscientific perspective, the dorsal stream, also known as the 'where'-pathway, is action-oriented and faster than the ventral, object-oriented or 'what'-pathway (Clark, 2008), and is also considered the primary mode of processing (Kuzmicova, 2012; Noe, 2006, Brosch, 2018). These qualities, associated with perception, appear to be maintained in visual mental imagery (Kozhevnikov et al., 2010, p.29). Kuzmicova's and D'Angiulli's studies suggest that dynamic imagery positively correlates with short latency and ease of immersion, which they associate with reliance on schemata, or default visualisation which does not stand out in terms of intensity. From cognitive film theory, however, a different explanation might emerge in the form of motion blur. This phenomenon, present in real life as well as films, could exist in visual mental imagery as well. Transitioning from a fast-paced passage to slower action (Brosch proposes "an elongation in narrated time(...) combined with a closely focused attention by a fictional character on an object") which may also have the added effect of lessening motion blur.

The existence of gaps in description may lead to more intense emotions associated with visual mental imagery than does exhaustive descriptive text, according to Amadeo D'Angiulli's subjective studies of visualisation which employed the VVIQ (2013). One possible explanation could be that gaps in description allow the reader to conjure an image that is more meaningful to them, and closer to their existing framework - which, as mentioned earlier, is closer to automaticity and therefore faster (Auyoung, 2015). This idea is supported by D'Angiulli's experiments which negatively correlate image latency to self-reported vividness. This inverse relationship between vividness and description completeness held true for static as well as dynamic narratives. However, Cavanagh (2005) proposes that gaps (in this case, in visual art) are not only necessary, they are indeed 'the essence of art'. The gap is the object of the artist's exploration: how much should be revealed, and how much should remain hidden in order for a piece of art to express its creator, and at the same time allow space for the viewer's thoughts, emotions, experiences, to insert itself. The author explores human perception in this context, and finds that individuals are less likely to notice impossible physicality (for example, shadows in irregular positions, inconsistent shadows and mirror angles, contradictory foreground-background compositions) when the work they admire evokes powerful affects.

Not only does the viewer's perception become more lenient when mentally engaged with a piece of compelling art, the artist's perception has been shown to change as well. Imagination activated by emotions such as admiration and fear: intense 'looking', directed at an object or entity, dictated by powerful emotions, results in neural networks for perception that would respond more effectively to the shape, colour, and other traits of said object or entity. This would result in the brain 'seeing' these traits in other contexts, such as in the cracks on a cave wall. Onians (2017) proposes that fear, adrenaline and cortisol, cause Michelangelo to draw the profile of a terrifying face of a Turk (a nation with whom Italy was in conflict) while designing the columns of Casa Buonarroti. If fear, and other emotions, can shape creative work in a non-conscious manner, and can likewise involuntarily alter the viewer's perception of impossible physicality, then what effect will emotions have on the process from which many of these experiences arise, namely visual mental imagery.

# Chapter 6

# Methods of Measuring Imagery

From the establishment of the topic of visual mental imagery as a scientific interest in 1880 by Galton, research has revealed two distinct functions within the larger category. Namely, spatial manipulation appears to be a separate process from visualisation, be it realistic or fantastic, and thus requires its distinct test design. Furthermore, different types of measures (subjective, where the participant recounts their experience, and objective, where they use mental imagery to resolve a task), have been shown not to correlate reliably. In other words, the ability to imagine, and the ability to use the ensuing image, may be two distinct functions.

## 6.1. Subjective Measures

Starting with the publication of Galton's 'Statistics of Mental Imagery' in 1880, the measurement of mental imagery has relied on two parallel methods: the subjective method, where participants are asked to rate or otherwise describe their experience as it relates to mental imagery. To this category pertain the aforementioned VVIQ and “Questionnaire upon Mental Imagery” (upon which VVIQ is based), as well as Galton's own “Breakfast Table Questionnaire” (1883) and the test of Visual Imagery Control (TVIC). The second category is the so-called “objective method”, where participants are faced with tests, the answers to which can only be attained by employing mental imagery (McAvinue & Robertson, 2007). Emily Troscianko, whose studies the present dissertation references to a great extent, employs both methods concomitantly: in first instance, the participant engages in a round of testing where mental imagery is necessarily employed in order for any answer to be reached. This is then followed by a subjective description of the experience formulated in the participant's own words (Troscianko 2013). At the same time, correlational and factor analytic studies have not managed to consistently relate these two types of measurement (McAvinue & Robertson, 2007), and small-scale observations have also shown great discrepancies between the reliance on, and manipulation of mental imagery, versus its phenomenology (Troscianko, 2013).

A further three categories can be established for visual mental imagery tests: firstly, those which question vividness, or intensity of the conjured image (BTQ, QMI and the more recent and widely used VVIQ). Secondly, there is the ability to manipulate or control mental imagery, tested by the TVIC (Test of Visual Imagery Control) which nevertheless has low internal consistency estimates, and thirdly, the preference, or how often the testee relies on visual imagery over verbal encoding in their daily habits and in order to solve tasks presented in the test. To the latter category belong the IDQ or Individual Differences Questionnaire, and IDQ-Imagery Habit Scale (IDQ-IHS) with satisfactory psychometric properties (McAvinue & Robertson, 2007). A correlation matrix relating vividness, control, and preference of visual mental imagery over verbal encoding in the context of a meta-analytical study showed three independent factors: vividness, preference, and control (Robertson, 1994).

## 6.2. Correlates with Other Cognitive Functions

Testing mental imagery as a standalone process is not a trivial venture. In order to circumvent some of the difficulty, several studies have attempted to relate mental imagery questionnaires with other cognitive tasks which are better established in specialised literature. Another goal has been to test whether mental imagery is a good predictor of cognitive abilities such as learning, memory and perception, all of which are considered to rely on imagery to some extent. Unfortunately, findings thus far are mixed, with results ranging from low-level correlation (Marks, 1983; Ernest, 1977) to no observable correlation (White, 1977; Neisser, 1970; Kaufman, 1981; Schwitzgebel, 2002). McAvinue and Robertson (2007) in a review of mental imagery measurements to date suggests this may be due to the lack of real-world validation for subjective testing:

whether a participant considers their own experience with visual mental imagery as intense or vivid may not reflect their objective neurological response. Furthermore, the complexity of the tests themselves, some of which do not comprehensively consider the abilities required to complete the task successfully, would most likely limit their predictive ability. This is exacerbated by the fact that the above-mentioned imagery tests also fail to conceptually differentiate, and measure separately for control, vividness and preference (McAvinue & Robertson, 2007). On the other hand, imagery questionnaires do seem to correlate consistently with physiological reaction such as increased heart rate and electrodermal activity, salivation, sexual arousal, skin temperature and muscle action currents (Robertson, 1994).

## 6.3. Objective measures

Objective measures for visual mental imagery are standardised, with satisfactory psychometric evaluations (McAvinue & Robertson, 2007). Although suggestions have been made in the past that spatial tests do not necessarily make use of mental imagery, which has been proposed to be the cause behind the lack of correlation between these types of tests and subjective questionnaires, evidence does not support this assumption (Poltrock & Brown, 1984). On the other hand, subjective tests have received criticism due to their reliance on introspection, a process which can neither be observed nor trusted to be accurate, due to known biases in human psychology. For example, social desirability or the desire to respond to the examiner's expectations may play a part in the participant's impression of their experience (Neisser, 1970). Despite this criticism, both types of tests appear to be of interest for a holistic understanding of the various abilities which relate to 'visual mental imagery'. Objective measures, testing one's ability to manipulate visual information spatially, and subjective measures, inquiring into the phenomenology and humanistic aspect of the ability, but which also seem to rely mostly on object, rather than spatial, imagery (Richardson, 1983) may both offer insight into the interaction between emotion and visual mental imagery processes.

# Chapter 7

# The Issue of Vividness

The Vividness of Visual Imagery Questionnaire (VVIQ) is the standard testing method for aphantasia and phantasia, conditions at opposite sides of the spectrum of visual imagery ability. However, both the term 'vividness' which informs the measurement scale, and the questions asked in the context of the test, have received criticism in the fields of cognitive psychology, as well as cognitive literary study.

## 7.1. The Ambiguous Meaning of 'Vividness'

Several scholars have pointed out that the term "vividness", although relied upon extensively in visual mental imagery research and clinical testing (Brosch, 2018; Herz & Schooler, 2002 etc.) is not operationally defined. Attempts to comprehensively decode the term have, in fact, shown that it is a combination of several disparate concepts that make up the intuitively-understood notion of 'vividness'. Namely, "a combination of clarity and liveliness", where clarity is "the brightness of the image's colours and the sharpness of the outline and details", and clarity is "how dynamic, vigorous and alive the image is" (Marks, 1972b). From the onset, it becomes apparent that 'vividness' is expected to encapsulate an array of qualities, many of which are oftentimes not simultaneous. One need only look at an impressionist painting, or a motion-blurred panning shot in a noir film to understand that it is not necessary, and may even be disadvantageous, for an image to be both saturated and sharp in order for it to strongly impress upon its viewer (Kandel, 2017).

## 7.2. Standardised Visual Terms

From a purely visual standpoint, vividness seems to refer to several concepts which pertain to, and are widely used, in film, photography and computer-generated images, as the emergence of image-manipulation and image-generation software has prompted the standardisation of specialised vocabulary. Now, we may speak of hue, value, and saturation as qualities which are necessary and sufficient to describe the colour properties of a pixel (Selan, 2012; Brejon, 2020).

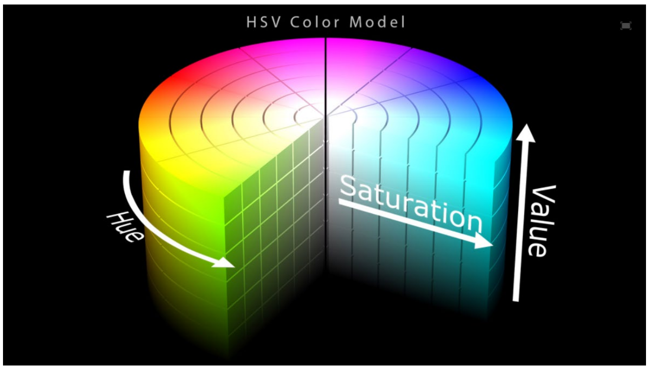



**Image 3**. The HSV (Hue, Saturation, Value) model for interpreting colour.

'Contrast', and 'sharpness', may be adopted to describe specifically the difference in value between pixels across an image. For example, a black-and-white photograph with very dark and very light values has 'high contrast'; however, it is the difference in value for adjacent pixels which describes 'sharpness', i.e. clean edges (versus bleeding or blurred values across object edges). 'Luminance' is what is colloquially known as brightness, and correlates with HSV (hue, saturation, value) - for example, a 50%- value, 100%-saturated yellow has higher luminance than a 50%-value, 100%-saturated blue, because it is perceived as 'brighter' (WorkWithColor, 2021). We can extrapolate, then, that a 'vivid' image would be one described by high luminance, high saturation, and high sharpness. This would be in line with the way VVIQ is formulated, "dim and vague" rating at 2, versus "perfectly realistic, as vivid as real seeing" at the highest rating of 5. In fact, this description is closer to the original methodology proposed by Galton in 1880, who asked participants to rate the "illumination, definition and colouring" of the imagery they conjured. Using modern neuroimaging techniques, we may have a better chance at correlating saturated and sharp imagery with the strength of neural response in the visual cortex (Milton et al., 2021).

## 7.3. Vividness as Emotional Intensity

At the same time, a number of scientists argue that at the core of vividness is not the quality of the image, but rather the emotion associated with it, "the feeling of being there"; in other words the strength of the affective connection that the imager feels with *the idea of* the image they have conjured, whether it be self-prompted or visualised from literary text (Richardson, 1994; Troscianko, 2013; Kuzmičová, 2012a, 2014). Furthermore, in the case of subjective testing, the above-mentioned image qualities are reported by the participant. Therefore, what is asked of the participant is their impression of the image, not its reality (Richardson, 1994). Troscianko's observations seem to point to a similar conclusion: a number of participants who found it difficult to conjure imagery in the context of VVIQ nonetheless reported "intense" imagery during their reading of Kafka (2013). Troscianko suggests the reason for this is that the VVIQ test asks participants to conjure imagery without helping them substitute themselves in the situation. As mentioned earlier in this dissertation (5.2 Emotional Correlates of Visual Imagery), one's ability to visualise text, and the feeling of immersion, are influenced by the ease with which the reader can introduce themselves in the story, termed the "presence effect" (Kuzmičová, 2014). Not being presented in storytelling format, VVIQ does not offer a personal, emotional component: it offers "isolated, mostly static visual descriptions", while engaging literature relies on "enactive descriptions in a narrative context" (Troscianko, 2013).

Reuniting the two lines of thought, several authors have proposed that the term 'vividness' be regarded as straddling two separate concepts: cognitively, there is a visual dimension describing the percept-like content, and affectively, there are emotional cues to which the participant responds (Robertson, 1994; McAvinue & Robertson, 2007; Troscianko, 2013; Jajdelska et al., 2010). Borrowing from the terminology used in these studies, a new rating system can be developed, which divides the two disparate dimensions into Level of Detail (LoD), referring strictly to the sharpness of the image; Level of Intensity (LoI), covering the emotional aspect and disregarding actual visual qualities, the measure of which will instead be termed Saturation, in line with colour theory. Hue and Value are disregarded, as dark imagery need not be any less rich or impactful than colourful or bright mental visual imagery. Furthermore, it is likely that, presented in a story format where the participant is encouraged to immerse themselves, the same descriptions VVIQ makes use of would prompt more intense imagery, and would result in higher scores. At the same time, it is possible that we will see positive correlations between empathy quotient scores (Baron-Cohen & Wheelwright, 2004), and VVIQ scores.

## 7.4. The Language of VVIQ

Further criticism of VVIQ targets its language: Troscianko also underlines the overlap between "imagining" and "seeing" that is present in the explanatory introduction, as well as the rating scale of the questionnaire (2013). For example, visual imagery is described as the ability to "see in the mind's eye", and the highest score on the VVIQ scale is associated with images that are "perfectly clear and as vivid as normal vision". This is, according to Troscianko and supported by Chara and Verplanck's study (1986) simply unattainable: participants who confidently gave their experience the highest score, when submitted to an additional test of looking out the window for 30s, then turning back to the wall and rating their conjuration of that same image which they had been looking at, recognized that not even a fresh, immediate recall was nearly as vivid as actual sight. They proceeded to lower their previous ratings by one, or even two points on the VVIQ scale. This, Troscianko notes, is not because their mental imagery had not been intense, but because in all its intensity it does not behave as real vision does (2013). The same argument that Richardson makes applies here: perhaps it is the idea of the image, or the affective relationship with it, that gives the participant the impression of intensity, which is subsequently reflected in the score (1994). This type of language which ties imagery to perception may be problematic, but it is nevertheless difficult to eliminate, as it allows for mutual understanding when discussing a highly personal experience.

# Chapter 8

# Emotion/Visual Imagery Questionnaire (EVIQ)

The multidisciplinary research outlined in previous chapters was used to inform the design of a novel experiment, one which tested for a single mental imagery process (namely, conjuring) and measured five distinct parameters (Level of Intensity - emotional; Level of Detail, Saturation, Sharpness - visual, and Latency - metavisual) in four emotional conditions (joy, affection, fear and sadness). Emotional vs. non-emotional responses were further identified to create a statistical comparison between dependent variables (emotions, in one context, and imagery parameters, in another).

## 8.1. Participants

The purpose of this experiment was to determine how emotion modulates visual mental imagery: namely, if there is any correlation between heightened emotion and quality of visual mental imagery, and if this correlation differs by type of evoked emotion. Due to practical restrictions (lack of access to a laboratory setting and specialised equipment, as well as lack of funding to compensate participants), the experiment was conducted online, as a questionnaire (titled EVIQ, or Emotion/Visual Imagery Questionnaire). A larger sample of participants was intended to balance the impact this choice in method may have had on the validity of the experiment.

The EVIQ was sent to a particular population - artists working in the field of visual effects for film -, at once because this population was accessible to the author, and because the terms employed in describing the variables (level of detail (LoD), saturation, sharpness, level of intensity (LoI), latency (or ease)) are ones used on a regular basis in the field, and therefore there needn't be a concern for misunderstanding. This resulted in an initial sample of $n$=34 (12 female). Three participants reported feeling no emotion throughout the test, and their data was therefore discounted (*n*=31, 11 female).

## 8.2 Materials

The design of this study was within-subject factorial, with no overt control group. This choice was prompted by the difficulty in designing text which would, at the same time, evoke visual mental imagery, and not evoke any emotion. However, a type of control emerged in the resulting data, and was used to spontaneously create an emotive vs. non-emotive condition comparison. The independent variable was the emotion evoked by the text, while the dependent variables, as mentioned above, were level of detail (LoD), saturation, sharpness, level of intensity (LoI) and latency. All participants were presented with 4 texts extracted from the same author, namely from the novel 'All the light we cannot see' (Doerr, 2014), and modified to a similar length and structure. Each excerpt was selected to evoke one of four emotions: joy, affection, sadness, fear. All excerpts were investigated according to the cognitive literary studies theory presented in previous chapters (see 5.2. Emotions Correlates of Visual Imagery and 5.3. Narratology and Vividness) and modifications were made to equalise their narratological structure. These changes are as follows: any mention of specific colours or times of day was removed so as not to influence the answers on saturation (bright red is by definition less saturated than pale blue). The texts have also been equalised in terms of number of characters, range of actions (all texts are largely static, with small, contained movements, predominantly executed by the main character), number of environments (each text mentions 2 environments). Each text follows the movements and reactions of one main character, which should prompt perceptual mimesis. Furthermore, in line with the multi-modal imagery theory (Kuzmičová, 2012), the texts were equalised for number and type of sensorial imagery. As they were written by the same author, the same 'gaps in narrative' should be present, so as not to confound latency across the four conditions (Auyoung, 2015).

The four texts were randomised so as to avoid order or carryover effects. All texts contained a number of 'check questions', where the participant was asked to type in an answer. The intent behind these questions was to force the participant to conjure specific imagery related to the variable they were subsequently asked to rate, for example: 'what colour is the woman's dress?' followed by 'how saturated is the image?'. A secondary purpose was to check whether a pattern would emerge, for example whether a joyful scene (a child eating cake) would result in brighter, happier colours than a scene charged with negative emotion (a child leaving an orphanage). These 'check questions' were not taken into consideration in the final statistical analysis, but they were investigated for trends or oddities, to see if they might reveal possible confounding variables, such as the trend mentioned above. Notably, emotion was such a check question, and proved highly valuable in the redesign of the experiment outlined in subchapter 8.4 Procedure. For the full texts and questions please refer to Appendix A.

## 8.3 Procedure

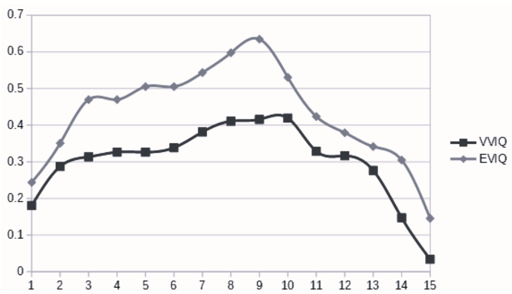
In the first iteration of this experiment, each participant was asked to complete the Vividness of Visual Imagery Questionnaire before proceeding to read the texts. At the end of each text, participants were asked which emotion the excerpt evoked. An initial run of this experiment (*n*=15, 3 female) quickly revealed that the design of the experiment was flawed, in that it did not effectively induce emotion in the participants. 10 individuals reported feeling no emotion in 3 or more conditions. Due to time constraints, this version of the experiment was abandoned; a modified version was run instead, which resulted in the final data analysed in the following subchapters. This version presented participants with 5 photos, each held for 2s, before presenting the text. This method of inducing emotion, described in studies of perception (Carrasco et al., 2006), was chosen in the detriment of having the participant recount an emotional autobiographical episode because, as mentioned in the literature review, the level of emotion associated with autobiographical memory is dependent on one's ability to conjure mental imagery (3.2 Autobiographical Memory)(Wicken et al., 2021). The photos were equalised for saturation and hue (range of colours) as well as for size of the subject within frame, number and genus of subjects depicted.

The second iteration of the EVIQ proved better suited for the needs: three out of 34 participants reported feeling no emotion for all conditions, their answers consequently disregarded in final calculations; all remaining participants (*n*=31, 11 female) reported emotion in at least 2 conditions, allowing for a basis of comparison. Inducing emotion before presenting the texts also reduced the possibility of learning or adjustment effects. The participants are less likely to have felt no emotion at the beginning of the text, effectively providing false data for the first questions, and emotion-impacted data for latter questions per condition. The VVIQ was dropped for time concerns (the questionnaire was already long, and the rate of mortality high as suggested by the JATOS record of discontinued and failed attempts). Moreover, there was little merit in comparing the VVIQ to EVIQ results, which was the initial intent, as the EVIQ by itself provided enough information, and the VVIQ is not devoid of emotional cues, therefore lacking as control. In the case of the second iteration, all 'check questions' regarding emotion revealed that the evoked emotion was, indeed, close to the intended emotion. For example, for 'sadness' answers such as 'loss', 'emptiness', 'sorrow', 'desolation' etc were considered valid.

# 8.4 Results

## 8.4.1. First Design

Results for the first iteration of the EVIQ and VVIQ were normalised according to the mean and standard deviation (scaled to mean = 0 and standard deviation = 1). All conditions for the EVIQ were pooled into a single statistical description, as were all answers for VVIQ. Comparing the curves of these two tests, there is limited support for greater scores under the EVIQ compared to VVIQ. This is in line with Troscianko's study (2013), which shows participants who scored 1 on the VVIQ (criterion for a diagnosis of aphantasia), nevertheless were able to conjure imagery during more potent readings of Kafka. However, it must be noted that, despite the apparent correlation, the sample size was small (n=15), highly skewed for gender (20% female), and that over 66% of this sample reported no emotion on the EVIQ test.




| VVIQ normal | EVIQ normal |
|---|---|
| 0.18 | 0.24 |
| 0.29 | 0.35 |
| 0.31 | 0.47 |
| 0.33 | 0.47 |
| 0.33 | 0.51 |
| 0.34 | 0.51 |
| 0.38 | 0.54 |
| 0.41 | 0.60 |
| 0.42 | 0.63 |
| 0.42 | 0.53 |
| 0.33 | 0.42 |
| 0.32 | 0.38 |
| 0.28 | 0.34 |
| 0.15 | 0.30 |
| 0.03 | 0.15 |

**Graph 1.** Scatter and normalised values for VVIQ and EVIQ in the first iteration of the experiment

### 8.4.2 Second Design

Results from the second iteration of the EVIQ were normalised , and statistically described. Single-factor ANOVA (alpha = 0.05) was run per variable, comparing normalised data across the four different emotions. Out of all five variables, only saturation analysis revealed statistically significant differences between conditions (F = 4.63, F critical = 2.69), with affection and joy higher than fear and sadness.

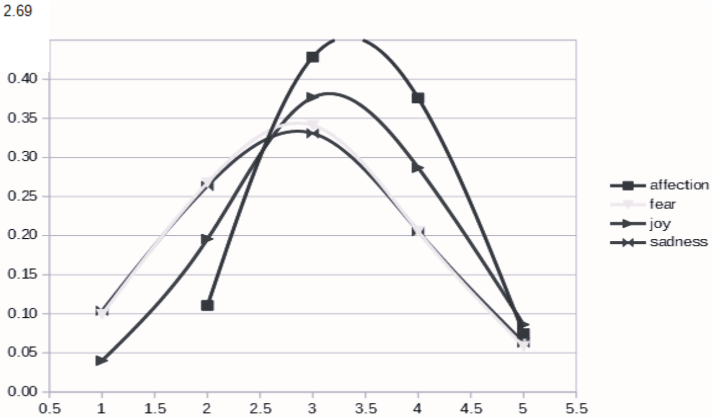
**ANOVA - Single Factor**

Alpha 0.05

| Groups | Count | Sum | Mean | Variance |
|---|---|---|---|---|
| elation | 28.00 | 9.39 | 0.34 | 0.02 |
| fear | 29.00 | 7.11 | 0.25 | 0.01 |
| joy | 27.00 | 7.34 | 0.27 | 0.01 |
| sadness | 28.00 | 6.83 | 0.24 | 0.01 |

| Source of Variation | SS | df | MS | F | P-value | F critical |
|---|---|---|---|---|---|---|
| Between Groups | 0.15 | 3.00 | 0.05 | 4.64 | 0.00 | 2.69 |
| Within Groups | 1.20 | 108.00 | 0.01 | | | |
| Total | 1.36 | 111.00 | | | | |

**Table 1.** ANOVA results for saturation across conditions




**Graph 2.** Point scatter for saturation across conditions.

Neither Sharpness (*F* = 1.55) nor Level of Detail (*F* = 1.02) were affected by negative vs. positive emotions in the manner predicted by perception studies. Latency did not reach statistical significance (*F* = 1.81), and the Level of Intensity appeared to be the least affected (*F* = 0.76). For ANOVA tables and graphs, please refer to Appendix B.1.

A further within-group statistical analysis was conducted on the data obtained from participants who declared not feeling any emotion in at least one condition (*n* = 16, 6 female). First, each variable was assessed for all conditions taken together (ex. Scores for Level of Detail for empathy, fear, joy and sadness pooled together). Statistically significant differences were observed for Sharpness when comparing emotive vs. non-emotive scores (*F* = 26.89, F critical = 3.99) and for Saturation (*F* = 21.58). In both cases the non-emotive scores were significantly lower than the emotive ones. Level of Intensity (*F* = 3.72), Latency (F = 0.63) and Level of Detail (*F* = 0.00) did not show any significant discrepancies between the two conditions. ANOVA tables and resulting graphs are available in Appendix B.2. In a second round, emotive vs. non emotive scores were pooled for all variables and assessed per emotion. Fear only had one participant who declared not feeling any emotion while reading the text, and therefore could not be assessed. Sadness (F = 8.10, F critical = 3.93) and Affection (F =

4.51) presented statistically significant differences whereby the emotive condition had higher scores then the non-emotive participants. Joy (F = 1.40) remained below statistical significance. These results are available in Appendix B.3.

## 8.5 Discussion

The review of existing research in perception studies prompted the following expectations: a 'narrowing' of visual mental imagery for negative emotions (fear and sadness, in this case), and, conversely, 'broadening' in the positive emotions. It was unclear how this would translate in terms of detail, sharpness, saturation, intensity and latency, but the assumption was that some difference would be observed, supporting the claims that different emotions impact VMI differently, and that dividing 'vividness' into a set of narrower and more clearly defined parameters is necessary. Latency was predicted to correlate positively with negative emotions, as studies in perception note quicker orientation towards threatening or negatively charged stimuli. Intensity, being a measure of emotional rather than visual quality, was expected to be higher in emotive than in non-emotive participants.

The results outlined in the previous subchapter partially support the initial predictions. Saturation indeed correlates positively with empathy and joy; however, none of the other variables showed statistically significant differences between conditions, suggesting that the same narrowing and broadening effect either does not translate from perception to visual mental imagery, or that the experiment design did not accurately test for this effect. It is possible, as the original perception studies (Derryberry & Tucker, 1994, Zadra & Clore, 2011) were visual matching or problem-solving tasks, which may translate to visual mental imagery control and preference, rather than conjuring.

Moreover, the prediction that visual mental imagery scores would correlate positively with emotion appears to be partially supported. Saturation and sharpness scores were higher in participants who also declared having an emotional response to the text; however, intensity, detail and latency showed no correlation with emotion. Due to the very small sample available (*n* =16) for this secondary analysis, not enough data points were gathered to allow for isolating each specific emotion, or at least a pooling of data per emotional value (negative or positive). Instead, data from all emotions was pooled together and analysed. If any specific effects were to exist in distinct emotions, this would not be apparent in the results. It is, therefore, possible that detail and latency would be impacted, but not by emotion in general, rather by specific positive or negative emotions.

In perception studies, sadness was shown to inhibit VMI (Keogh & Pearson, 2020). However, EVIQ results show significantly higher scores in the emotive than in the non-emotive condition. It is unclear why this would be the case. It is possible, as this experiment relied on a subjective method, that participants reported the impression of more salient mental imagery rather than its objective quality. Moreover, given the neuroscientific storytelling theory outlined earlier, it is possible that sadness in the conjuring process has a different effect because of the bond, or mimesis, which it prompts. The same mimesis effect is likely not to apply to experiments which do not employ narrative structure. It would be interesting to see as well if these results can be replicated with other mental imagery processes such as control (2D or 3D).

Empathy scores (Baron-Cohen & Wheelwright, 2004) were not run for this iteration of the experiment, for the same reason that VVIQ was dropped in the second trial, namely because the mortality rate was high due to the test taking a very long time. It would be interesting to see, in future research, if the prediction that empathy scores correlate positively with EVIQ scores stands true.

Taken together, the results of the experiment and the theory upon which it relies, could be interpreted as follows: Sharpness and Saturation are indeed two visual qualities which future studies in visual mental imagery should measure separately. Any differences in Latency would likely be more readily apparent with non-subjective methods, such as EEG, fMRI, skin conductivity. The Level of Detail, although widely used in image studies, could potentially be discarded as it showed the least change, and is also tenuously supported by specialized literature. Lastly, any future studies should test separately for the different VMI processes. At the moment, the most widely used method (VVIQ) tests for conjuring as well as control, while measuring a single variable, namely 'vividness'.

## 8.6 Limitations

As mentioned in a previous chapter (6.1. Subjective Measures), questionnaires rely on the impression of the participant, on their subjective experience. With the matter at hand, the various measured qualities of the evoked visual mental image may interact to a large degree; for example an image may appear more saturated and easier to conjure if it is also intense. However, while it is unclear to what degree the specific aspects are indeed as related by the participant, or whether their interaction is too great to tell, it may be safe to say whether emotion impacted the overall quality of the imagery. It must be kept in mind that this is what the experiment at hand is intended to measure: the impression of mental imagery, not its quality, objectively. However, for future studies, an objective method such as skin conductivity, EEG or fMRI should be considered.

Moreover, the original control condition (VVIQ) was dropped in the second iteration of the experiment, due to practical considerations (time to complete the experiment) as well as due the realisation that the VVIQ contains emotional cues, and therefore cannot be considered a true control. For any subsequent studies, the author strongly suggests a modified control condition, although this may prove difficult to create. Numerous studies have shown the human tendency for assigning emotion, narration, purpose, action and reaction structures to even the most simple information (Kahnemann, 2011:74-78), therefore determining a visual imagery exercise which would confidently not result in emotion may not be straightforward.

We have allowed the participation of non-native English speakers, as long as they expressed their confidence in reading comprehension. At the same time, it is not fully understood how English (or text in any secondary or tertiary language) may impact visual imagery, even with full proficiency. Similarly, participants were asked if they were diagnosed with a reading disorder; a single participant answered positively to this question so it was not possible to note whether this impacted their understanding and, consequently, the visualisation of the text, compared to other participants. However, this participant's score across all conditions was very high (median = 5), which suggests their disorder may have had no impact. It would be interesting to see if this holds true for future studies, and with a much larger sample, or if this participant was an outlier.

As mentioned in earlier subchapters, the variables were selected based on standardised, specialised terminology which, while familiar to everyone participating in the EVIQ, may be difficult for the larger population. For any generalised iterations of this experiment, a review of the terms and their substitution for popular language, if available, is recommended.

# Chapter 9

# Conclusion

The dissertation at hand proposed the following two theories: firstly, that different emotions modulate visual mental imagery (or the ability to conjure sensations, images, smells, sounds and tastes in their absence from the immediate environment (Bence, 2018)) in specific ways, depending on their value as either positive or negative, but also in the specific emotional response they generate in the participant (joy, affection, fear, sadness). Secondly, that standardised methods of measurement (the Vividness of Visual Imagery Questionnaire (VVIQ) (Marks, 1973)) do not accurately demonstrate these differences, and that more focused, clearly defined operational terms are needed. Both of these theories are based on a multidisciplinary approach interconnecting psychological, neuroscientific and cognitive literary theory studies.

In order to inform the first theory, cognitive processes closely related to or associated with visual mental imagery were identified, namely perception, memory and Default Mode Network processes, the set of interconnected areas of the brain identified as consistently active when the brain is not engaged in a particular task but in a state of free creation, or daydreaming (Buckner et al., 2008). Some studies of perception outlined intersections with emotion, and showed a 'narrowing' or perception after negative emotional cues, and conversely a 'broadening' after positive cues. The emerging Emotion/Visual Imagery Questionnaire contained similar visual cues (photos) as outlined by perception studies (Derryberry & Tucker, 1994, Zadra & Clore, 2011). Research indicates that visual mental imagery may be a core process in autobiographical memory, with aphants (individuals who are unable to conjure visual imagery) less likely to remember scenes accurately in terms of image or sound, and unlikely to associate emotion to their memories. Therefore, autobiographical recounting, which is another common choice in inducing emotion in participants, was eliminated from the EVIQ so as not to confound the resulting data (D'Argembeau & Van der Linden, 2006; Milton et al., 2021).

Neuroscientific research and cognitive literary scientific research both informed the criticism of existing standards of measurement, the most widely used being the

VVIQ. Neural correlates pointed towards different predictors for the accuracy, sharpness or level of detail of visual mental imagery which correlated positively with V1 surface area (Bergmann et al., 2016), than for strength, or intensity which was shown to correlate negatively with resting activity and excitability levels in V1-V3 (Keogh et al., 2020). Further distinction between terms was borrowed from image manipulation and generation fields, where a clear description of colour and image quality in standardised terms is paramount (Selan, 2012; Brejon, 2020). Sharpness and Saturation were identified as relevant to the study of mental imagery. Cognitive literary science, a field proposed by Troscianko and Burke (2017) to bridge the gap between cognitive studies and philology, has dived more deeply into what makes text visually and emotionally evocative. Research has found a number of predictors, amongst which perceptual mimesis, static as opposed to moving imagery, linear description in space and time. These findings were used to modify the EVIQ texts for greater potency, and to equivalate them across all emotional conditions. At the same time, the conditions themselves were prompted by neuroscientific research in storytelling, which outlined the overlap between brain biochemistry and emotional phenomenology, from which identification of core, distinct emotions was made possible (Lindquist et al., 2012; Philips. 2017; Peterson, 2017).

The ensuing test, titled Emotion/Visual Imagery Questionnaire or EVIQ, had a within-subjects design, measuring rating scales for the five variables identified above. This subjective approach is intended to measure the impression of visual mental imagery; imagery control as well as preference or manipulation tasks were discounted as they have been shown to measure distinct parameters from 'vividness' or image quality tests (Robertson, 1994). Statistical differences were observed between dependent variables, suggesting that, indeed 'vividness' as a standard term may be too broad to capture the intricacies of the visual imagery process. The resulting data also made apparent that emotional intensity should justifiably be kept separate from other parameters of visual quality, such as sharpness, saturation, or level of detail. Overall, the data showed several positive correlations between emotion and visual mental imagery. Unfortunately, not enough data was collected to more accurately limit the correlations between types of emotions in an emotional vs non-emotional context (control).

The applications for continued research in the field of emotion and visual mental imagery are vast, and varied. In the field of cognitive psychology, an understanding of visual mental imagery and its processes may lead us closer to defining visual imagination, which in turn could shed more light on cognitive processes in general, or specifically inform our approach to the creative process. For example, if a specific emotional state is shown to be highly beneficial to the creative process, a strategy could be developed to induce it on cue. From a socioeconomic perspective, this would aid not only the productivity and quality of output in creative industries, such as visual effects, advertisement, design, architecture etc., but more importantly allow for the creation of guidelines for controlling the work environment. In some, if not all of these industries, the current approach is notoriously high-pressure, under the assumption that stress facilitates creation, and if not, at least that it does negatively impact it. This is, of course, detrimental to the mental health and work-life balance of professionals, while also hurting the growth and sustainability of the industry in the long run.

In artificial and machine learning, visual mental imagery models have been successfully applied to decision-making as well as task-independent processes for agents which need to orient in space, or for distributional semantic models which contain both text and visual information. A particularly promising branch of research has emerged in decoding visual cortex information using Artificial Neural Networks (specifically, Generative Adversarial Networks). This research has shown that not only can fMRI information from the visual cortex be translated into imagery, but this can happen outside of conscious awareness, before volitional engagement or during sleep (Nishimoto et al., 2011; Albers et al., 2013; Koenig-Robert & Pearson, 2019). One can only speculate what advancements access to this kind of information could prompt, in clinical applications as well as creative endeavours. Associations between visual cortex activation and synthesis of neurotransmitters associated with emotion (outlined in 5.1. The Neuroscience of Storytelling) could as well have clinical applications and inform the treatment of intrusive mental imagery in cases of psychosis, depression, PTSD (Ramussen et al., 2019; Berg et al., 2020).

# Appendix A

## EVIQ

### A.1.1 Fear (not explicitly named in the test)

Marie-Laure is 16 years old and blind.

She holds beneath her fingers the miniature wooden model of her uncle's house where she currently lives. Where she currently kneels on the sixth floor alone, as a dozen bomber planes roar towards her. <br>

The windows rattle in their housings. The anti-air guns unleash another volley. The earth rotates just a bit farther.

Picture the room. How detailed is the image? scale input 1-5

Opening the model involves a cunning series of steps: find a seam with your fingernails, slide the bottom to the right, detach a side rail, remove a hidden key from inside the rail.

Now the bombers are so close that the floors start to throb under her knees. Out in the hall, the crystal pendants of the chandelier chime.

She twists the chimney of the miniature house ninety degrees and finds the key hole. Her fingers tremble. Sirens wail.

Picture the girl's facial expression. How saturated is the image? scale input 1-5

She holds her breath. For too long a moment the key doesn't find its place and it seems like she will never make it in time. The next second, a click and release: the model opens, she slides off a wooden panel and turns it over.

A stone drops into her palm.

It's cold. The size of a pigeon's egg. The shape of a teardrop.

> What colour is the stone? text input
>
> How sharp is the image? scale input 1-5

She clutches the tiny wooden house in one hand and the stone in the other. The room feels flimsy, tenuous. Giant fingertips seem about to punch through its walls.

'Papa?' she whispers. But no-one answers.

> Did the text and photos elicit any emotion? text input
>
> On a scale of 1-5, how intense was the visual imagery provoked by the entire text? scale input 1-5
>
> On a scale of 1-5, how easy was it to conjure? scale input 1-5

### A.1.1 Joy (not explicitly named in the test)

15-year old Werner peers over the top of the radio set the couple asked him to fix: to his left, the woman reads a magazine; to his right, her husband speaks into the telephone.

Could they have missed something so simple? It feels like a gift. Werner rewinds the resistance track and splices the wires and plugs in the radio. When he turns it on, he half-expects it to be broken; instead, the murmur of a saxophone emerges.

At the table, the woman puts down the magazine and exclaims with joy. Werner climbs out from behind the radio, his eyes wide with excitement, his mind clear of all feeling save triumph. His first job, perfectly accomplished.

> What is Werner's facial expression at this moment? text input

How sharp is that image? scale input 1-5

'He fixed it! Two grown men couldn't figure it out, but he fixed it in half a minute!' the woman praises, flourishing her brilliant fingernails and breaking into childlike laughter. Behind her there is a torrent of bright music. The small, wooden box produces a vivid, full sound: Werner has never heard another like it.

What colour is the woman's dress? text input

How saturated is the image? scale input 1-5

The husband ushers Werner to the dining room table and calls for the maid to bring cake. Immediately it appears: four wedges on a plain white plate. Each is dusted with confectioner's sugar and topped by a dollop of whipped cream.

Werner takes a piece. Powdered sugar cascades down his chin. He eats the piece, then another, then a third.

Picture the cake. How detailed is the image? scale input 1-5

The husband watches with his head slightly cocked, amused, considering something.

"I could have a job for you, son.", he says after a while. " You could belong."

What emotion does the text provoke? text input

- On a scale of 1-5, how intense was the visual imagery provoked by the text? scale input 1-5
- On a scale of 1-5, how easy was it to conjure? scale input 1-5

### A.1.3 Affection (not explicitly named in the test)

"You have to swear." his younger sister says. "Do you swear?" Amid rusted scraps of iron and shredded garbage, wormy creek-bottom muck, she has discovered ten yards of copper wire. Her eyes are bright tunnels. Never would she have imagined finding such a treasure.

Her brother glances at the trees, the creek , then back at his sister. “I swear”.

Picture the girl. How saturated is the image? scale input 1-5

Together they smuggle the wire home and loop it back and forth through nail holes outside the attic window. Then they attach it to the radio. Almost immediately, on a shortwave band, they can hear someone talking in a strange language full of z’s and z’s. “Is it Russian?”

Her brother thinks it’s Hungarian.

“How far away is Hungary?” she asks.

“A thousand kilometres?”

She gapes.

What time of day is it? text input

Picture the sky. How detailed is the image? scale input 1-5

After lights-out, she sneaks up to her brother’s room; instead of drawing together, they lie hip-to-hip listening till midnight, till one, till two. They hear British reports they cannot understand; they hear an Austrian woman pontificating about the proper makeup for a cocktail party. They muffle their laughs, hide their excitement under the soft blanket.

Picture the Austrian woman’s facial expression. How sharp is the image? scale input 1-5

Voices, it turns out, streak into their small town from all over the continent, through the clouds, the dust, the shingles on the tattered roof; an ancient sea spilling through the streets, and the air streaming with possibility.

What emotion does the text provoke? text input

On a scale of 1-5, how intense was the visual imagery provoked by the text?

On a scale of 1-5, how easy was it to conjure?

### A.1.4 Sadness (not explicitly named in the test)

He remembers his caretaker at the orphanage. How she looked early in the morning of his departure, standing in her nightdress beside the bed as light poured in from the hall lamp; fussing over his bag, folding his clothes neatly while all the other children were asleep.

She seemed lost, dazed, as if she could not absorb how quickly things were changing around her. She said she was proud. She said he should do his best. "You're a smart boy", she said. "You'll do well." She kept adjusting and readjusting his collar. When he said "It's only a week," her eyes filled slowly, as if some internal flood were gradually overwhelming her.

Describe the caretaker's hair in 2-3 words. text input

How sharp is the image? scale input 1-5

Now, two years later, he understands the reason for her tears. He understands, too, he was never supposed to go back.

In the dim light of the wooden barrack which is now his home he only has the memories of his days at the orphanage to keep him warm. Mail does not reach him; months pass and he does not write the sister he left behind. Instead, he sometimes folds paper aeroplanes, like they used to do together when they were children, not that he's much older now.

Picture the barrack. How detailed is the image? scale input 1-5

On the small dusty table he leans over the sheet with intense concentration, folding and turning it over methodically, running his finger over the creases until a wide-winged plane with a long forked tail emerges. He pushes it into the air and it sails neatly across the small space, flying straight and true, and smacks into the window nose-first. Outside, the wind is howling and snow rushes into the glass with a deafening sound.

Picture the boy. How saturated is the image?  scale input 1-5

There is no dignity in his work, no pride. He would shed a tear for himself, for his sister, if he had any left.

What emotion does the text provoke? text input

On a scale of 1-5, how intense was the visual imagery provoked by the text?

On a scale of 1-5, how easy was it to conjure?

# Appendix B

# Single-factor ANOVA between conditions

### B.1.1 Level of Detail

| affection | fear | joy | sadness |
|---|---|---|---|
| 0.05 | 0.21 | 0.21 | 0.30 |
| 0.29 | 0.30 | 0.24 | 0.16 |
| 0.05 | 0.21 | 0.21 | 0.14 |
| 0.31 | 0.24 | 0.30 | 0.31 |
| 0.31 | 0.09 | 0.30 | 0.30 |
| 0.14 | 0.24 | 0.11 | 0.14 |
| 0.31 | 0.24 | 0.24 | 0.30 |
| 0.31 | 0.30 | 0.30 | 0.31 |
| 0.29 | 0.30 | 0.30 | 0.30 |
| 0.14 | 0.21 | 0.24 | 0.16 |
| 0.14 | 0.11 | 0.24 | 0.16 |
| 0.17 | 0.21 | 0.30 | 0.30 |
| 0.29 | 0.21 | 0.30 | 0.31 |
| 0.05 | 0.11 | 0.24 | 0.04 |
| 0.14 | 0.30 | 0.30 | 0.16 |
| 0.31 | 0.24 | 0.24 | 0.31 |
| 0.14 | 0.21 | 0.24 | 0.30 |
| 0.17 | 0.21 | 0.30 | 0.14 |
| 0.29 | 0.09 | 0.24 | 0.30 |
| 0.31 | 0.30 | 0.11 | 0.30 |
| 0.17 | 0.30 | 0.30 | 0.30 |
| 0.29 | 0.21 | 0.24 | 0.14 |
| 0.31 | 0.24 | 0.11 | 0.30 |
| 0.29 | 0.11 | 0.21 | 0.31 |
| 0.14 | 0.24 | 0.11 | 0.16 |
| 0.31 | 0.21 | 0.24 | 0.30 |

| | | | |
|---|---|---|---|
| 0.17 | 0.09 | 0.30 | 0.14 |
| 0.14 | 0.11 | 0.11 | 0.04 |
| 0.31 | 0.24 | 0.24 | 0.31 |
| 0.14 | 0.11 | 0.24 | 0.14 |
| 0.31 | 0.11 | 0.24 | 0.30 |

**ANOVA - Single Factor**

Alpha 0.05

| Groups | Count | Sum | Mean | Variance |
|---|---|---|---|---|
| affection | 31 | 6.735184337 | 0.217264011 | 0.00836865 |
| fear | 31 | 6.266530934 | 0.202146159 | 0.005108761 |
| joy | 31 | 7.257317767 | 0.234107025 | 0.003858219 |
| sadness | 31 | 7.165072645 | 0.231131376 | 0.007554865 |

| Source of Variation | SS | df | MS | F | P-value | F critical |
|---|---|---|---|---|---|---|
| Between Groups | 0.01995651779 | 3 | 0.006652173 | 1.069030143 | 0.364972942 | 2.68016757 |
| Within Groups | 0.74671487653 | 120 | 0.006222624 | | | |
| Total | 0.76667139431 | 123 | | | | |

### B.1.2 Level of Intensity

| affection | fear | joy | sadness |
|---|---|---|---|
| 0.02 | 0.09 | 0.08 | 0.14 |
| 0.16 | 0.09 | 0.08 | 0.14 |
| 0.16 | 0.09 | 0.08 | 0.14 |
| 0.16 | 0.33 | 0.36 | 0.14 |
| 0.16 | 0.33 | 0.36 | 0.14 |
| 0.16 | 0.33 | 0.36 | 0.38 |
| 0.39 | 0.33 | 0.36 | 0.38 |
| 0.39 | 0.33 | 0.36 | 0.38 |
| 0.39 | 0.33 | 0.36 | 0.38 |
| 0.39 | 0.33 | 0.42 | 0.38 |
| 0.39 | 0.33 | 0.42 | 0.38 |
| 0.39 | 0.33 | 0.42 | 0.38 |
| 0.39 | 0.33 | 0.42 | 0.38 |
| 0.39 | 0.39 | 0.42 | 0.35 |
| 0.39 | 0.39 | 0.42 | 0.35 |
| 0.39 | 0.39 | 0.42 | 0.35 |

| | | | |
|---|---|---|---|
| 0.39 | 0.39 | 0.42 | 0.35 |
| 0.32 | 0.39 | 0.42 | 0.35 |
| 0.32 | 0.39 | 0.42 | 0.35 |
| 0.32 | 0.39 | 0.42 | 0.35 |
| 0.32 | 0.39 | 0.42 | 0.35 |
| 0.32 | 0.39 | 0.42 | 0.35 |
| 0.32 | 0.39 | 0.42 | 0.35 |
| 0.32 | 0.39 | 0.13 | 0.35 |
| 0.32 | 0.15 | 0.13 | 0.11 |
| 0.09 | 0.15 | 0.13 | 0.11 |
| 0.09 | 0.15 | 0.13 | 0.11 |
| 0.09 | 0.15 | | 0.11 |
| | 0.15 | | |

**ANOVA - Single Factor**

Alpha 0.05

| Groups | Count | Sum | Mean | Variance |
|---|---|---|---|---|
| affection | 28 | 7.946757914 | 0.283812783 | 0.013973246 |
| fear | 29 | 8.681430827 | 0.299359684 | 0.012182359 |
| joy | 27 | 8.814844714 | 0.32647573 | 0.018601541 |
| sadness | 28 | 7.958737317 | 0.284240618 | 0.012802544 |

| Source of Variation | SS | df | MS | F | P-value | F critical |
|---|---|---|---|---|---|---|
| Between Groups | 0.032877834 | 3 | 0.010959278 | 0.764752731 | 0.516232047 | 2.688691468 |
| Within Groups | 1.547692463 | 108 | 0.014330486 | | | |
| Total | 1.580570297 | 111 | | | | |

### B.1.3 Level of Saturation

| affection | fear | joy | sad |
|---|---|---|---|
| 0.11 | 0.10 | 0.04 | 0.10 |
| 0.11 | 0.10 | 0.20 | 0.10 |
| 0.11 | 0.10 | 0.20 | 0.26 |
| 0.11 | 0.27 | 0.20 | 0.26 |
| 0.43 | 0.27 | 0.20 | 0.26 |
| 0.43 | 0.27 | 0.38 | 0.26 |
| 0.43 | 0.27 | 0.38 | 0.26 |
| 0.43 | 0.27 | 0.38 | 0.26 |
| 0.43 | 0.27 | 0.38 | 0.26 |
| 0.43 | 0.27 | 0.38 | 0.26 |

| | | | |
|---|---|---|---|
| 0.43 | 0.27 | 0.38 | 0.26 |
| 0.43 | 0.27 | 0.38 | 0.26 |
| 0.43 | 0.27 | 0.38 | 0.33 |
| 0.43 | 0.27 | 0.38 | 0.33 |
| 0.38 | 0.34 | 0.29 | 0.33 |
| 0.38 | 0.34 | 0.29 | 0.33 |
| 0.38 | 0.34 | 0.29 | 0.33 |
| 0.38 | 0.34 | 0.29 | 0.33 |
| 0.38 | 0.34 | 0.29 | 0.33 |
| 0.38 | 0.34 | 0.29 | 0.33 |
| 0.38 | 0.34 | 0.29 | 0.33 |
| 0.38 | 0.34 | 0.29 | 0.21 |
| 0.38 | 0.34 | 0.29 | 0.21 |
| 0.38 | 0.21 | 0.29 | 0.21 |
| 0.38 | 0.21 | 0.09 | 0.21 |
| 0.38 | 0.21 | 0.09 | 0.06 |
| 0.07 | 0.06 | 0.09 | 0.06 |
| 0.07 | 0.06 | | 0.06 |
| | 0.06 | | |

**ANOVA - Single Factor**

| Alpha | | 0.05 | | |
|---|---|---|---|---|

| Groups | Count | Sum | Mean | Variance |
|---|---|---|---|---|
| affection | 28 | 9.389469172 | 0.335338185 | 0.016453542 |
| fear | 29 | 7.10680237 | 0.245062151 | 0.00933236 |
| joy | 27 | 7.341801081 | 0.271918559 | 0.010831426 |
| sadness | 28 | 6.833634415 | 0.244058372 | 0.007957962 |

| Source of Variation | SS | df | MS | F | P-value | F critical |
|---|---|---|---|---|---|---|
| Between Groups | 0.154847651 | 3 | 0.051615884 | 4.637569826 | 0.004330183 | 2.688691468 |
| Within Groups | 1.202033747 | 108 | 0.011129942 | | | |
| Total | 1.356881398 | 111 | | | | |

### B.1.4 Sharpness

| affection | fear | joy | sad |
|---|---|---|---|
| 0.08 | 0.02 | 0.08 | 0.02 |
| 0.08 | 0.12 | 0.08 | 0.12 |
| 0.08 | 0.12 | 0.08 | 0.12 |
| 0.25 | 0.12 | 0.08 | 0.12 |

| | | | |
|---|---|---|---|
| 0.25 | 0.12 | 0.29 | 0.12 |
| 0.25 | 0.32 | 0.29 | 0.12 |
| 0.25 | 0.32 | 0.29 | 0.35 |
| 0.25 | 0.32 | 0.29 | 0.35 |
| 0.25 | 0.32 | 0.40 | 0.35 |
| 0.25 | 0.32 | 0.40 | 0.35 |
| 0.25 | 0.36 | 0.40 | 0.35 |
| 0.25 | 0.36 | 0.40 | 0.36 |
| 0.25 | 0.36 | 0.40 | 0.36 |
| 0.25 | 0.36 | 0.40 | 0.36 |
| 0.35 | 0.36 | 0.40 | 0.36 |
| 0.35 | 0.36 | 0.40 | 0.36 |
| 0.35 | 0.36 | 0.40 | 0.36 |
| 0.35 | 0.36 | 0.40 | 0.36 |
| 0.23 | 0.36 | 0.40 | 0.36 |
| 0.23 | 0.36 | 0.40 | 0.36 |
| 0.23 | 0.36 | 0.19 | 0.36 |
| 0.23 | 0.36 | 0.19 | 0.36 |
| 0.23 | 0.36 | 0.19 | 0.36 |
| 0.23 | 0.16 | 0.19 | 0.36 |
| 0.23 | 0.16 | 0.19 | 0.36 |
| 0.23 | 0.16 | 0.19 | 0.13 |
| 0.07 | 0.16 | 0.19 | 0.13 |
| 0.07 | 0.16 | | 0.13 |
| | 0.16 | | |

**ANOVA - Single Factor**

| Alpha | | 0.05 | | |
|---|---|---|---|---|

| Groups | Count | Sum | Mean | Variance |
|---|---|---|---|---|
| affection | 28 | 6.317425708 | 0.225622347 | 0.006352527 |
| fear | 29 | 7.677406671 | 0.264738161 | 0.012304098 |
| joy | 27 | 7.599986034 | 0.281480964 | 0.015123019 |
| sadness | 28 | 7.805633081 | 0.27877261 | 0.01369387 |

| Source of Variation | SS | df | MS | F | P-value | F critical |
|---|---|---|---|---|---|---|
| Between Groups | 0.055366005 | 3 | 0.018455335 | 1.558427838 | 0.203718024 | 2.688691468 |
| Within Groups | 1.278965975 | 108 | 0.011842278 | | | |
| Total | 1.33433198 | 111 | | | | |

### B.1.5 Latency

| affection | fear | joy | sad |
|---|---|---|---|
| 0.01 | 0.02 | 0.09 | 0.07 |

| | | | |
|---|---|---|---|
| 0.11 | 0.15 | 0.09 | 0.20 |
| 0.11 | 0.15 | 0.38 | 0.20 |
| 0.11 | 0.15 | 0.38 | 0.20 |
| 0.33 | 0.15 | 0.38 | 0.20 |
| 0.33 | 0.15 | 0.38 | 0.20 |
| 0.33 | 0.36 | 0.38 | 0.20 |
| 0.33 | 0.36 | 0.38 | 0.31 |
| 0.33 | 0.36 | 0.38 | 0.31 |
| 0.33 | 0.36 | 0.38 | 0.31 |
| 0.33 | 0.36 | 0.38 | 0.31 |
| 0.33 | 0.36 | 0.38 | 0.31 |
| 0.33 | 0.36 | 0.38 | 0.31 |
| 0.37 | 0.36 | 0.38 | 0.31 |
| 0.37 | 0.36 | 0.38 | 0.31 |
| 0.37 | 0.36 | 0.41 | 0.31 |
| 0.37 | 0.33 | 0.41 | 0.31 |
| 0.37 | 0.33 | 0.41 | 0.25 |
| 0.37 | 0.33 | 0.41 | 0.25 |
| 0.37 | 0.33 | 0.41 | 0.25 |
| 0.37 | 0.33 | 0.41 | 0.25 |
| 0.37 | 0.33 | 0.11 | 0.25 |
| 0.16 | 0.33 | 0.11 | 0.25 |
| 0.16 | 0.33 | 0.11 | 0.25 |
| 0.16 | 0.33 | 0.11 | 0.11 |
| 0.16 | 0.12 | 0.11 | 0.11 |
| 0.16 | 0.12 | 0.11 | 0.11 |
| 0.16 | 0.12 | | 0.11 |
| 0.16 | 0.12 | | |
| | 0.12 | | |

**ANOVA - Single Factor**

Alpha 0.05

| Groups | Count | Sum | Mean | Variance |
|---|---|---|---|---|
| affection | 29 | 7.667031839 | 0.264380408 | 0.012297946 |
| fear | 30 | 7.945947735 | 0.264864924 | 0.012654412 |
| joy | 27 | 8.187711489 | 0.303248574 | 0.01689758 |
| sadness | 28 | 6.586542308 | 0.235233654 | 0.005322319 |

| Source of Variation | SS | df | MS | F | P-value | F critical |
|---|---|---|---|---|---|---|
| Between Groups | 0.064044871 | 3 | 0.02134829 | 1.814264713 | 0.148758967 | 2.687139227 |
| Within Groups | 1.294360143 | 110 | 0.01176691 | | | |
| Total | 1.358405014 | 113 | | | | |

# Appendix C

# Single-factor ANOVA for Emotion vs. Control

## C.1 Quality of Mental Imagery vs Control

### C.1.1 Level of Detail

| emotion | no emotion |
|---|---|
| 0.11 | 0.10 |
| 0.11 | 0.10 |
| 0.11 | 0.10 |
| 0.11 | 0.10 |
| 0.11 | 0.22 |
| 0.11 | 0.22 |
| 0.11 | 0.22 |
| 0.11 | 0.22 |
| 0.23 | 0.22 |
| 0.23 | 0.28 |
| 0.23 | 0.28 |
| 0.23 | 0.28 |
| 0.23 | 0.28 |
| 0.23 | 0.22 |
| 0.23 | 0.22 |
| 0.23 | 0.22 |
| 0.23 | 0.22 |
| 0.23 | 0.22 |
| 0.23 | 0.10 |
| 0.29 | 0.10 |
| 0.29 | 0.10 |
| 0.29 | 0.10 |
| 0.29 | |

0.29

0.21

0.21

0.21

0.21

0.21

0.21

0.21

0.21

0.21

0.21

0.21

0.21

0.09

0.09

0.09

0.09

0.09

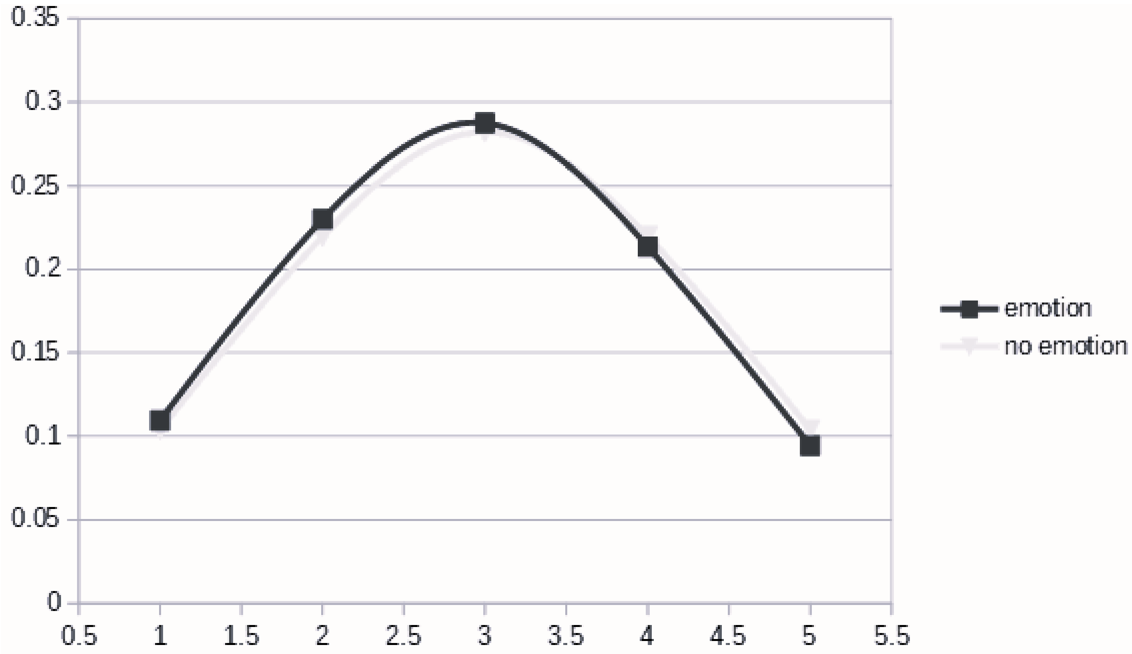
0.09

**ANOVA - Single Factor**

| Alpha | 0.05 | | | | | |
|---|---|---|---|---|---|---|

| Groups | Count | Sum | Mean | Variance |
|---|---|---|---|---|
| Column 1 | 42 | 7.968439419 | 0.189724748 | 0.004358589 |
| Column 2 | 22 | 4.155564003 | 0.188889273 | 0.004866495 |

| Source of Variation | SS | df | MS | F | P-value | F critical |
|---|---|---|---|---|---|---|
| Between Groups | 1.00776E-05 | 1 | 1.00776E-05 | 0.002224341 | 0.962534972 | 3.995887126 |
| Within Groups | 0.28089852 | 62 | 0.004530621 | | | |
| Total | 0.280908598 | 63 | | | | |




**C.1.2 Level of Intensity**

| emotion | no emotion |
|---|---|
| 0.15 | 0.20 |
| 0.15 | 0.20 |
| 0.15 | 0.20 |
| 0.15 | 0.20 |
| 0.15 | 0.20 |
| 0.15 | 0.44 |
| 0.15 | 0.44 |
| 0.15 | 0.44 |
| 0.15 | 0.44 |
| 0.15 | 0.44 |
| 0.15 | 0.44 |
| 0.36 | 0.44 |
| 0.36 | 0.44 |
| 0.36 | 0.44 |
| 0.36 | 0.44 |
| 0.36 | 0.44 |
| 0.36 | 0.28 |
| 0.36 | 0.28 |
| 0.36 | 0.28 |
| 0.33 | 0.28 |
| 0.33 | 0.05 |
| 0.33 | 0.05 |

0.33

0.33

0.33

0.33

0.33

0.33

0.33

0.33

0.33

0.33

0.33

0.33

0.33

0.33

0.33

0.11

0.11

0.11

0.11

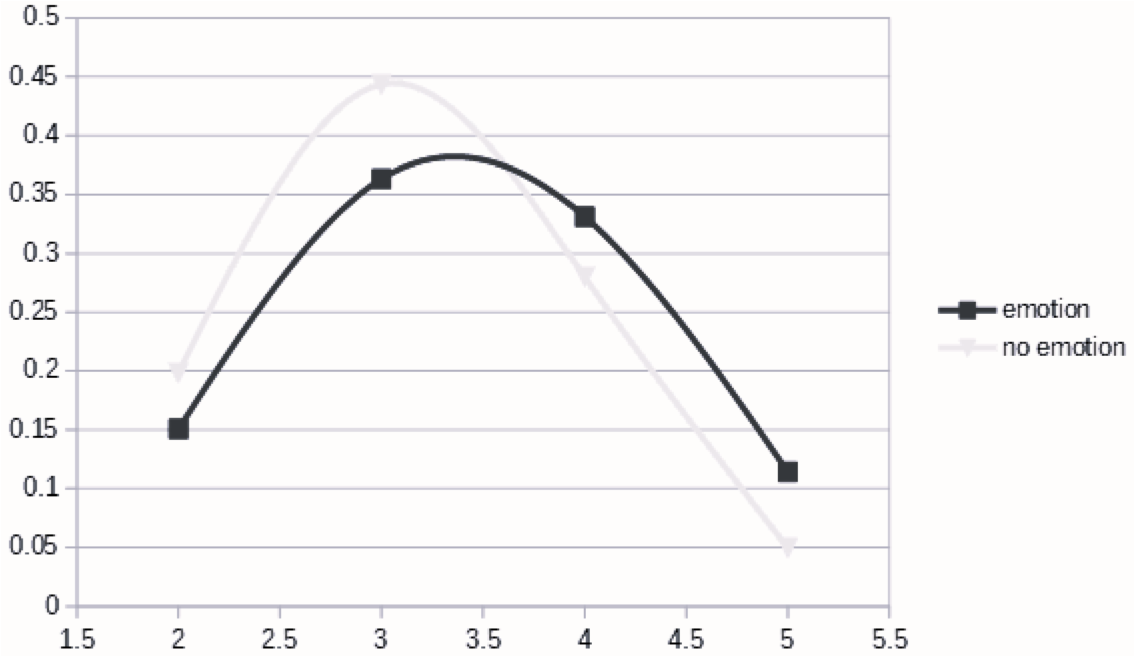
0.11

**ANOVA - Single Factor**

Alpha 0.05

| Groups | Count | Sum | Mean | Variance |
|---|---|---|---|---|
| Column 1 | 42 | 11.09772372 | 0.264231517 | 0.010106154 |
| Column 2 | 22 | 7.090219173 | 0.32228269 | 0.018786181 |

| Source of Variation | SS | df | MS | F | P-value | F critical |
|---|---|---|---|---|---|---|
| Between Groups | 0.048653489 | 1 | 0.048653489 | 3.729333169 | 0.058039751 | 3.995887126 |
| Within Groups | 0.808862117 | 62 | 0.013046163 | | | |
| Total | 0.857515606 | 63 | | | | |




**C.1.3 Saturation**

| emotion | no emotion |
|---|---|
| 0.04 | 0.10 |
| 0.04 | 0.10 |
| 0.27 | 0.10 |
| 0.27 | 0.10 |
| 0.27 | 0.10 |
| 0.27 | 0.22 |
| 0.27 | 0.22 |
| 0.27 | 0.22 |
| 0.27 | 0.28 |
| 0.27 | 0.28 |
| 0.27 | 0.28 |
| 0.27 | 0.28 |
| 0.47 | 0.22 |
| 0.47 | 0.22 |
| 0.47 | 0.22 |
| 0.47 | 0.22 |
| 0.47 | 0.22 |
| 0.47 | 0.22 |
| 0.47 | 0.22 |
| 0.47 | 0.10 |
| 0.47 | 0.10 |

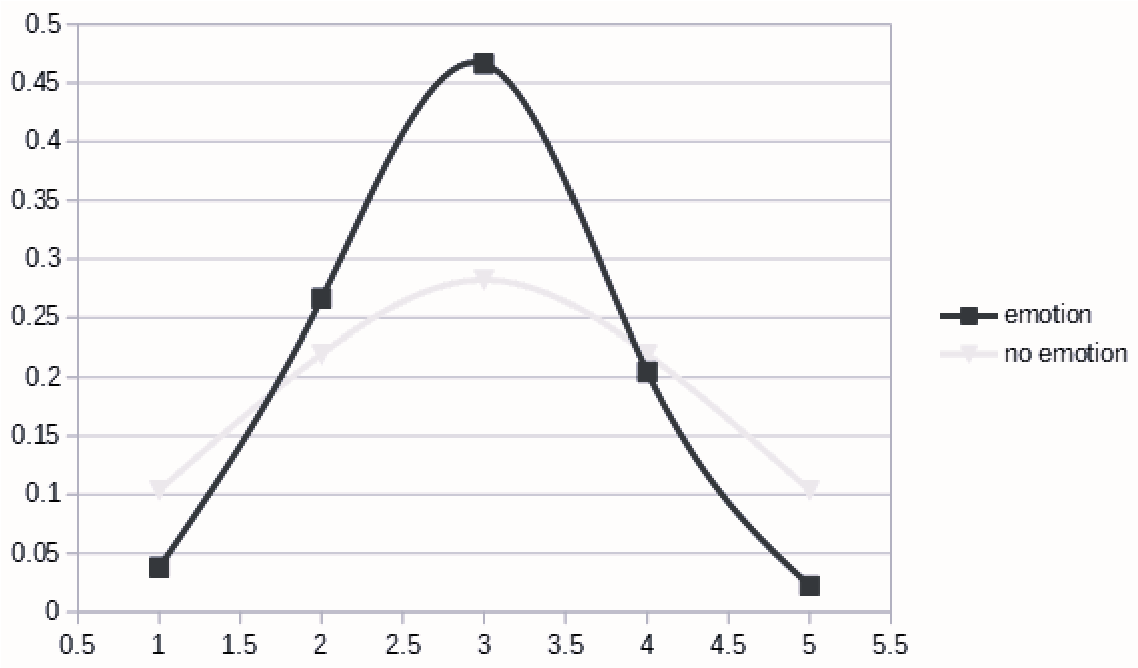
| | |
|---|---|
| 0.47 | 0.10 |
| 0.47 | |
| 0.47 | |
| 0.47 | |
| 0.47 | |
| 0.47 | |
| 0.47 | |
| 0.47 | |
| 0.47 | |
| 0.47 | |
| 0.47 | |
| 0.47 | |
| 0.20 | |
| 0.20 | |
| 0.20 | |
| 0.20 | |
| 0.20 | |
| 0.20 | |
| 0.20 | |
| 0.20 | |
| 0.02 | |

**ANOVA - Single Factor**

| Alpha | 0.05 |
|---|---|

| Groups | Count | Sum | Mean | Variance |
|---|---|---|---|---|
| Column 1 | 42 | 14.194762 | 0.337970524 | 0.019991312 |
| Column 2 | 22 | 4.155564003 | 0.188889273 | 0.004866495 |

| Source of Variation | SS | df | MS | F | P-value | F critical |
|---|---|---|---|---|---|---|
| Between Groups | 0.320876605 | 1 | 0.320876605 | 21.58112637 | 1.8158E-05 | 3.995887126 |
| Within Groups | 0.921840185 | 62 | 0.01486839 | | | |
| Total | 1.242716791 | 63 | | | | |




### C.1.4 Sharpness

| emotion | no emotion |
|---|---|
| 0.03 | 0.10 |
| 0.18 | 0.15 |
| 0.18 | 0.15 |
| 0.18 | 0.15 |
| 0.18 | 0.15 |
| 0.18 | 0.15 |
| 0.18 | 0.19 |
| 0.18 | 0.19 |
| 0.18 | 0.19 |
| 0.18 | 0.18 |
| 0.18 | 0.18 |
| 0.40 | 0.18 |
| 0.40 | 0.18 |
| 0.40 | 0.18 |
| 0.40 | 0.18 |
| 0.40 | 0.18 |
| 0.40 | 0.18 |
| 0.40 | 0.18 |
| 0.40 | 0.18 |
| 0.40 | 0.18 |
| 0.40 | 0.14 |
| 0.40 | 0.14 |

0.30

0.30

0.30

0.30

0.30

0.30

0.30

0.30

0.30

0.30

0.30

0.30

0.30

0.30

0.30

0.30

0.30

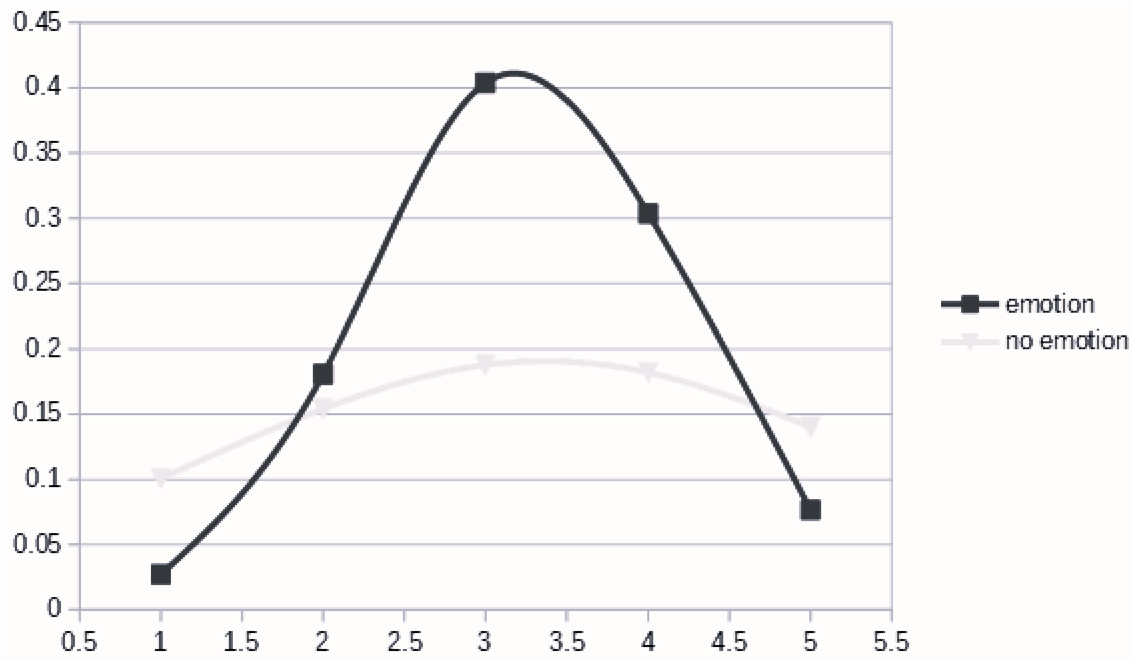
0.30

0.08

0.08

**ANOVA - Single Factor**

| | | | | | | |
|---|---|---|---|---|---|---|
| Alpha | 0.05 | | | | | |
| | | | | | | |
| Groups | Count | Sum | Mean | Variance | | |
| Column 1 | 42 | 11.89299615 | 0.283166575 | 0.010330955 | | |
| Column 2 | 22 | 3.717594332 | 0.168981561 | 0.00049086 | | |
| | | | | | | |
| Source of Variation | SS | df | MS | F | P-value | F critical |
| Between Groups | 0.188239266 | 1 | 0.188239266 | 26.89893379 | 2.49721E-06 | 3.995887126 |
| Within Groups | 0.433877215 | 62 | 0.00699802 | | | |
| Total | 0.62211648 | 63 | | | | |




### C.1.5 Latency

| emotion | no emotion |
|---|---|
| 0.03 | 0.02 |
| 0.03 | 0.17 |
| 0.19 | 0.17 |
| 0.19 | 0.41 |
| 0.19 | 0.41 |
| 0.19 | 0.41 |
| 0.19 | 0.41 |
| 0.19 | 0.41 |
| 0.19 | 0.41 |
| 0.40 | 0.41 |
| 0.40 | 0.41 |
| 0.40 | 0.41 |
| 0.40 | 0.41 |
| 0.40 | 0.41 |
| 0.40 | 0.32 |
| 0.40 | 0.32 |
| 0.40 | 0.32 |
| 0.40 | 0.32 |
| 0.40 | 0.32 |
| 0.40 | 0.32 |

| | |
|---|---|
| 0.40 | 0.08 |
| 0.40 | 0.08 |
| 0.40 | |
| 0.40 | |
| 0.40 | |
| 0.30 | |
| 0.30 | |
| 0.30 | |
| 0.30 | |
| 0.30 | |
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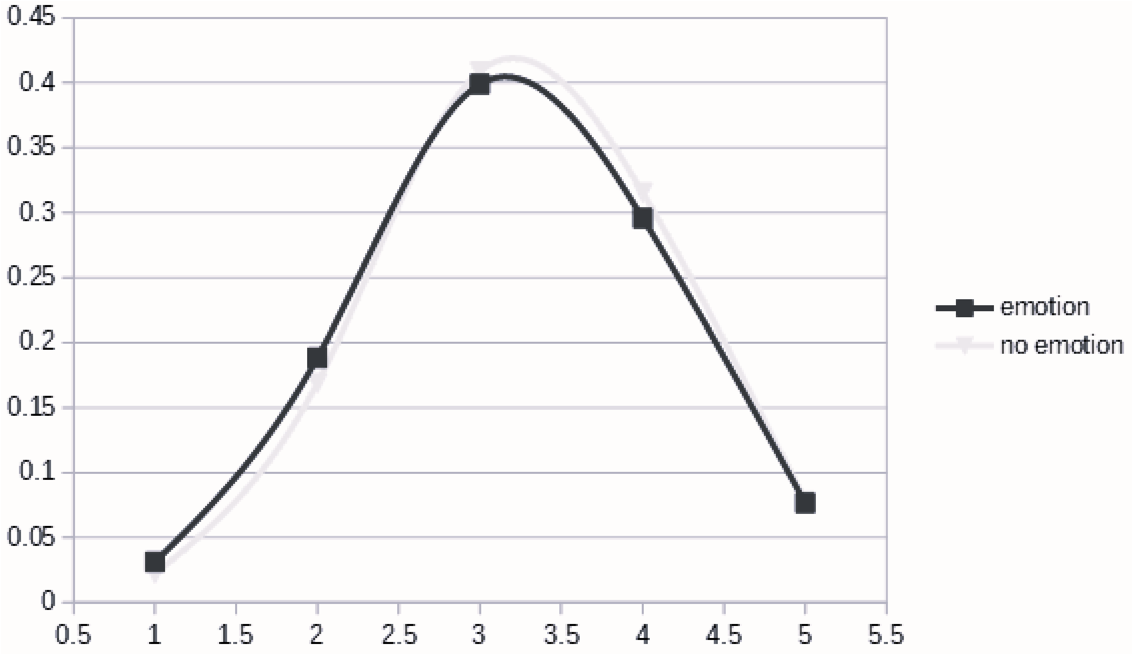
| 0.30 | |
| 0.30 | |
| 0.30 | |
| 0.30 | |
| 0.30 | |
| 0.30 | |
| 0.30 | |
| 0.08 | |
| 0.08 | |
| 0.08 | |

**ANOVA - Single Factor**

Alpha 0.05

| Groups | Count | Sum | Mean | Variance |
|---|---|---|---|---|
| Column 1 | 42 | 12.13418048 | 0.288909059 | 0.012999838 |
| Column 2 | 22 | 6.904347774 | 0.31383399 | 0.016099528 |

| Source of Variation | SS | df | MS | F | P-value | F critical |
|---|---|---|---|---|---|---|
| Between Groups | 0.008969328 | 1 | 0.008969328 | 0.638398468 | 0.427341638 | 3.995887126 |
| Within Groups | 0.871083467 | 62 | 0.014049733 | | | |
| Total | 0.880052795 | 63 | | | | |




# C.2 Distinct Emotions vs Control

### C.2.1 Sadness

| sadness | no emotion |
|---|---|
| 0.07 | 0.14 |
| 0.07 | 0.14 |
| 0.07 | 0.14 |
| 0.07 | 0.14 |
| 0.07 | 0.14 |
| 0.26 | 0.14 |
| 0.26 | 0.26 |
| 0.26 | 0.26 |
| 0.26 | 0.26 |
| 0.26 | 0.26 |
| 0.26 | 0.26 |
| 0.26 | 0.26 |
| 0.26 | 0.29 |
| 0.26 | 0.29 |
| 0.26 | 0.29 |
| 0.26 | 0.29 |
| 0.26 | 0.29 |
| 0.26 | 0.29 |

| | |
|---|---|
| 0.26 | 0.18 |
| 0.39 | 0.18 |
| 0.39 | 0.18 |
| 0.39 | 0.18 |
| 0.39 | 0.07 |
| 0.39 | 0.07 |
| 0.39 | 0.07 |
| 0.39 | |
| 0.39 | |
| 0.39 | |
| 0.39 | |
| 0.39 | |
| 0.39 | |
| 0.39 | |
| 0.39 | |
| 0.39 | |
| 0.39 | |
| 0.39 | |
| 0.39 | |
| 0.39 | |
| 0.22 | |
| 0.22 | |
| 0.22 | |
| 0.22 | |
| 0.22 | |
| 0.22 | |
| 0.22 | |
| 0.22 | |
| 0.22 | |
| 0.22 | |

0.22

0.22

0.22

0.22

0.22

0.05

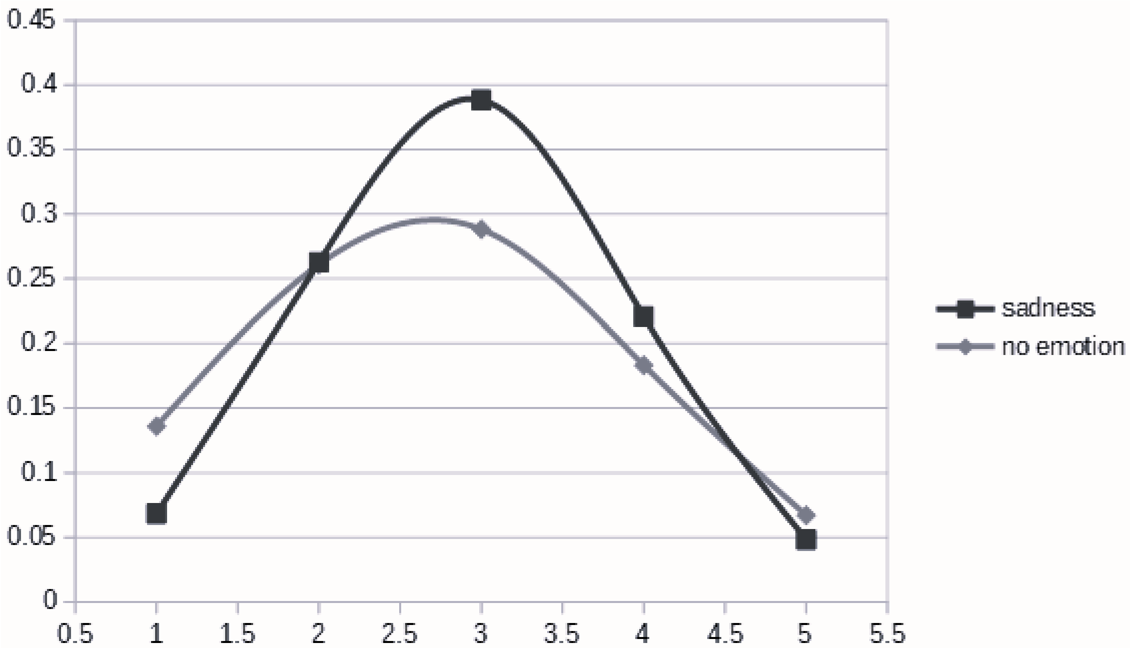
0.05

**ANOVA - Single Factor**

Alpha 0.05

| Groups | Count | Sum | Mean | Variance |
|---|---|---|---|---|
| Column 1 | 55 | 14.80872456 | 0.269249537 | 0.011196514 |
| Column 2 | 25 | 5.045463675 | 0.201818547 | 0.00615593 |

| Source of Variation | SS | df | MS | F | P-value | F critical |
|---|---|---|---|---|---|---|
| Between Groups | 0.078150505 | 1 | 0.078150505 | 8.102221551 | 0.005647067 | 3.963472051 |
| Within Groups | 0.752354074 | 78 | 0.009645565 | | | |
| Total | 0.830504579 | 79 | | | | |




### C.2.2 Affection

affection no emotion

| | |
|---|---|
| 0.04 | 0.03 |
| 0.20 | 0.03 |
| 0.20 | 0.03 |
| 0.20 | 0.14 |
| 0.20 | 0.14 |
| 0.20 | 0.14 |
| 0.20 | 0.14 |
| 0.20 | 0.14 |
| 0.40 | 0.14 |
| 0.40 | 0.30 |
| 0.40 | 0.30 |
| 0.40 | 0.30 |
| 0.40 | 0.30 |
| 0.40 | 0.30 |
| 0.40 | 0.30 |
| 0.40 | 0.30 |
| 0.40 | 0.30 |
| 0.40 | 0.32 |
| 0.40 | 0.32 |
| 0.40 | 0.32 |
| 0.40 | 0.32 |
| 0.40 | 0.32 |
| 0.40 | 0.32 |
| 0.40 | 0.32 |
| 0.28 | 0.32 |
| 0.28 | 0.32 |
| 0.28 | 0.32 |
| 0.28 | 0.32 |
| 0.28 | 0.32 |
| 0.28 | 0.32 |
| 0.28 | 0.32 |
| 0.07 | 0.32 |
| 0.07 | 0.32 |
| 0.07 | 0.32 |
| 0.07 | 0.32 |
| | 0.16 |
| | 0.16 |
| | 0.16 |
| | 0.16 |

0.16

0.16

0.16

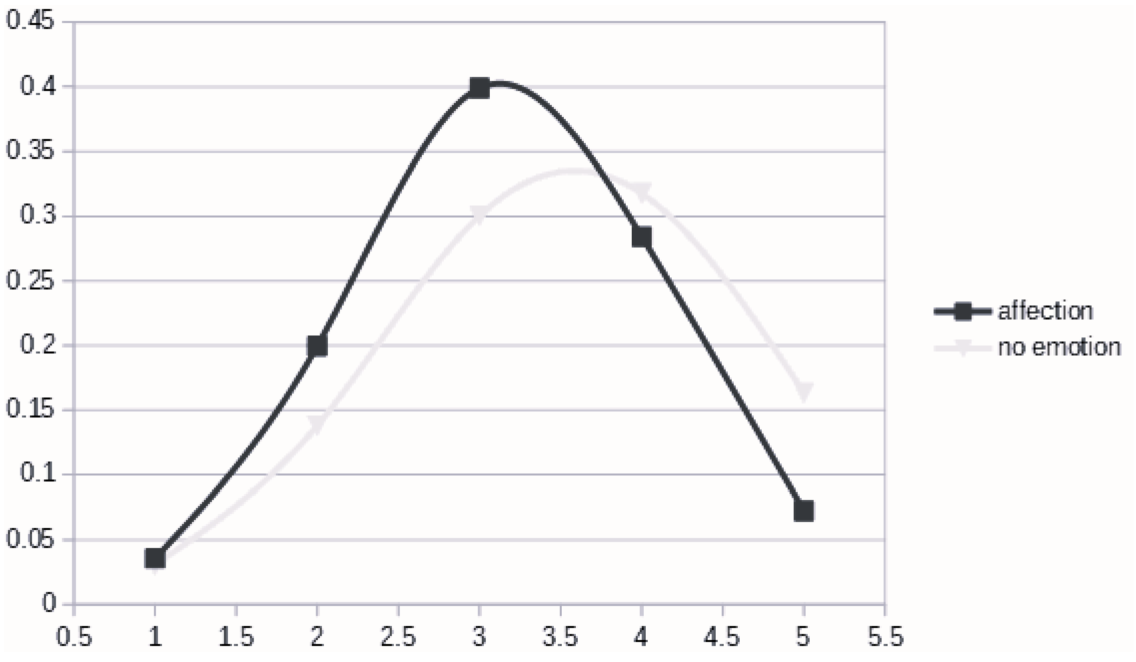
0.16

0.16

0.16

**ANOVA - Single Factor**

| | | | | | | |
|---|---|---|---|---|---|---|
| Alpha | | 0.05 | | | | |
| | | | | | | |
| Groups | Count | Sum | Mean | Variance | | |
| Column 1 | | 35 | 10.09748428 | 0.288499551 | 0.014762351 | |
| Column 2 | | 45 | 10.67754563 | 0.237278792 | 0.008867602 | |
| | | | | | | |
| Source of Variation | SS | df | MS | F | P-value | F critical |
| Between Groups | 0.051651459 | 1 | 0.051651459 | 4.51612937 | 0.03674252 | 3.963472051 |
| Within Groups | 0.892094423 | 78 | 0.011437108 | | | |
| Total | 0.943745882 | 79 | | | | |




### C.2.3 Joy

| joy | emotion |
|---|---|
| 0.04 | 0.04 |

| | |
|---|---|
| 0.04 | 0.04 |
| 0.04 | 0.27 |
| 0.34 | 0.27 |
| 0.34 | 0.27 |
| 0.34 | 0.27 |
| 0.34 | 0.27 |
| 0.34 | 0.27 |
| 0.34 | 0.27 |
| 0.34 | 0.27 |
| 0.34 | 0.47 |
| 0.34 | 0.47 |
| 0.34 | 0.47 |
| 0.34 | 0.47 |
| 0.34 | 0.47 |
| 0.49 | 0.47 |
| 0.49 | 0.47 |
| 0.49 | 0.47 |
| 0.49 | 0.47 |
| 0.49 | 0.47 |
| 0.49 | 0.47 |
| 0.49 | 0.47 |
| 0.49 | 0.47 |
| 0.49 | 0.47 |
| 0.49 | 0.47 |
| 0.49 | 0.47 |
| 0.49 | 0.47 |
| 0.49 | 0.20 |
| 0.49 | 0.20 |
| 0.49 | 0.20 |
| 0.49 | 0.20 |
| 0.49 | 0.20 |
| 0.49 | 0.20 |
| 0.49 | 0.20 |
| 0.49 | 0.20 |
| 0.49 | |
| 0.49 | |
| 0.49 | |
| 0.49 | |
| 0.49 | |

0.12

0.12

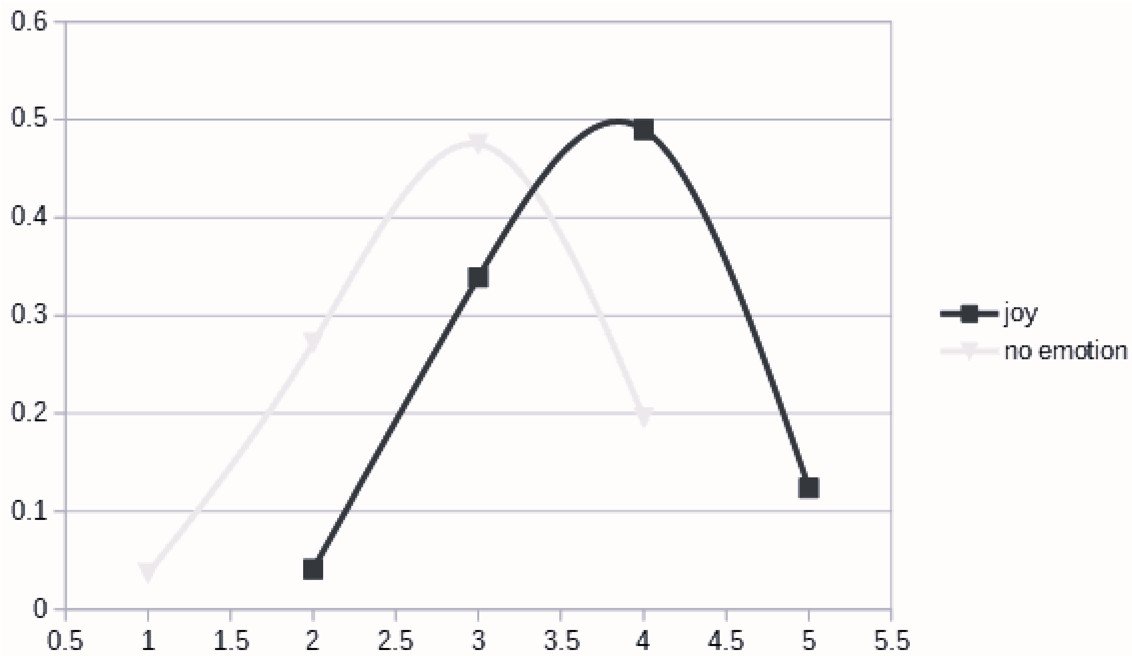
0.12

0.12

0.12

**ANOVA - Single Factor**

| | | | | | | |
|---|---|---|---|---|---|---|
| Alpha | | 0.05 | | | | |
| | | | | | | |
| Groups | Count | Sum | Mean | Variance | | |
| Column 1 | 45 | 17.0541609 | 0.378981353 | 0.022595838 | | |
| Column 2 | 35 | 11.88885254 | 0.339681501 | 0.020505375 | | |
| | | | | | | |
| Source of Variation | SS | df | MS | F | P-value | F critical |
| Between Groups | 0.030406918 | 1 | 0.030406918 | 1.402234909 | 0.23994572 | 3.963472051 |
| Within Groups | 1.691399636 | 78 | 0.021684611 | | | |
| Total | 1.721806554 | 79 | | | | |



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