A Systematic Study of Personification in Synaesthesia: Behavioural and Neuroimaging Studies

A thesis submitted for the degree of

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By

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Dedicated to

Ben

...Together with little Alice we will slip past the smooth, cold surface of the looking-glass and find ourselves in a wonderland, where everything is at once so familiar and recognizable, yet so strange and uncommon (Luria, 1969).

Abstract

In synaesthetic personification, personality traits and other human characteristics are attributed to linguistic sequences and objects. Such non-perceptual concurrents are different from those found in most frequently studied types of synaesthesia, in which the eliciting stimuli induce sensory experiences. Here, subjective reports from synaesthetes were analysed and the cognitive and neural mechanisms underlying personification were investigated. Specifically, the neural bases of personification were examined using functional MRI in order to establish whether brain regions implicated in social cognition are involved in implementing personification. Additional behavioural tests were used to determine whether personification of inanimate objects is automatic in synaesthesia. Subjective reports describing general characteristics of synaesthetic personification were collected using a semi-structured questionnaire. A Stroop-like paradigm was developed in order to examine the automaticity of object personification, similarly to the previous investigations. Synaesthetes were significantly slower in responding to incongruent than to congruent stimuli. This difference was not found in the control group. The functional neuroimaging investigations demonstrated that brain regions involved in synaesthetic personification of graphemes and objects partially overlap with brain areas activated in normal social cognition, including the temporo-parietal junction, precuneus and posterior cingulate cortex. Activations were observed in areas known to be correlated with mentalising, reflecting the social and affective character of concurrents described in subjective reports. Psychological factors linked with personification in previous studies were also assessed in personifiers, using empathy, mentalising and loneliness scales. Neither heightened empathy nor mentalising were found to be necessary for personification, but personifying synaesthetes in the study felt lonelier than the general population, and this was more pronounced in those who personified more. These results demonstrate that personification shares many defining characteristics with classical forms of synaesthesia. Ascribing humanlike characteristics to graphemes and objects is a spontaneous and automatic process, inducer-concurrent pairings are consistent over time and the phenomenological character of concurrents is reflected in functional neuroanatomy. Furthermore, the neuroimaging findings are consistent with the suggestions that synaesthetes have a lower threshold for activation brain regions implicated in self-projection and mentalising, which may facilitate the personification processes in synaesthesia.

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Chapter 1 Introduction

1.1 Overview

The broad aim of this thesis is to investigate personification synaesthesia (also known as sequence-personality synaesthesia), its phenomenology, cognitive and neural mechanisms. Personification synaesthesia is a special form of synaesthesia, in which inducers are usually linguistic sequences, whereas concurrents belong to the social and interpersonal domains, including personality traits, mental states, and social relationships between personified items. In order to understand investigations into the mechanisms underlying this form of synaesthesia, it is important to review not only the current state of research on synaesthesia, but also research on social cognition, with particular focus on mentalising processes.

The first part of the Introduction provides a general overview of synaesthesia followed by a review current state of research on personification synaesthesia (Section 1.3), including both theoretical accounts and empirical investigations. The cognitive and neural models for understanding other people are presented in Section 1.4. Although, the scope of research for social cognition includes many different topics, such as empathy, mentalising, anthropomorphism, morality, recognizing oneself, self-knowledge and more, the focus of this section is on the most relevant aspects of social cognition for understanding personification in synaesthesia, namely on mentalising (understanding mental states), empathy and anthropomorphism.

1.2 A general introduction to synaesthesia

1.2.1 Definition

The term synaesthesia originates from Greek and means the ‘union of the senses’ (Sagiv, 2005). In psychology, synaesthesia is defined as a heritable, perceptual condition, in which one stimulus evokes a subsequent sensory experience in another perceptual system or processing stream. For example, in colour-sound synaesthesia, seeing a colour may induce an additional sensory experience of sound or in personification synaesthesia seeing a number may co-occur with a belief that this number is an old man who is married to another number.

Synaesthesia can be induced not only by an external stimulus, but also can be produced by an internally generated mental image of an eliciting stimulus (Spiller and Jansari, 2008). This means that synaesthetic experience can be induced not only by hearing or seeing an inducer, but also by visualising it.

To be included in the spectrum of synaesthesia, the cross-modal correspondences have to be consistent over time, involuntary and idiosyncratic (Cytowic, 1997; Cytowic and Eagleman, 2009). This means that synaesthetic pairings between inducer and concurrent are consistently linked with each other (e.g., ‘A’ is always green), specific for a particular synaesthete (e.g., ‘A’ for a particular synaesthete is green, whereas for another one is yellow), and are elicited without conscious effort.

1.2.2 Frameworks for understanding synaesthesia

Three main groups of accounts of synaesthesia can be found in the literature. The first emphasizes associative learning as an important factor facilitating synaesthesia, second explains synaesthesia from the developmental perspective, whereas the third one investigates it within a neurocognitive framework.

1.2.2.1 Associative learning accounts

Associative learning accounts of synaesthesia emphasize the importance of an early childhood exposure to repeatedly presented pairings. This hypothesis has been put forward as early as 1893 by Mary Calkins who noted that all variants of synaesthesia may result from "forgotten childhood associations" (Calkins, 1893, p. 455). For example, synaesthetic redness of 'A' would be likely to arise as a result of playing with coloured set of letters in childhood, where 'A' was coloured red, 'B' was yellow, 'C' was green etc. More recently, associative learning was proposed as a plausible account explaining the weak variant of synaesthesia (Martino and Marks, 2001). Associative learning by itself cannot explain synaesthesia given that synaesthesia has genetic basis (Baron-Cohen, 1996; Asher et al., 2009), but it can be helpful in understanding some aspects of this phenomenon; specifically, the pattern of correspondences between inducing stimuli and the concurrent induced experiences.

1.2.2.2 Developmental accounts

Developmental accounts of synaesthesia suggest that all people are born as synaesthetes (the neonatal hypothesis). Non-synaesthetes lose synaesthesia as a result of the development of modularity in the brain, whereas in synaesthetes this process is disrupted which consequently leads to synaesthetic sensations (Maurer, 1997). Developmental investigations into synaesthesia also highlight the importance of genetic factors in explaining synaesthesia. Synaesthesia has been shown to have a genetic basis and to be a heritable trait. Based on the observation that synaesthesia occurs more often among females than males, Baron-Cohen et al. (1996) has postulated that synaesthesia is a dominant trait inherited via the X chromosome. The genetics of synaesthesia have been recently investigated by Asher and co-workers (2009). They examined over forty families, all of which contained members with auditory-visual synaesthesia and concluded that there is linkage between auditory-visual synaesthesia and chromosomes 5q33, 6p12, and 12p12. The results of the study by Asher et al. (2009) contradicted the hypothesis of Baron-Cohen et al., and implied that synaesthesia is linked to the X chromosome, since the study reported two cases of male-to-male transmission of synaesthesia. Although genetic basis of auditory-visual synaesthesia have been suggested, further examinations of synaesthesia genetics are necessary. Currently, research on the genetic basis of synaesthesia has moved away from trying to identify a single synaesthesia gene and towards identifying more complex way of inheriting synaesthesia with multiple genes involved and different ways of inheritance (Asher, submitted).

1.2.2.3 Neurocognitive accounts

Neurocognitive accounts for synaesthesia propose two main alternative explanations for synaesthesia. The first, the structural (hyperconnectivity) hypothesis, assumes the existence of additional cross-wired connections between brain areas involved in inducer and concurrent processing (Hubbard and Ramachandran, 2005; Ramachandran and Hubbard, 2001). The second explanation, the so-called functional hypothesis, posits that the synaesthetic experience arises due to functional differences at the neural level (for example, via disinhibition of normal connections) with the connections between brain areas being the same as in the brains of non-synaesthetes (Grossenbacher and Lovelace, 2001; Ward et al., 2006).

Arguments supporting the functional hypothesis are based on research on cross-modal correspondences in non-synaesthetes, together with studies reporting pharmacologically induced synaesthetic-like experiences as well as synaesthetic experiences induced by meditation and hypnosis in non-synaesthetes.

Research on cross-modal correspondences in the general population includes correspondences between various senses and cognitive streams. Touch-vision, pitch-lightness and spatial-numeral correspondences have been reviewed recently by Sagiv and Ward (2006). Although cross-modal correspondences frequently involve sensory experiences, correspondences between affective characteristics and shapes have also been described. Lyman (1979) asked 60 students to judge curly and sharp shapes with the given list of adjectives. The participants tended to assess the sharp shape as angry, brave, frustrated, jealous, nervous, and resentful, whereas the smooth, rounded shape was associated with such concepts as calm, friendly, good, happy, home, kind etc. Lyman (1979) proposed that the relationship between shapes and affective characteristics may result the similarities between physiognomic expressions of emotional states and shapes of lines. Affective states can be also evoked by verbal sounds, musical sounds and moods (Odbert, Karwoski and Eckersson, 1942). Among cross-modal correspondences between linguistic sound and shape, 'maluma' and 'takete' effect (a contemporary version of which is 'buba' and 'kiki') constitute a cross-modal correspondence that has been reported to occur both in children and adults (Kohler, 1947; Irwin and Newland, 1940). When subjects are presented with two curves and two names ("takete" and "maluma"), they tended to name a sharp curve "takete", and the smooth curve - "maluma" (Kohler, 1947). This correspondence has been found to occur in childhood and to produce the inverse effect – when children asked to draw linear representations of these words, they tend to create rounded shapes for "maluma" and sharp for "takete" (Marks, 1978). Another peculiar phenomenon relating to the cross-modal correspondences in language was presented by Sapir (1929) who showed that words with the vowel 'a' are thought of as indicating larger objects that words containing the vowel 'i'.

Synaesthetic experience can be induced in non-synaesthetes pharmacologically by psychedelic drugs, such as mescaline or ayahuasca (Klüver, 1966; Shanon, 2002), and also in the state between sleep and wakefulness (Sagiv and Ben-Tal, submitted). This supports the notion of the functional hypothesis that the disinhibition of normal neural connections can induce synaesthetic experience. Additional evidence for the functional model has been provided by research on posthypnotic suggestion and meditation (Walsh, 2005) inducing cross-modal synaesthetic experiences. Cohen-Kadosh and co-workers (2009) showed that it is possible to hypnotically induce synaesthetic-like experiences and behaviour in non-synaesthetes. This supports the notion that synaesthesia is functionally mediated rather than hardwired via additional neural connections.

However, recent neuroimaging studies provide evidence that there are structural differences between synaesthetic and non-synaesthetic brain. Rouw and Scholte (2007) used DTI to measure fractional anisotropy and found increased structural connectivity for the white matter underlying the parietal cortex and the fusiform gyrus in grapheme-colour synaesthetes. Recently Weiss and Fink (2009) conducted the first VBM study in synaesthetes. The authors investigated whether there are changes in grey matter in grapheme-colour synaesthetes. The VBM study of eighteen grapheme-colour synaesthetes confirmed the presence of increased grey matter volumes in the left caudal intraparietal sulcus and the right fusiform gyrus. Moreover, Hänggi, Wotruba and Jäncke (2011) carried out a study examining global brain connectivity patterns in synaesthetes and controls, and showed differences between global network typology between those groups implying the existence of hyperconnectivity in the brains of synaesthetes. Sinke et al (2012) provided evidence for functional connectivity between the left parietal cortex (BA7) and primary visual areas (BA18) in grapheme colour synaesthesia.

The VBM, DTI and global connectivity patterns data delivered evidence suggesting structural differences in the synaesthetes' brains may be the primary cause of congenital synaesthesia, and additionally supported the hypothesis that the synaesthetic experience mechanism arises from direct, feedforward connections between adjacent cortical areas. Bargary and Mitchell (2008) suggested three possible developmental mechanisms leading to the increased inter- and intra-areal feedforward connectivity – failure in axon guidance, border formation and/or pruning. Mitchell (submitted) listed Ephrins and Eph-receptors, semaphorins and their receptors, netrins, slits and Robos, cadherins, neurotrophins and cell adhesion molecules from the L1 family as receptors mediating path finding of thalamocortical connections and border formation between cortical areas. The mutations of genes associated with these functions have been suggested to produce synaesthesia. Also, disruptions in the normal developmental pruning of transient cross-modal connections might result in synaesthesia (Maurer and Mondloch, 2004).

Considering the evidence supporting anatomical differences in synaesthetic brain provided by the VBM and DTI studies described above, the question arises as to whether these structural differences precede or result from synaesthetic experiences. Future developmental neuroimaging studies seem to be necessary to answer this question.

1.2.3 Classifications of synaesthesia

Synaesthesia is a highly heterogeneous condition. According to Sean Day (2012), synaesthetic experiences can be classified into at least sixty-five different variants of synaesthesia.

Depending on criteria such as the number of sensory modalities and cognitive systems involved, the type of eliciting stimuli and its direction, the time of onset of synaesthesia in lifetime and its vividness, types of synaesthesia can be classified in various ways. Classification schemes include:

1. Classification according to on the **number of sensory modalities** and **cognitive systems** involved (see Figure 1.1):

    - Intramodal synaesthesia – inducer and concurrent occur within the same modality. For example, colour-grapheme synaesthesia could be considered as an intramodal type of synaesthesia if the concurring colour is induced by a visual representation of a grapheme.

    - Bimodal synaesthesia – in this synaesthetic experience, inducer and concurrent belong to different modalities, as, for example, in the case of colour-sound synaesthesia.

    - Polymodal synaesthesia – this occurs in complex synaesthetic experiences when more than two concurrents occur in response to inducer at the same time; for example, as occurring in the complex synaesthesia of Shereshevskii (Luria, 1969) who when hearing sounds saw colours, felt tastes and experienced touch.

    - Inter-system synaesthesia – these forms of synaesthesia may engage a motor system or affective system in response to perceptual system. This could be illustrated with an example of synaesthete who experienced tastes in response to movement (Grossenbacher, 1997).

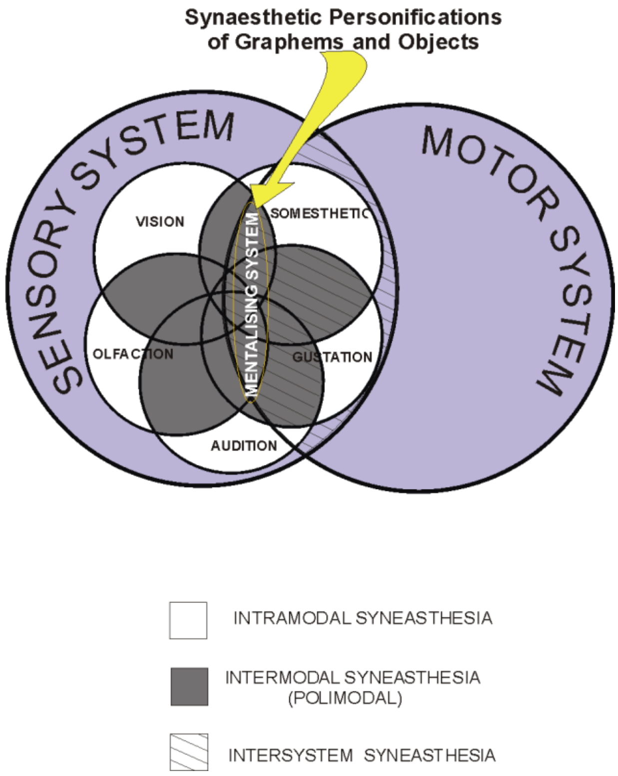

Figure 1.1 A schematic representation of synaesthesia types based on the sensory modalities and cognitive systems involved

2. Classification according to the **type of the eliciting stimulus:**

- Perceptual – hallucinogenic-like synaesthetic experiences, such as synaesthetic experience in congenital synaesthesia. For example, coloured hearing is a perceptual variant of synaesthesia that occurs when synaesthetes hear sounds and see colours induced by them at this same time.

- Conceptual – non-perceptual synaesthesia, usually generated by thinking about concepts, metaphoric.

3. Classification according to the **directionality** of synaesthesia:

- Unidirectional – most types of synaesthesia have been found to be unidirectional. For example, graphemes will induce genders but not *vice versa*.

- Bidirectional – Cohen Kadosh (2007) reported a synaesthete with bi-directional colour-grapheme synaesthesia.

4. Classification according to the **onset** of synaesthesia in lifetime:

- Congenital – usually appears early in childhood and lasts throughout the lifespan; this type of synaesthesia is heritable, involuntary and specific.

- Acquired – synaesthesia can develop as a result of biochemical or neurological brain dysfunctions, e.g. the acquired synaesthesia in retinitis pigmentosa (Armel and Ramachandran, 1999), or coloured hearing, which occurred after lesion of the ventrolateral nucleus of the thalamus in the right hemisphere (Ro et al., 2007).

- Transient – a temporary synaesthesia induced by using hallucinogenic drugs or hypnotic suggestion.

5. Classification according to the **vividness** in synaesthesia experienced:

- Strong synaesthesia – this is inborn, experienced from an early childhood, vivid, perceptual, more common among women than among men, and usually unidirectional (Martino and Marks, 2001). Subjective reports suggest that the intensity of synaesthetic experience may vary, and sometimes include vivid, perceptual experiences, but sometimes include weaker and less vivid associations.

- Weak synaesthesia – this is common, contextual, metaphorical and bidirectional (Martino and Marks, 2001).

Considering the criteria described above under which different synaesthetic categories can be described, it can be seen that sequence-personality synaesthesia is inter-system (as it involves general cognitive stream and social cognitive stream of processing) with conceptual type of the eliciting stimulus (graphemes, concepts etc), unidirectional and strong, vivid synaesthesia that appears in an early childhood. A more detailed overview of the sequence-personality synaesthesia is provided in Section 1.3.

6. Classification according to the **spatial extent** of synaesthesia experienced:

    - Projector – the concurrent is experienced ‘in the mind’s eye’ (e.g. synaesthetic colour elicited by grapheme may be ‘placed out there on the page’)

    - Associator - the synaesthetic concurrent is experienced in ‘external space’, usually in the personal space (e.g., synaesthetic colour may be perceived as ‘inside the head’) (Dixon, Smilek and Merikle, 2004).

1.3 Synaesthetic personification

1.3.1 Introduction[1]

Synaesthetes attribute not only colours to graphemes and linguistic sequences, but may also attribute genders and personality traits. This automatic attribution is common among synaesthetes and seems to be as involuntary, and in many cases is relatively stable over time, similarly to colour associations. Moreover, synaesthetes who experience this form of personification often attribute not only genders and personality traits but also a whole range of social and personal attributes to letters, numbers, other sequences, concepts and certain objects. These may include family relationships, mental states, moods, and more. It is now recognised that such instances of personification may qualify as a type of synaesthesia in their own right (Amin et al., 2011). This is in line with modern definitions of synaesthesia. For example, Hubbard (2007) defines synaesthesia as a condition in which stimulation of one sensory or cognitive stream induces an involuntary and idiosyncratic experience in one or more additional modalities or streams that remains consistent over the time[2]. Sequence-personality synaesthesia fulfils these requirements: The inducer and concurrent belong to different cognitive streams; the correspondences are idiosyncratic, involuntarily elicited, and consistent over time (although some synaesthetes reported maturation of grapheme personalities together with their own maturation).

[1] A modified version of this chapter has been submitted for publication in the Oxford Handbook of Synaesthesia (forthcoming, 2013).

[2] For further discussion on the issue of defining synaesthesia, the reader is referred to Simner (2010) or Sagiv, Ilbeigi, and Ben-Tal (2011).

Such variants of synaesthesia involving some sort of personification have been referred to using overlapping or partially-overlapping terminologies, including: *Letter dramatisation* (Calkins, 1895), *ordinal linguistic personification (OLP)* (Simner and Holenstein, 2007), *sequence-personality synaesthesia* (Simner, Gärtner and Taylor, 2011) and *social synaesthesia* or simply *personification* (Amin et al., 2011).

Letter dramatisation is a term coined over a hundred years ago by Mary Calkins (1893) to describe the personification of graphemes among synaesthetes. As contemporary research has extended the concept to include other inducers (e.g. objects, body parts, weekdays, months, seasons, etc.), this phrase is not used in the modern synaesthesia literature. Instead, Julia Simner and Karen Holestein (2007) emphasised the ordinal and linguistic nature of inducers evoking synaesthetic personifications (letters, numbers, weekdays, months, seasons etc.), labelling it o*rdinal linguistic personification*. Given that the range of reported synaesthetic inducers is wider than just ordinal linguistic sequences and include everyday objects, (Simner, Gartner and Taylor, 2011) recently suggested the new term *sequence-personality synaesthesia*. A different feature of this phenomenon has been highlighted in the last of these designations – *social synaesthesia* (Amin et al., 2011), in which emphasis is placed not on the nature of inducer but rather on the social aspect of co-occurring synaesthetic experiences involving concepts from social cognition/perception, such as personality traits, mental states, moods, social roles, etc. For clarity, in this chapter, I will refer to this variant of synaesthesia as sequence-personality synaesthesia or simply personification.

1.3.2 Historical background

Historical reports on synaesthetic personifications appeared as early as the end of nineteenth century. At the time, two prominent figures in Psychology were working on personifications in synaesthesia: the American psychologist and philosopher Mary Calkins and the Swiss professor of psychology - and friend of Carl Jung – Theodore Flournoy. The first studies of synaesthetic personifications were mostly explorative and descriptive, primarily resulting in phenomenological descriptions of synaesthetic experiences (Calkins, 1893; Flournoy, 1893; Patrick, 1893). In a group study of 'dramatization' of letters, numbers and musical notes, Calkins (1895) attempted to identify the rules governing this type of synaesthesia. Personality/number associations were found twice as frequently as personality/letter associations. Calkins hypothesised that numbers are more likely than letters to be the subject of emotional associations due to the greater level of 'intellectual engagement' involved in number processing compared to letter processing. In her research, Calkins noted that synaesthetes not only attribute personalities to graphemes, but also tend to like and dislike them. For example, the numbers 2 and 5 are often perceived as more likable than prime numbers such as 7, 11 and 13, and this may result from "*the actual experience of facility in the use of even numbers, and of difficulties with the unyielding indivisibility of prime numbers*" (Calkins, 1895, p.101). In the twentieth century, sequence-personality synaesthesia is mentioned (though not identified as a distinct phenomenon) by the eminent Russian neuropsychologist Aleksander Luria in *The Mind of a Mnemonist* (1969), an elaborate case study of Solomon Shereshevskii, a synaesthete who had at least fivefold synaesthesia. In the chapter dedicated to mental images, there is a passage in which Shereshevskii describes his personifications:

"Take the number 1. This is a proud, well-built man; 2 is a high-spirited woman; 3 is a gloomy person (why, I don't know); 6 a man with a swollen foot; 7 a man with a moustache; 8 a very stout woman - a sack within a sack. As for the number 87, what I see is a fat woman and a man twirling his moustache" (Luria, 1969, p.31).

The historical account of sequence-personality synaesthesia provided some observations about its phenomenology, but systematic empirical studies were not carried out. Although a cognitive mechanism underlying affective associations (positive versus negative) to graphemes was suggested (Calkins, 1895), there was no widely accepted framework for explaining personifications in synaesthesia.

1.3.3 Characteristics of sequence-personality synaesthesia

The first contemporary investigations into sequence-personality synaesthesia have focused not only on providing phenomenological descriptions of synaesthetic personifications (Cytowic, 2002; Sagiv, 2005), but have also aimed to verify empirically the reality of cross-modal correspondences by testing for their involuntary character and consistency over time – both considered core qualities of synaesthesia (Rich et al., 2005). A number of recent studies have employed behavioural congruity paradigms as well as consistency tests similar to those used to study other forms of synaesthesia (see below). Neuroimaging methods have also been employed to uncover the neural basis of the phenomenon (Amin et al., 2011).

1.3.3.1 Automaticity and the involuntary nature of personification

Most paradigms used to objectively assess the automaticity and involuntary nature of personification reports rely on the fact that personifications tend to be consistent over time, at least in some cases. In other words, some synaesthetes show relatively consistent mappings between at least some inducers (e.g., graphemes) and concurrents (e.g., gender). Thus before turning to examine the automaticity of personification, the consistency of inducer-concurrent pairings needs to be demonstrated. Indeed the consistency of these reports has been confirmed in both individual cases (Simner and Holenstein, 2007; Smilek et al., 2007) and group studies (Amin et al., 2011; Simner, Gartner and Taylor, 2011). The automatic and involuntary character of sequence-personality synaesthesia has been tested using innovative variants of the Stroop (1935) and Navon figure paradigms, as shown in Table 1.1. In the variant of Stroop test, the synaesthetic gender of the letter either matches the gender of the target stimulus (congruent trial) or mismatches the target gender (incongruent trial). For example, a synaesthete, having seen a letter A (which to this particular synaesthete is feminine), will be presented with a picture of a female's face in the congruent trial, whereas in the incongruent trial, the letter A will be followed by a masculine face (which does not match with the letter's gender). When synaesthetes are asked to make speed judgments of the target face gender, it is expected that synaesthetes will be faster to respond in congruent trials than in incongruent trials (Dixon et al., 2000; Smilek et al., 2001). Simner and Holenstein (2007), using a modified

Stroop paradigm, presented a synaesthetic participant AP with girl and boy names to assess whether semantic gender judgments can be affected by synaesthetic genders, and whether this occurs automatically. In the experimental task, the synaesthetic gender of the first letter of the English names used was congruent with the semantic gender of the words in half of the trials; the other half were incongruent. The aim was to establish whether the synaesthetic gender associated with the first letter is processed automatically and interferes with gender judgments for whole words (English names). A congruency effect was indeed observed; reactions times where faster when the synaesthetic gender of the first letter matched the name gender, suggesting automatic processing. Simner and Holenstein (2007) could employ this type of Stroop-like paradigm only after they verified that for AP, the genders of words (in this case name) are likely to take the gender of the first letter (a similar effect is noted in grapheme-colour synaesthesia, where the colour of initial letters spreads throughout the whole word, giving the word its colour; Rich et al., 2005). To determine this, AP was asked to indicate how feminine/masculine a particular name is on a line scale from extremely female to extremely male when seeing female/male names whose initial letter's synaesthetic gender was congruent/incongruent with semantic gender of the word (English name). The experiment showed that AP's semantic masculinity/femininity were influenced by the synaesthetic genders: AP perceives as more feminine female names starting with a feminine synaesthetic gender (congruent condition) compared with female names starting with a masculine synaesthetic gender (incongruent condition). This same effect occurred with masculine synaesthetic gender. For example, if presented with name Betsy, AP thought of Betsy as less feminine than controls, because for her, the synaesthetic gender of b is male and interferes with semantic gender. Although this type of letter-to-word transfer applies to genders of names, it does not apply to linguistic sequences such as days of the week, months of the year. Such frequently used words are often associated with their own synaesthetic gender (or colour for that matter), that is independent of the gender associated with the first letter.

Table 1.1 Studies on the automaticity of personification in synaesthesia

Study	**Personification Type**	**Testing Method**	**Study Size**
Amin, 2005	Grapheme-gender	Navon figure (letter gender discrimination)	Group study (6 synaesthetes)
Simner and Holenstein, 2007	Letter-gender	Stroop paradigm (name gender discrimination)	Case study of AP
Amin et al., 2011	Grapheme-gender	Stroop paradigm (face gender discrimination)	Group study (5 synaesthetes)

Another Stroop-like task for studying the automaticity of gender-letter pairings was developed by Amin et al. (2011). The authors presented a target face preceded by a letter prime. Participants were asked to judge whether the presented face was a female or a male face. As predicted, synaesthetes had significantly slower average reaction times in incongruent trials compared with congruent trials, even though the grapheme primes were irrelevant to the task. This effect was not found in non-synaesthetes, even when they chose the letters that were most masculine/feminine in their opinion to be included into experimental trials. The results from the study provide converging evidence that synaesthetic gender-grapheme associations are involuntary and automatic, which differentiate synaesthetic and non-synaesthetic personifications of graphemes.

An alternative way of testing for automaticity of grapheme-gender utilised a variant of a Navon-type figure – using male or female stick figures made of graphemes (Amin, 2005; Sagiv, Olu-Lafe, Amin, and Ward, 2006). The gender synaesthetes associated with the graphemes making up the stick figures were either congruent or incongruent with the gender depicted by the stick figure. A congruity effect was observed here too, demonstrating once again that synaesthetes find it hard to ignore the gender associated with graphemes, even when it is irrelevant and sometimes detrimental to the task. Of course, the innovative use of established testing techniques provided compelling objective evidence not only for the automaticity but also for the reality of synaesthetic personification.

1.3.3.2 Prevalence of sequence-personality synaesthesia

While sequence personality synaesthesia is recognised as a relatively common type of synaesthesia (Cytowic and Eagleman, 2009; Simner et al., 2011), as yet no large-scale study of the general population has been conducted that would provide an estimate of its prevalence. In 2007, Simner and Holenstein carried out a survey of 219 individuals. In this group they found three synaesthetic personifiers, suggesting that about 1 in 73 people have personifications for ordinal sequences or objects. A similar prevalence (about 1.4%) can be found in a historical text showing that among 75 men and women, there was one female synaesthete associating personalities to numbers (Patrick, 1893).

Among the population of synaesthetes, personification is fairly common: 33% of the 248 synaesthetes studied by Amin et al. (2011) reported experiencing genders and/or personalities to graphemes. More than three quarters of the synaesthetes who attribute personalities and genders to graphemes also personified objects, such as fruit and vegetables, computers, household objects and others. Graphemes and objects are personified on a daily basis, and the attribution of social and affective characteristics is conceptually driven although some of the synaesthetes testified that colour[3], shape, number parity and sound of graphemes may play a role in determining the specific pattern of associations of personalities and genders. For example, in descriptions provided by synaesthetes responding to the questionnaire employed by Amin et al. 2011, 26% of synaesthetes indicated that grapheme shape influenced the gender associated with them (e.g., they quote two synaesthetes who indicate that rounded letters were often thought of as more feminine). According to self-reports gathered by Amin et al. (2011), sequence-personality synaesthesia has been experienced by individuals when they were as young as seven years old – around the time when they acquire reading and writing skills.

1.3.3.3 Categories of inducers and concurrents

Although synaesthetic experiences can be induced by many different types of stimuli – emotions, flavours, musical sounds, temperature and others, the most common inducers are linguistic constructs, including letters, numbers, weekdays and months. We can differentiate between two different types of inducers in personification: Linguistic inducers, such as graphemes, weekdays, months, and non-linguistic inducers, including body parts, inanimate objects, geometrical shapes, plants, colours, spatial concepts (e.g. left-right) and so on. In contrast to

[3] This is consistent with Simner and Hubbard's (2006) observation that graphemes' colours and genders interact. For example, they find that synaesthetes are slower to state the synaesthetic gender of letters if these are printed in colours from other letters with mis-matching (but not matching) genders.

non-linguistic inducers, linguistic inducers often have a conventional order (e.g. alphabetical sequence) that may influence how synaesthetes personify them (e.g., friendships or kinship relations; Simner and Holenstein, 2007). For example, 1 and 2 are more likely to have a relationship (play together or parenting to 3) than with 8 or 9. Similarly, anecdotal evidence suggests that personified non-linguistic inducers (e.g., inanimate objects) tend to have some sort of relationship with their own kind; for example, coffee mugs might miss a broken mug from the same set (Amin et al. 2011). Another synaesthete tested by Sobczak, Sagiv, and Williams (2011) described a family of mushrooms consisting of mother mushroom, father mushroom and their children, which she perceived as having mental lives and interactions. A similar picture can be seen in linguistic inducers: For example, one of the synaesthetes we tested noted that*: "The personalities of all my letters and numbers centre around a 'pecking order' based on age and leadership relationships.... All are 'nice' personalities, quiet, confident, respectful, staying within their order. No moods. i.e., my letters, numbers, months and days have more 'relationship' to one another than personalities."*

This description, and our discussion thus far of personifications, show that the concurrent experiences are not purely sensory (i.e., they are not only colours, tastes, and so on), but rather, they are conceptual categories (e.g., personality types). Moreover, they are at times social descriptions and this suggests that, in sequence-personality synaesthesia, the concurrents belong to the interpersonal domain: They may reflect individual characteristics (gender, personality, physical appearance, cognitive abilities, occupation, mental states, moods, attitudes, interests, inclinations) as well as 'social interactions' between inducers (e.g., emotive and behavioural responses to other units; Simner and Holenstein, 2007; Amin et al., 2011). Smilek et al. (2007) classified the social and affective characteristics attributed in sequence personality synaesthesia into four more specific types: Physical (gender, physical appearance), personal (cognitive abilities, occupation, personality, mental states, moods, attitudes, interests, inclinations), relational (emotive and behavioural responses to other units) and social role (occupation, familial and non familial relationships). From the comparison between the social attributes to graphemes in the historical and contemporary literature, it can be concluded that although synaesthesia is congenital, life experiences can influence the personality traits that are being attributed to graphemes and other sequences (Simner and Holenstein, 2007). Concurrents such as "society girl", "policy girl", "housekeeper" (Patrick, 1893, p.509) are rather uncommon among synaesthetes today.

1.3.4 Theories of sequence-personality synaesthesia

After establishing the genuineness of sequence-personality synaesthesia, researchers are attempting to provide an explanatory framework for the phenomenon. In order to explain how it arises, researchers look at the underlying neural mechanisms in addition to the phenomenological characteristics and behavioural consequences. One neurobiological framework for understanding sequence-personality synaesthesia focuses on the cross-activation hypothesis (Hubbard, Brang, and Ramachandran, 2011), whereas a more functional alternative approach describes the condition as a by-product of the developmental mechanisms for social cognition. These two approaches will be discussed below.

1.3.4.1 Neural cross-talk and neural over-excitation as models proposed for explaining sequence-personality synaesthesia

Cross-activation has been proposed as a plausible brain mechanism of synaesthesia. Cross-activation in synaesthesia denotes the process of the inducer activating not only inducer-specific brain areas but also cross-activating brain areas that are involved in concurrent processing. For example, in grapheme-colour synaesthesia the experience of the grapheme activates the grapheme processing specific area and also cross-activates the colour-selective area the brain of synaesthete, which is not observed in non-synaesthetes. This may results from either direct (Hubbard and Ramachandran, 2005; Rich and Mattingley, 2002) and/or indirect cross-talk between brain areas (Smilek et al., 2001; Grossenbacher and Lovelace, 2001). These may be facilitated by either structural or functional differences in connectivity in synaesthetes' brains. The functional model of cross-talk assumes that there are no structural differences in the brains of synaesthetes and non-synaesthetes, with synaesthetic cross-activations arising as a result of disinhibition of normal connections (Ward, Huckstep, and Tsakanikos, 2006). Conversely, the structural explanation of synaesthetic cross activation highlights anatomical differences between the synaesthetic and non-synaesthetic brain, i.e., additional feedforward neural pathways connecting the particular brain areas involved in processing the inducers and concurrents in a given type of synaesthesia.

While functional neuroimaging studies showed that such explanation for grapheme-colour synaesthesia is plausible, (Hubbard and Ramachandran, 2005), more recent studies provided direct evidence for hyper-connectivity (Rouw and

Scholte, 2007; Weiss and Fink, 2009) using Diffusion Tensor Imaging (DTI), suggesting that there are structural differences between ‘synaesthetes’ and ‘non-synaesthetes’ brains. However, future developmental neuroimaging studies seem to be necessary in order to clarify whether hyper connectivity precedes function specialisation and what the role of learning and practice is.

Could sequence-personality synaesthesia be also explained within this framework? Simner and Hubbard (2006) argue that sequence-personality synaesthesia is likely to arise as a result of cross-talk between the left inferior parietal lobule (in particular the angular gyrus) and temporo-parietal junction that mediate sequence information, and the ‘social brain’ regions associated with mental states and personality trait attribution, such as the amygdala, somatosensory cortex, frontal and parietal regions. It is suggested that the angular gyrus is a crucial area in inducing cross-modal pairings in sequence personality synaesthesia due to its importance in processing ordinal sequence information, which has been well documented in neuropsychological studies of semantic agnosia and acalculia (Dehaene and Cohen, 1997; Turconi and Seron, 2002; Cappeletti, Butterworth and Kopelman, 2001). Synaesthetic concurrents in this variant of synaesthesia include social and affective associations, therefore it is likely that neural correlates involved in generating these experiences overlap with the neural systems involved in implementing general social cognition. Previous neuroimaging experiments (e.g. Castelli et al., 2002; Martin and Weisberg, 2003; Schultz et al., 2003) provided evidence that personification of non-randomly moving shapes (similar to Heider and Simmel’s animations, 1944) activates some of the same brain areas that have been found to be active during interaction with or observation of other human beings. The inferior frontal cortex is crucial for personality judgments (Herberlein and Saxe, 2005). Additionally, the temporo-parietal junction, posterior cingulate cortex/precuneus, the amygdala, prefrontal cortex and fusiform gyrus may also play a role in generating social and affective concurrents reported in sequence-personality synaesthesia. The first case study examining empirically the neural substrates of sequence mapping synaesthesia provided only partial support for these predictions. Amin et al (2011) tested AA - a 38 year female synaesthete who attributes genders to letters - using functional MRI. The study identified the medial part of the superior parietal lobule – the precuneus - as a possible brain region mediating the attribution of gender to letters. Aiming to establish whether personification in synaesthesia arise automatically, Amin et al. asked AA to perform a letter repetition detection task (rather than to focus on the synaesthetic experiences of genders). Given that the synaesthetic gender of letters was irrelevant to the task, the authors argue that the observed differences in precuneus activity when AA was presented with letters with genders and letters without genders, may indeed reflect automatic processes associated with synaesthetic personifications. As the precuneus is associated with self-referential processing (information related to oneself) as well as with mental imagery (e.g., Cavanna and Trimble 2006), Amin et al. (2011) proposed two corresponding possible mechanisms for synaesthetic personification. One possibility is that synaesthesia is an extraordinary manifestation of mental imagery that is elicited automatically, and has well defined inducers and concurrences. The second hypothesis emphasises the self-processing functions; it was suggested that this variant of synaesthesia may reflect as an unusual projection of one's own mental states onto letters and numerals. Similar explanation for the precuneus activation has been also proposed in another case study of a synaesthete who personifies inanimate objects (Sobczak, Sagiv and Williams, 2011). The self-projection hypothesis is in line with current theory in social neuroscience on how we get to know the minds of others: We never perceive the minds of others directly since mental states are unobservable constructs, but we infer intentions, feelings and personality traits of others using self-referential accounts, by accessing one's own mental states that serve as a model of the minds of others, and then project them on the target (Mitchell, 2008). Could this suggest that the attribution of social and affective characteristics to graphemes in synaesthesia is merely an extension of normal social cognition, in which projection of one's own mental states includes not only other humans but also non-humans entities as targets? The hypothesis that sequence-personality synaesthesia is a misattribution of self-referential processing will be presented further in the following section.

1.3.4.2 Personification synaesthesia as a misattribution of self-referential processing

According to the neonatal synaesthesia hypothesis (e.g., Maurer and Mondloch 2005), all newborn babies experience synaesthesia or, at the very least, some sort of sensory confusion; they experience uni-sensory stimuli with all their senses as a consequence of having a cortex that is not fully developed. This ability disappears with the development of the nervous system as cortical areas acquire functional specialisation. Could this also apply to synaesthetic personification? Young children assign life and conscious mental states to non-living objects and concepts; this was referred to as ‘animism’ in the early literature (Piaget, 1929). Animistic thought in early childhood gradually decreases during cognitive development and is ultimately replaced by more logical thought. According to this model of development, a child’s progression from perceiving all functional objects as endowed with conscious life, passes through a stage of assigning these attributes to objects that are in any motion, and a few years later only to things that move on their own accord, to reach the stage in which animate characteristics are only attributed to living things. After this stage, the animistic mode of cognition (similar to that of personification) is almost completely replaced by logical reasoning and human-like qualities are not longer attributed explicitly to inanimate objects. Piaget (1929), studying animistic thought in children, hypothesised that the excessive animistic mode of thinking (including personification) serves as a mechanism that is used to construct reality with the self as a model. This links with contemporary research into the way we construct social reality. The discovery of mirror neurons demonstrates this well. Mirror neurons fire both when we observe others performing an action and when we perform the same action ourselves. This constitutes a neural, mirror-like mechanism enabling understanding of the actions, emotions and feelings of other people, presumably through a simulation process (for a review, see Bastiaansen et al., 2009). Personification in synaesthetic adults may represent an excessive manifestation of the human tendency to perceive reality using the self as a model, which in turn derives from younger children’s animistic thought which children use as an undeveloped filter through which they learn about social world. In other words, synaesthetic personification could represent a residual expression of childhood animism.

The brain areas associated with self-referential processing such as the insula, the precuneus, the inferior frontal cortex, the posterior cingulate, have been found to be involved in implementation of animistic thought (Sobczak, 2009; Sobczak, Sagiv, and Williams, 2011). Furthermore, evidence from neuropsychology suggests that lesions of the right (and sometimes left) parietal cortex may result in peculiar misattributions of agency, which might itself sometimes involve animistic attributions. Specifically, patients with such lesions frequently display delusional misidentifications of body parts, thinking that their left arm or left leg does not belong to them. They often attribute their limbs to other people - their wife, examiner, or fellow patient. This condition - somatoparaphrenia is a subtype of asomatognosia (unawareness of one's limb ownership). Interestingly, some patients also assign personalities to their limbs and give misidentified arms or legs nicknames such as “George”, or “Silly Billy” (Critchley 1955, p. 286). Misattribution of animacy and agency has also been found after frontal lobe damage. For example, Feinberg and Keenan (2005) describe a peculiar case of personification known as “phantom child syndrome” which is thought to represent a delusional reduplication of self. The patient believed that he is in the process of adopting a child with “problems”. Such patients deny that they have certain problems themselves, instead attributing them to the “phantom child”.

In summary, evidence from neuroimaging and neuropsychology is consistent with the idea that misattribution of the self could explain synaesthetic personification, however, this framework for understanding personification remain tentative and needs to be tested directly in future studies involving synaesthetes.

1.3.5 Similarities and differences between synaesthetic personifications and non-synaesthetic personifications

Personification and animism involving the attribution of human-like social and affective characteristics to non-human entities can be observed not only in synaesthesia, but also in non-synaesthetes' everyday life. Examples include personification of objects, both in childhood and in adulthood (Piaget 1929; Bouldin and Pratt 1999; Epley, Akalis, Waytz, and Cacioppo 2008), the attribution of masculine/feminine genders to nouns in many languages (Corbett, 1991), as well as the attribution of agency, personality traits and moods to body parts (usually limbs) following brain injury (Critchley, 1955). Personification is widespread in various cultures in metaphors, folk legends and myths (Guthrie, 1993). For example, according to one Russian superstition, if you drop a fork (masculine) a male guest will visit your house, but if you drop a spoon (feminine) – this will be a female guest (Corbett, 1991). Personification is also utilised in design and 'human factors engineering', in which social rules are used when designing human-computer interactions (Nass et al., 1997), as well as in advertising, where, in the field of marketing, consumers are frequently invited to assign a human personality to branded objects (Ouwersloot and Tudorica, 2001).

Young children often think of inanimate objects as if they were humans, endowing them with life-like features (animism). It has been suggested that children's tendency to personify is a normal stage in cognitive development (Piaget, 1929), but can also be linked with social isolation; solitary children frequently create imaginary friends. Often these imaginary companions exist entirely in their imaginations, but sometimes the focus of their imaginations are physical objects such as dolls or other toys that have ascribed to them elaborate personalities and biographies (Bouldin and Pratt, 1999). Additionally, among adults, loneliness and inability to create social bonds may be compensated by attaching social and affective characteristics to animals, inanimate objects and also religious agents (Epley, Akalis, Waytz, and Cacioppo, 2008).

In many languages, nouns have masculine/feminine grammatical genders that influence the way people think about inanimate objects: objects with feminine linguistic genders are thought to be more feminine, and objects with masculine grammatical gender are perceived as more masculine (Boroditsky, Schmidt and Phillips, 2003). This effect can be observed already in children of 8-9 years, who, when asked to assign voices to inanimate objects (presented together with their labels), ascribe voices to presented objects congruent with their grammatical genders (Sera, Berge, and de Castillo, 1994). Boroditsky and her colleagues found that the adjectives used to describe nouns tend to be feminine when the noun concerned has feminine grammatical gender and more masculine when noun has masculine gender. Furthermore, adjectives usually associated more with femininity (such as calm, friendly, good, happy, kind) tended to be used for descriptions of rounded shapes, whereas adjectives associated with masculinity (e.g., angry, brave, frustrated, jealous, nervous, and resentful) were used when describing a spiky shape (Lyman, 1979). Thus, shapes may be associated with at least implicitly with some social and affective characteristics. Additional, musical sounds can evoke attributions of moods (Odbert, Karwoski and Eckersson, 1942), and letters can induce associations of personality traits (Simner, Gartner and Taylor, 2011). Simner and her colleagues examined whether synaesthetes and non-synaesthetes exhibited similar patterns of letter-personality correspondences. While non-synaesthetes' personifications of letters were less elaborated and less consistent over time compared with synaesthetes, both groups seem to share the underlying rules for the personality trait attribution to letters. Using Goldberg's Big Five personality traits questionnaire, Simner et al. (2011) found that both synaesthetes and non-synaesthetes tend to associate frequently occurring letters (e.g., the letter A compared with the letter Z) with personalities low in neuroticism and high in agreeableness; the main difference between the groups is therefore that in synaesthetes, the personality-letter associations occur explicitly, whereas in non-synaesthetes, they are implicit.

1.3.6 Summary

In this chapter, I have attempted to provide a broad overview of personifications including the phenomenology, as well as behavioural and neural characteristics. Sequence-personality synaesthesia appears to be consistent over time. Furthermore, the associations between inducer and concurrent are automatically and involuntarily elicited. The variety of inducers in this variant of synaesthesia include linguistic (graphemes, weekdays, months, etc) and non-linguistic inducers (inanimate objects, colours, body parts, etc). The concurrent synaesthetic experiences have affective and social characteristics, and fall into following general groups: physical, personal, relational, and social role descriptions. Several lines of evidence suggest that some forms of personification occur in non-synaesthetes too; examples include childhood animistic thought, mild forms of personification in everyday life, personifications of body parts, as well as gender attributions to linguistic constructs (i.e., grammatical gender). Synaesthetes and non-synaesthetes alike think of the letters that are more frequently used as rather agreeable and not neurotic. However, non-synaesthetes do so only implicitly, compared with synaesthetes, for whom these pairings occur involuntarily and they are aware of them explicitly in everyday life. A similar pattern is found when considering object personification. Preliminary neuroimaging evidence suggests that grapheme personification depends on the posterior parts of parietal cortex, namely the precuneus, which is involved in mental imagery and self-referential processing. Synaesthetic personification may therefore represent a special case of mental imagery or the involuntary projection of one's own mental states onto graphemes and/or inanimate objects. As in other forms of synaesthesia, it is conceivable that cross-activation of brain areas could underlie personification (e.g., cross-talk between the angular gyrus and some of the 'social brain' areas). At the developmental level, it has been proposed that sequence-personality synaesthesia may represent a residual expression of childhood animism, an early stage in social cognitive development (Amin et al., 2011). Although there are many differences between the accounts described here for sequence-personality synaesthesia, they all seem to point to the observation that (as in other types of synaesthesia) this variant may be utilising a universal mechanism (e.g., Sagiv and Ward, 2006). Admittedly, the study of synaesthetic personification using cognitive neuroscience methods is only in its infancy. It would therefore be wise to regard these frameworks for understanding synaesthetic personification as tentative, at least until further evidence becomes available.

1.4 Understanding other people

Person-related knowledge includes psychological predispositions, appearance, feelings, mental states, social functioning and others. However, the main difference between human and object perception is the presence of mind (Harris and Fiske, 2009) in humanised (people) perception and its absence in dehumanised (object) perception. Since in synaesthetic personification, letters, numbers and objects are perceived as having ‘mental lives’ (humanized perception), the following section provides an overview of mechanisms that are involved in thinking of minds of other people.

1.4.1 Introduction to reasoning about other people

In our everyday life, we observe others’ behavior and interpret it in terms of intentions, beliefs, desires, goals and reasons. Mental states, personality traits and feelings that we recognise in others are not directly accessible but rather inferred indirectly from observable behaviour. The process of understanding one’s own mental states and mental states of others has been referred to as *mentalising* (Shany-Ur and Shamay-Tsoory, 2011) or *theory of mind* (ToM) (Premack and Woodruff, 1978). Mental states usually refer to intentions, beliefs, attitudes, emotions, feelings and so on. However, in developmental and cognitive psychology, ToM is defined in a narrower way, where ascribed mental states include only knowledge and beliefs, but not affective mental states.

1.4.2 Models for understanding the self and others

In cognitive psychology, there are two main groups of explanatory models for understanding the self and others: theory theories and simulation theories. The theory-theory approaches imply that humans contain implicit theories describing the rules that govern our own behaviour and the behaviour of others (Wellman, 2002). Accordingly to the theory-theory, understanding the mind is based on a folk psychological theory. Broadly speaking, we get to know what other people think and intend using sets of rules for constructing theories that are innate to humans (Carruthers, 1996) or that developed them in an early childhood (Churchland, 1991). A type of the theory-theory - the modularity approach - implies that mentalising processes are governed by a module or mechanism that is specialised and dedicated for mind reading (Leslie, 1987) and therefore is sometimes considered as a domain-specific account (Ward, 2012). This approach was inspired by the false belief tasks research in children with autism. In 1985, Baron-Cohen, Frith and Leslie conducted a false belief task study on normally developing children, children with autism and children with Down syndrome, showing that only the group of autistic children failed the false-belief task test. Drawing inferences from false-belief experiments involving participants with autistic spectrum disorder, researchers concluded that if autism impairs only the ability to infer mental states of others, whereas the ability to create coherent behavioural or mechanical stories is intact, there must be a special module dedicated to understanding minds of other people (Baron-Cohen, Frith and Leslie, 1985). Therefore, the modular approach to mentalising implicates that theory of mind module is a separate from other neurocognitive abilities but simultaneously builds on other mental abilities. The modular approach consists of four interrelated components (Baron-Cohen, 1995): intentionality detector (ID), eye direction detector (EDD), shared attention mechanism (SAM), and theory of mind mechanism (ToMM). ID is a mechanism involved in the interpretation of animated stimuli in terms of volitional mental states such as desires and goals, and is activated whenever one perceives (not necessarily visually) that another person or object is in motion. A good illustration of ID is the classical agency attribution experiment, in which subjects attribute intentions and desires to moving geometric shapes, interpreting their movement as motivated by mental states (Heider and Simmel, 1944). The EDD (eye direction detection) function is an evolutionary produced mechanism developed for the rapid detection of eyelike stimuli in the environment (Baron-Cohen, 1995). Already at the early age of two months, infants tend to look significantly much longer at eyes than other facial parts (Maurer, 1985). Eye direction detection is a form of dyadic representation as it relates only to two entities that are in relation to each other. SAM (shared attention mechanism) is defined as the ability to follow the gaze of other agents and by doing so to identify the objects seen by the agent. The shared attention mechanism is usually developed by the age of nine months (Butterworth, 1991; Baron-Cohen, 1995). The shared attention mechanism requires constructing triadic representations of self, other and the target perceived by the other, to form joint attention. ToMM is an innate capacity to engage in folk psychology and infer 'epistemic' mental states, including pretending, imagining, dreaming, believing, thinking and so on (Baron-Cohen, 1995).

In contrast to the theory-theory models, simulation theory (ST) accounts do not require using prior knowledge or psychological laws to infer mental states. Instead, they imply that people understand mental states of others through the use their own mental apparatus by simulating another person's mental states. To infer third person mental attributions one has to imaginatively simulate the same feelings, intentions or desires as the other person and then is able to predict the behaviour of that person. Goldman (2008) illustrates the simulation process with a chess player who, to predict the next move of the opponent, needs to imagine what next steps the opponent has to take to win the game. To do so, the player needs to switch to the opponent's perspective by pretending his desire to win, and in this way the player is able work out what decisions his opponent will potentially make to win. Accordingly to simulation theory, people understand the minds of others through the use of their own minds to imitate (or 'mirror') the minds of others. After simulating the mental states of others, people assign (project) their own, recreated mental states onto others.

Waytz and Mitchell (2011) distinguish two different types of simulation – **mirroring** and **self-projection**. These two simulation types are employed in inferring mental states differently, and which of them is used in any particular situation is strongly dependent on the physical presence of the person whose mental states one wants to infer. Mirroring would usually occur when one can perceive observable cues suggesting what the observed person is experiencing. These perceived cues induce similar experiences in the observer and this is also reflected in neural responses. Self-projection is a type of simulation that is used to infer mental states of others when they are not physically present and in the absence of behavioural cues. This means that when people can rely on using perceptual cues such as bodily movement, facial expressions, tone of voice and other observable information that are used in mirroring for inferring mental states of others, they will use mirroring rather than self-projection. Conversely, when parents wonder how their children are feeling when they are at school, when people gossip about others or when they try to predict the boss's mood at work before asking for promotion, they use the self-projection mechanism to do so. Therefore Waytz and Mitchell (2011) suggest that self-projection and mirroring are dissociable functions that operate in different contexts. At the neural level, the brain mirror neuron system has been found to be involved in mirroring for the simulation of mental states. Although mirror neurons were discovered first in primates (di Pellergino et al., 1992) and only later in humans (Iacoboni et al., 1999), contemporary research provides evidence that observation of another's action elicits somatotopic activations in premotor cortex (Buccino et al., 2001), lateral prefrontal cortex (inferior frontal gyrus) or inferior parietal gyrus, but also in brain regions mediating pain (Singer et al., 2004), touch (Keysers et al., 2004) and facial expressions of emotions (Carr et al., 2003), including disgust (Wicker et al., 2003). Findings considering mirror properties of neurons in humans are mostly recorded using fMRI, however there is also evidence from single-cell recordings conducted on epileptic patients. Mukamel et al. (2010) observed activity in 21 patients from neurons located in the cingulated cortex, supplementary motor area and medial temporal cortex. The examination was limited to only these regions as the main focus of the clinical intervention was to identify seizure foci, and the mirror-neuron study was only an additional investigation. The experiment included observation, activity and control phases.

During the observation phase, participants were presented with short film clips of facial expressions (frowns and smiles) and films of hand actions with precision grips. During the action phase, participants were asked to perform the types of actions they had previously seen when prompted by the written words describing them (for example, “smile”, “hand”). The researchers found that activity in eleven neuronal cells increased during both observation and the execution of an action, and no significant change in activity occurred during viewing of the word describing these actions. This suggests that mirror neurons are not just purely visual neurons responding to the picture of an action or a word describing an action.

Self-projection mechanism for mental states understanding has been associated with the brain’s default mode network, which includes the medial prefrontal cortex, precuneus and posterior cingulated and lateral parietal cortex (Raichle et al., 2001). These regions have been shown to be involved in implementing the ability to imagine one’s own mental states outside of one’s current situation and also in the ability to imagine the mental states of others (Waytz and Mitchell, 2011). Therefore, being able to reflect on the contents of one’s own mind appears to be inseparable from the capacity to understand the minds of others. In the light of this theory, it appears plausible that synaesthetes who personify objects and linguistic sequences tend to misidentify their own emotional and mental states as belonging to objects and letters (Sobczak-Edmans and Sagiv, in press).

1.4.3 Anthropomorphism in social cognition

Simulation theories assume that one has to imitate (mirror) mental states of another in order to understand them. Once a particular mental state has been recreated, it is projected on another and assigned to them as the other's own mental states. There are instances in which the projected emotions or beliefs are egocentrically biased by one's own non-corresponding mental states. This occurs when the person who tries to understand mental states of others fails to monitor their own genuine mental states and exclude them from the simulated, projected mental states. This happens, for example, in anthropomorphism - humans' tendency to attribute distinctively human traits (mental states, including intentions, feelings and/or physical appearance) to non-human agents (Guthrie, 1993; Waytz, Cacioppo and Epley, 2010).

Humans frequently anthropomorphise the entities surrounding them and this tendency appears to be much stronger in early childhood than in adulthood. For children, nearly all that surrounds them has consciousness - trees, clouds, animals, plants, rocks, the wind, the moon and other non-human things have human-like qualities (Piaget, 1929). Anthropomorphic processes have been suggested to be an early, developmental mechanisms reinforcing the development of theory of mind (Amin et al., 2011; Sobczak-Edmans and Sagiv, in press), and therefore animism could be considered as a basic psychological mechanism underlying social cognition (Sobczak, 2009).

This mode of thought is still present later in life and occurs in metaphors, folk legends, myths and religion (Guthrie, 1993). Anthropomorphic attribution of human-like characteristics is also found in many languages that have grammatical gender. For example in the Polish language, in which gender is assigned to all nouns, a moon has masculine grammatical gender and a cloud has a feminine grammatical gender. As noted earlier (Section 1.3), anthropomorphic thought is also utilised in design and human factors engineering, (Nass et al., 1997) and advertising (Ouwersloot and Tudorica, 2001; Delbaere, McQuarrie and Phillips, 2011). This widespread anthropomorphic mode of thinking has been proposed to be a failure in the universal function of perception, namely in generating interpretations to perceived stimuli (Guthrie, 1993). Accordingly, anthropomorphic perception endows objects and events with life-like features, such as anger, anxiety or different social clues indicating danger, and is adaptive in the sense that it promotes the survival and reproductive prospects of the organism. Highlighting its adaptive role, Guthrie (1993) implies that over-attribution of mental states to inanimate things and events is preferable to a more restricted attribution which may result in missing some social clues indicating danger.

Empirical psychological investigations into anthropomorphism focus on the cognitive and neural mechanisms involved in anthropomorphism, and also on variety of factors that increase the tendency to anthropomorphise (Waytz, Cacioppo and Epley, 2010). There are three major factors increasing anthropomorphism. The first relates to the knowledge elicited by the agent. As young children initially develop a concept of the self and only later in development acquire more complex knowledge about different agents, they therefore exhibit an egocentric bias in reasoning when explaining less well-known stimuli, which increases their propensity to anthropomorphise. The egocentric/homocentric knowledge is more easily accessible when the perceived stimulus morphologically resembles a human. People frequently attribute their own beliefs and desires to others that seem to be similar to them (Epley et al., 2004). Considering that the self often serves as a pattern for reasoning about unfamiliar others, Waytz and colleges (2010) hypothesised that anthropomorphism is more likely to occur when perceiving unfamiliar agents. Social motivation is a second of the factors increasing anthropomorphism. Humans have a basic need to affiliate and create social connections with others. Lack of social connections and social isolation can be compensated by anthropomorphising animals, gadgets and religious agents (Epley, Akalis, Waytz, and Cacioppo, 2008). Effectance motivation, described as a need to understand, control and predict one's own environment has been proposed as a third determinant of anthropomorphism. This account considers anthropomorphism as a mechanism fullfilling the need to understand and control non-human agents in environment by endowing them with human-like qualities.

The neural correlates of anthropomorphism have been examined in functional imaging studies using variations of stimuli. Brain function in response to anthropomorphism was tested using variations of classic Heider-Simmel animations (Castelli, Happe, Frith and Frith, 2000; Castelli, Frith, Happe and Frith, 2002; Tavares, Lawrence and Barnard, 2008), point-light walkers (Herberlain and Saxe, 2005) and also by asking participants to make dispositional attributions to objects (Harris and Fiske, 2009). Although brain activations between studies varied, in all of them anthropomorphic processes activated some of the social brain regions, including PFC, TPJ, STS and temporal poles adjacent to the amygdale. Patients with Asperger's Syndrome had difficulties in giving anthropomorphic descriptions while watching animated shapes, and also did not show activations in brain areas involved in social cognition (Castelli, Frith, Happe and Frith, 2002) supporting the notion that anthropomorphism might be one of the mechanisms underlying mentalising. Similar deficits in anthropomorphism were observed in patients with bilateral amygdala damage (Herberlein and Adolphs, 2004).

1.4.4 Neural correlates for understanding self and others

Social neuroscience seeks to investigate and understand in neural terms many social phenomena and their impact on our everyday behavior. The scope of this section, however, will be limited to reviewing the neural mechanisms underlying our ability to understand mental states, such as intentions, beliefs and desires, known in literature as *mentalising* (Frith and Frith, 2003), *mind-reading* (Baron-Cohen, 1995) or *theory of mind* (Premack and Woodruff, 1978).

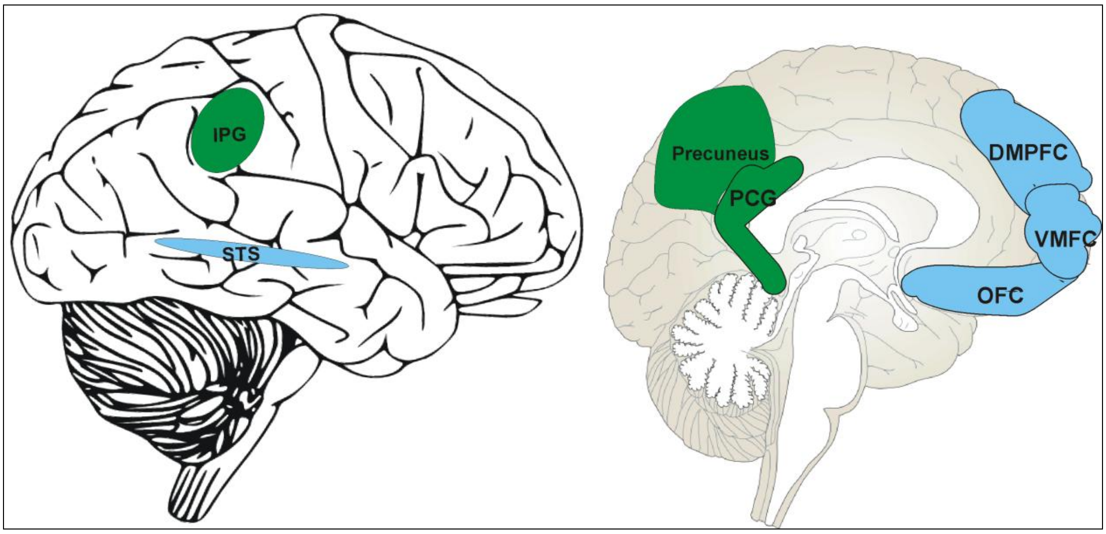

Figure1.2 Brain regions important in mentalising. Areas implicated in the understanding one's own mental states are marked in green. On the lateral surface, these include the inferior posterior gyrus (IPG), comprising Brodmann areas 39 and 40, and on the medial surface, the precuneus (PC), comprising of Brodmann area 7, the posterior cingulated gyrus (PCG), consisting of Brodmann areas 23, 31, and the ventromedial prefrontal cortex (VMPFC) comprising of Brodmann areas 11, 12, 25, and also 10 and 32 (on the ventral surface). Areas implicated in the understanding mental states of others are marked in blue. On the lateral surface, these include the temporo-parietal junction (TPJ), comprising Brodmann areas 39, 40, 22, superior temporal sulcus (STS), consisting of Brodmann area 22, and on the medial surface, the dorsomedial prefrontal cortex (DMPFC), comprising Brodmann areas 8, 9, and the orbitofrontal cortex (OFC), consisting of Brodmann areas 11 and 12.

Functional neuroimaging has indentified various brain regions involved in mental states understanding (see Fig. 1.2). Social brain regions involved in mentalising can be classified into two groups depending on whether agency is internally or externally attributed; that is, understanding oneself or others.

The right parietal posterior areas, namely the inferior parietal gyros, posterior cingulate cortex, precuneus and ventromedial prefrontal cortex and dorsomedial prefrontal cortex have been associated with implementing one's own mental states, which has been confirmed by studies on the neurophysiology of the self generated acts (Ruby and Decety, 2001; Farrer and Frith, 2002; Chaminade and

Decety, 2002), and studies on self reflection (Lombordo, 2010; Mitchell, Macrea, and Banaji, 2006). Studies on self generated acts frequently include schizophrenic patients experiencing passivity phenomena, in which they have the delusional belief that their thoughts and actions are not internally/self generated by them, but rather are under external control often attributed to aliens. In these patients, Spence et al. (1997) observed hyperactivation in the right inferior parietal cortex during execution of the joystick movement after hearing the sound. Similarly, in healthy individuals, the right inferior parietal cortex has been identified as a neural correlate of agency, allowing people to distinguish between self-generated actions and those produced by others, which was shown in Ruby and Decety, (2001) in a study where participants were asked to imagine that they were performing a given action (first-person perspective) or to imagine the experimenter was carried out that action. Being aware of not causing the action and assigning it to somebody else is linked with activation in the inferior parietal cortex (Farrer and Frith, 2002; Chaminade and Decety, 2002). The inferior parietal cortex is also implicated in bodily awareness, since lesions to this area frequently result in somatoparaphrenia (Berlucchi and Aglioti, 1997) or its stimulation may cause out of body experience (Blanke et al., 2002). TMS experiments confirm these findings. Uddin et al. (2006) showed that rTMS over the right IPL impairs the ability to discriminate self-faces from other-faces. The precuneus has been proposed to be a nodal structure for self-reference (Abu-Akel and Shamay-Tsoory, 2011) as it has functional connections with the inferior parietal lobule and medial prefrontal cortex. Additionally, the precuneus has been named a neural correlate of consciousness due to its high resting metabolic rate (Cavanna and Trimble, 2006). The precuneus, together with the posterior cingulated cortex and ventromedial prefrontal cortex, have been associated with explicit and implicit self-referential processing (Rameson, Satpute and Lieberman, 2010). The ventromedial prefrontal cortex has also been found to be active during autobiographical memory encoding (for review, see Gilboa, 2004) and not during episodic memory encoding. Lieberman (2007) suggests that this DLPFC activation in response to autobiographical events may be linked with ones' own mental states and feelings experienced during the events. The VMPFC in studies on understanding mental states has been activated when subjects were thinking about similar others (Mitchel et al., 2006), as well as when judging one's owns traits (Kelley et al., 2002) or mentally triggered thoughts reflecting on one's own personality traits (Kjaer, et al., 2002).

Brain regions that are found to be selectively active in understanding mental states of others include the superior temporal sulcus and orbitofrontal cortex (Abu-Akel and Shamay-Tsoory, 2011). The orbitofrontal cortex has been linked with implementing affective mental states of others (Hynes et al., 2006; Kana et al., 2009). The superior temporal sulcus has been reported to be involved in perception of eye gaze, mouth movement, and also goal-directed actions, such as grasping, tearing reaching and so on. Primate studies additionally showed that the superior temporal sulcus is sensitive to movements generated by others and not by themselves (Oram and Prett, 1994; Hietanen and Perrett, 1993).

1.4.4.1 Cognitive and affective mental states

Mentalising processes (self- and other-related) include cognitive and affective mental states. The ability to infer cognitive and affective mental states requires cognitive understanding of the difference between another person's knowledge and that of the one’s own, but to infer affective mental states requires in addition an emotional appreciation of another’s emotional state. The processing of cognitive mental states has been experimentally measured using cognitive theory of mind tasks, such as the false belief tasks, whereas to measure the processing of affective mental states researchers have used affective theory of mind tasks, such as irony or the faux pas task. Dorsal MPFC and DLPFC are brain areas involved in processing cognitive mentalising (Kalbe et al., 2010; Sommer et al., 2007). The brain regions that implement affective mentalising are PFC, vMPFC, OFC and ILFC (Hynes et al., 2006; Kipps and Hodges, 2006; Andreasen, Calage, and O’Leary, 2008; Hooker, Verosky, Germinea, Knight, and D’Esposito, 2008; Samson, Apperly, Kathirgamanathan, and Humphreys, 2005; Vogeley et al., 2001). Abu-Akel and Shamay-Tsoory (2011) pointed out that the listed areas for affective mental states processing have many anatomical connections with the amygdale, which itself is strongly involved in affective processing, whereas brain areas linked with cognitive processing do not have direct anatomical connections with the limbic brain areas involved in the processing of emotional states.

1.4.4.2 How does the brain utilises mechanisms to distinguish between self and other mental states?

It has been argued that the capacity to distinguish between self and other mental states is processed by the right fronto-parietal network (Decety and Sommerville, 2003; Uddin et al., 2006; Uddin et al., 2007) that include right lateral prefrontal cortex, mirror neurons in inferior parietal lobule (IPL) and inferior frontal gyrus

(IFG). Abu-Akel and Shamay-Tsoory (2011) proposed that this distinction is mediated by the ventral and dorsal attention systems. The first, the *ventral system*, consists of the right TPJ and right IFG and is involuntary involved in attentional reorientation in response to silent perceptual stimuli. The *dorsal system* is involuntary and includes bilaterally the intraparietal sulcus and the superior parietal lobe (BA5, 7), and also dorsal parts of frontal cortex (BA6 and 8). This system regulates goal-driven, top-down orientating attention. Both systems are functionally interactive – when the dorsal stream directs attention towards specific stimuli, the ventral stream filters signals and selects information. Anatomically, this interaction could occur through direct connections between the IPL and the precuneus (Lou et al., 2004) or/and through the middle frontal gyrus and the ACC, mediated via neural paths with the frontal eye field (dorsal system) and inferior frontal gyrus (ventral stream). Pointing towards the anatomical overlap (in TPJ and ACC) between mentalising and attentional systems, Abu-Akel and Shamy-Tsoory (2011) emphasized that the TPJ as is involved in both attentional and mentalising processing and responds to self and other mental states, suggesting that the attention signals in this region might act as a switch between self and other mental states. Similarly, the authors suggested that the anterior parts of ACC could be involved in navigating attention towards self and other mental states due to its connections with ventral and dorsal attention networks and being implicated in directing attention to mental states. Studies of neurological and psychiatric patients suggested that the misattribution of one’s own mental states to others could be one of the mechanisms explaining delusions in schizophrenia. Crespi and Badcock (2008) proposed that there is over-mentalising in schizophrenia, and this may result from a hyper-associative cognitive style, linked to oversensitivity in mental states attributions. The oversensitivity for mentalising in psychotic patients does not necessarily result in superior mentalistic skills, but frequently leads to inaccurate understanding of social world, which is manifested in delusional thinking.

1.4.5 Empathy

Broadly, empathy denotes our capacity to share feelings of other people (Singer and Lamm, 2009; Ward, 2012). However, in order to distinguish empathy from mentalising and other related concepts, researchers constructed more precise definitions of empathy. In 2004, Decety and Jackson proposed consisting of three parts model, in which all factors – affective sharing, emotion understanding and self-regulation interact with each other. Similarly, de Vignemont and Singer (2006) defined empathy as an affective state in a person that is isomorphic with observed or imagined affective state in another person, which require comprehension that the source of the affective state in oneself is in another (observed or imagined) person. These definitions make it possible to distinguish between empathy and mentalising by putting an emphasis on the presence of an affective state that is shared with another; this does not occur in mentalising (as it only regards drawing inferences about other people affective and cognitive mental states, without sharing affective response). This separation of empathy and mentalising in understanding mental states is used in psychopathology as an explanatory framework for understanding neurodevelopmental disorders, including psychopathic disorder (Blair, 2005), autistic spectrum disorder (Crespi and Badcock, 2008), schizophrenia with passivity phenomena (Shur, Shamay-Tsoory and Levkovitz, 2008) and Williams syndrome (Troisi, 2008: in Crespi and

Badcock, 2008), in which mentalising processes and empathy processes may be differently impaired (or not) within the same disorder.

The supporting evidence from research demonstrates that people with autistic spectrum disorder and Williams syndrome have deficits in understanding mental states but not in empathy (Blair, 2005; Crespi and Badcock, 2008; Shur, Shamay-Tsoory and Levkovitz, 2008; Troisi, 2008:in Crespi and Badcock, 2008). The inverted pattern of mentalising and empathy skills occurs in psychopaths, who are excellent in mindreading, but at this same time unable to share emotions with others. Empathic skills differ not only among people with disorders, but also among the general population – people are not equally empathic toward each other. The individual differences in empathy can be measured with standard empathy questionnaires such as the Interpersonal Reactivity Index (IRI; Davis, 1980) or Empathy Quotient (EQ; Baron-Cohen and Wheelwright, 2004).

1.4.5.1 Theories explaining empathy

Social psychologists attempt to explain mechanisms underlying empathy in terms of unconscious simulation (Ward, 2012). At the neural level this would be supported by mirror system for action which together with other brain areas (Iacoboni, 2009). Carr et al. (2003) conducted a functional neuroimaging study, in which participants were asked to observe emotional facial expressions and imitate them. Authors found increased activation in the premotor cortex (part of mirror system) when participants were imitating facial expressions, and also in the amygdala and insula. On basis of that they hypothesised that imitation processes activate representations that are shared by the self and other and then this information is transmitted to other parts of limbic system via insula. Ward (2012) argues that the action-to emotion model proposed by Carr et al. (2003) and Iacoboni (2009) is an over-simplification, as the concept of empathy is much broader than only imitation. This line of argument is also presented by Frederique de Vignemont and Tania Singer (2006) who argue that simulation of emotions in empathy does not require the mirror motor system activation, and can be explained within the general simulation approach (Ward, 2012). Singer et al. (2004) tested subjects in an fMRI scanner as they had a painful stimulation applied with an electrode or when they were watching an electric shock being applied to their loved-ones. The authors found activations in the anterior cingulated cortex, bilateral insula, brainstem and cerebellum, but they did not find activations in the mirror system for actions. Consequently, the authors argued that the mirror motor system is not necessary for sharing emotions in empathy. Instead, empathy could rely on the emotional network shared between self and other independently of the classic mirror motor system (de Vignemont and Singer, 2006). Furthermore, they proposed that neural responses to empathy are modulated by appraisal processes and also by information about emotional stimuli and their context as well as by one's empathy skills, and the relationship between empathizer and the target. Studies conducted by Bourgeois and Hess (2008), and van Baaren et al. (2009) provided empirical evidence that empathy is context-sensitive and depends on the type of the relationship between the empathiser and the target. Although the initial studies on shared neural circuits between self and other in the domain of empathy identified overlapping neural activations between self and other only in the affective component of pain (for review see Singer and

Lamm, 2009), the latter investigations provided evidence that brain areas associated with somatosensory processing also activates while observing another's person pain, especially in situations where one's attention is explicitly directed on somatosensory aspects of the pain (Lamm et al., 2007). The primary somatosensory cortex displayed increased activation when subjects were observing another person being pierced on their hand, which overlapped with primary somatosensory representations for touch of the hand in scanned participants. Also secondary somatosensory cortex (Jackson et al., 2006; Singer et al., 2006) activations were shared for self/other pain. The bulk of research investigating shared neural circuits between self and other in domain of empathy has focussed on empathy for pain, but also some studies examined shared networks in the domains of taste and smell showing shared neural representations for the experience of disgust and the observation of disgust in the anterior parts of insular cortex together with the frontal opercular taste cortex (Wicker et al., 2003). This same pattern of activation was observed when subjects were looking at the facial expressions displaying disgust (Jabbi et al., 2007), suggesting that these brain regions may be involved in translation of observed facial expressions into visceral states when self-simulating these expressions (Critchley et al., 2005), making them accessible for understanding emotional states observed in others (Keysers and Gazzola, 2007).

In conclusion, the empirical evidence suggests that the shared neural activations constitute a mechanism implementing empathic feelings and sensations, however additional research is needed to establish what aspect of empathy is actually shared - affective, somatosensory, or both.

1.4.6 Summary

This chapter provided a general overview of current state of knowledge on understanding the contents of minds of others. Two main theoretical approaches – theory theories and simulation theories have been discussed, together with the neural underpinnings of ‘social brain’ and empathy. Reviewed studies on anthropomorphism show that people attribute mental lives not only to other humans, but also to non-human entities, providing evidence of shared ‘social brain’ activations for anthropomorphism and general social cognition. Mirroring and self-projection are mechanisms proposed within the simulation theory framework suggested for mentalising with and without behavioural, perceptual cues about inferred mental states. Humans have the capacity not only to infer affective and cognitive contents of one another’s minds, but also the capacity to share affective responses with others. Empathy and mentalising appear to be interconnected, since the observed imbalance between the level of empathic and mentalising skills is frequently present in such psychopathological disorders as psychopathic disorder or Williams’ syndrome. Contemporary neuroimaging research on mentalising attempts to explain empathy using the simulation approach, suggesting that empathy could be explained in terms of unconscious simulation in brain mirror system or shared neural activations in somatosensory and/or affective component of empathy.

1.5 Motivation for the research in this thesis

Sequence-personality synaesthesia is a special case of synaesthesia, in which concurrents do not belong to the cognitive perceptual systems (for example, visual, auditory, etc) but rather are related to the social cognition system by which we get to know other people's personality traits, mental states, intentions, attitudes and feelings.

This work investigates the attribution of agency and mental states and other human-specific qualities to linguistic sequences and inanimate objects in sequence-personality synaesthesia. The phenomenon of attributing agency to inanimate things captured the interest of such prominent figures as Jean Piaget (1929) and Mary Calkins (1895), but has received limited attention since. Recent empirical investigations into personification in synaesthesia (Simner and Holenstein, 2007; Smilek, 2007; Amin et al., 2011) provided compelling evidence for its consistency over time and automaticity in experienced inducer-concurrent pairings, suggesting that personification can be considered as a type of synaesthesia.

The broad aim of this thesis is to provide a more detailed account for the phenomenology of personification, its underlying neural and cognitive mechanisms. First, a systematic study of the frequency of various categories of inducers and concurrents in synaesthetic personification will be carried out based on synaesthetes' self-reports. The categories of inducers considered will include weekdays and months of the year in addition to graphemes, whereas categories of concurrents will include gender, personality traits and moods, human-like appearance, social role and relationships. Additionally, functional neuroimaging studies will be carried out to establish the neural correlates of grapheme personification and inanimate object personification. For inanimate object personification, the investigation will also include a behavioural study, utilising a variation of the Stroop paradigm, which will examine the automaticity of this phenomenon. In the final study, the relationship between personification, social cognitive abilities (including empathy and mentalising) as well as loneliness will be examined in synaesthetes.

There are a number of issues that need to be addressed in order to better understand this phenomenon. First of all, it is necessary to establish how frequent social and affective descriptions of graphemes and inanimate objects are among personifiers. From the case studies described in the literature (Simner and Holenstein, 2007; Smilek et al., 2007) it cannot be determined. The only study that examined the frequency of synaesthetic concurrents in personification (Amin et al., 2011) focussed only on gender and personality attribution and did not include other attributed characteristics such as moods, appearance, social roles and relationships.

Accordingly, the aim of the first empirical chapter (Chapter 2) is to establish how common various categories of concurrents among synaesthetes are. For this purpose, a modified version of the semi-structured questionnaire designed by Amin et al (2011) will be used. The modified version includes more categories of concurrents (personality traits and moods, appearance, social role and

relationship), and an extended number of categories of inducers - weekdays, months and various subcategories of inanimate objects are now included.
The benefits of collecting and analysing subjective reports provided by synaesthetes lie in acquiring better understanding of the complex picture of synaesthetic personification, which in turn is helpful in framing appropriate research questions about the processes underlying it in the following studies.

The second empirical chapter (Chapter 3) examines the functional neuroanatomy of grapheme personification. To date, the findings of the only published case study exploring neural correlates of this particular phenomenon showed that self-referential processes are likely to be involved in personification. In view of the fact that there may be links between synaesthetic personification and general social cognition, it is hypothetised in this chapter that personification in synaesthesia shares functional neuroanatomy with general social cognitive processes, specifically mentalising processes when other people are absent (namely, a self-projection mechanism; Waytz and Mitchell, 2011).

Based on the review of literature of studies on mentalising processes, Waytz and Mitchell (2011) suggested that self-projection for mentalising is linked with the following brain areas: the precuneus, lateral parietal cortex, the posterior cingulated cortex, the superior temporal sulcus, the temporo-parietal junction and medial prefrontal cortex. Given that synaesthetes frequently report that intensities of grapheme personification differ for various letters and numbers, an additional aim of Chapter 3 is to establish whether these subjectively perceived differences are correlated with the changes in strength of the activation in the precuneus, as hypothetised by Amin et al (2011). The investigations carried out in Chapter 3 will make it possible to determine whether the precuneus activation observed in AA in that study for synaesthetic grapheme-gender pairings is specific only to that particular synaesthete or is true for other synaesthetes. Furthermore, the findings could provide additional evidence for the not fully voluntary character of personification and the reality of synaesthetic experience in personification, if the observed neural changes reflect the human-like aspects of concurrents by engaging regions from the 'social brain', even when synaesthetes are engaged in an unrelated task.

The issue of voluntary versus involuntary control is the focus of Chapter 4. The current synaesthesia literature provides only limited evidence that synaesthetic personification of inanimate objects is involuntary, from the case study of TE (Smilek et al., 2007). Accordingly, the purpose of the study in Chapter 4 is to seek evidence for the automaticity of synaesthetic personification of inanimate objects. This is important in two ways: Firstly, establishing the involuntary character of object personification in synaesthesia will provide empirical evidence that objects personification fulfils the automaticity criterion for possible inclusion of this phenomenon into the spectrum of synaesthesia. Secondly, comparison of these processes in synaesthetic and non-synaesthetic personification will enable to determine whether the same mechanisms underlie non-synaesthetic personification.

Chapter 5 utilises a similar methodology to that used in Chapter 3. It aims to examine the neural correlates of inanimate object personification. It is hypothetised that neural mechanisms involved in personification of inanimate objects in synaesthesia overlap with those involved in general social cognition. However, the study in Chapter 5 additionally tests a group of non-synaesthetes, since personification of objects also occurs in the general population albeit in a milder form. This study aims to examine whether the neural correlates of synaesthetic and non-synaesthetic personification of inanimate objects are similar. It is hypothetised that social brain regions will be activated even when synaesthetes are naïve to the real purpose of the study and are engaged in an unrelated task. It is expected that, under the same set of conditions, there will be no activations in regions involved in social cognition in the control group. However, it is expected that in the second phase of the study (when all participants are asked to focus their attention on the mental contents of 'lonely objects', the brain responses in both groups will include activations in social brain areas, but they will be greater and more extensive in synaesthetes. The importance of the findings about neural correlates of synaesthetic personification can provide new insights into the functional organisation of the neural mechanisms underlying social cognition and help us to determine whether mechanisms underlying personification are common to all of us or are specific to synaesthetes.

The last study in this thesis (Chapter 6) will complement the previous analysis of neural and cognitive mechanisms underlying synaesthetic personification by examining the relationship between seeing graphemes or inanimate objects as endowed with mental lives and empathic and mentalising abilities of synaesthetes. This will be examined using the Empathy Quotient (EQ; Baron-Cohen and Wheelwright, 2004) and the Mind in the Eyes Test (Eyes Test; Baron-Cohen et al., 2001). Mentalising abilities have not been yet studied in personifying synaesthetes and initial investigations of empathic abilities in personifiers did not provide a definite answer whether synaesthetes exhibit heightened empathy (Amin et al., 2011). Based on the finding that synaesthesia is associated with enhanced sensory processing in modalities of the concurrent (Bannisy et al., 2009), it is hypothetised that synaesthetes will show increased empathic and mentalising abilities compared to the general population. Additionally, the study in the Chapter 6 examines the possibility of increased loneliness in personifiers; this hypothesis stems from the observation that enhanced loneliness is associated with a tendency to see non-human entities as living agents co-occurs in the general population (Epley et al., 2008). Examining aspects of social functioning in synaesthetes and environmental factors (e.g. loneliness and social withdrawal) may help to shed light on the developmental processes underlying synaesthesia and also provide new insights into the developmental social cognition.

In sum, the research in this thesis will primarily enhance the understanding of synaesthetic personification and its cognitive and neural basis and investigate any relationship between personification and such psychological dispositions as empathy, mentalising and loneliness. Knowledge about the functional anatomy of personification may help to shed light not only on processes engaged in decoding and encoding mental states, but additionally on clinical conditions, such as schizophrenia or autistic spectrum disorder, in which mentalising appears to be crucial to the core clinical symptoms. It is hoped that greater understanding of the symptoms in these clinical conditions will improve the quality of care and treatment.

CHAPTER 2 Phenomenology of synaesthetic personification

2.1 Introduction

The first psychological investigations into personification in synaesthesia were mostly explorative and descriptive, aiming to provide a greater understanding of synaesthetic personification and to discover common features in sequence-personality synaesthesia (Calkins, 1893; Flournoy, 1893).

Calkins (1893) noticed that different linguistic sequences are personified with different frequency. She established that personality traits were two times more frequently attributed to numbers than to letters. Additionally, Calkins pointed out that synaesthetes have affective attitudes towards numbers: they tend to like more easily divisible numbers rather than prime numbers. A contemporary of Calkins, Flournoy (1893), also highlights that the subjective experience of synaesthetes may influence their likes and dislikes of particular letters and numbers, suggesting that the biographical experiences of synaesthetes can influence the personifications[4].

Flournoy's descriptions of the phenomenology of personification in synaesthesia included several types of inducers. The author provided descriptions of a few synaesthetes who personified graphemes, weekdays and inanimate objects.

[4] I am grateful to Lucille Lecoutre for translating from French into English Chapter VII from Flournoy's *Des Phenomenes de Synopsie*

Flournoy (1893) provided also interesting observations regarding concurrents in synaesthetic personification. Specifically, he noticed that qualities attributed to inanimate objects are not limited to genders and personalities, but also include aspects of human-like appearance. For example, to J.A., a 53 year old female synaesthete, flowers had facial expressions of babies. In a similar way as with objects, linguistic sequences were also were endowed with appearances resembling people. Flournoy (1893) mentioned a 21 year old, male synaesthete, to whom many letters and numbers have human-like bodies and faces and a 10 year old girl who thought of Saturday as a man dressed in red, Friday as a woman dressed in blue, Thursday as a man dressed like a Scotsman and so on.

Another interesting aspect of the concurring experience in sequence-personality synaesthesia mentioned by Flournoy indicated that some personalities of graphemes may shift focus from one negative trait to another over time. He illustrated this with an example of synaesthete who as a child thought of number 7 as a mean man, whereas once she grew up, the perceived personality of this number changed and 7 became an immoral man with a dissolute lifestyle. This may represent maturation processing with numbers acquiring more subtle descriptions, appropriate for an adult understanding of social norms.

Flournoy (1893) also suggested that personalities attributed to graphemes may be influenced by their shape. In his book, he describes a 16 year old synaesthete who classified personalities of graphemes according to their shapes (for example, to him G, D, and B were heavy, obese and dull letters, N, C, I, F, 1, 3, and 7 were elegant, whereas H, Z, M, R, 2, 5, and 8 were solemn and sombre).

More recently, Amin et al (2011) carried out a study exploring characteristics of personification in synaesthesia. They e-mailed semi-structured questionnaires to 81 synaesthetes from a synaesthesia database who reported personification of graphemes. The responses were collected from 34 synaesthetes who replied and completed the questionnaires. The questionnaire had three major sections – in the first of them subjects were asked to describe genders and personality traits they experienced for letters and numbers and in the second they were requested to provide answers about the general characteristics of personification in synaesthesia, such as the circumstances under which personification occurs, its frequency, age of onset, and whether or not personification occurs for letters in different languages. The third section consisted of questions on the personification of inanimate objects and related forms of synaesthesia including mirror-touch synaesthesia.

In their study Amin et al (2011) found that synaesthetes report personification not only for linguistic constructs such as letters and numerals, but also for inanimate objects, such as household objects, fruit and vegetables and other objects. Letters and numbers were personified with similar frequency. Nearly all of the synaesthetes reported the onset of personification in childhood (between as early as they can remember and seven years old) and experience it on a daily basis. Graphemes are personified the most frequently when they are imagined, thought of or seen (in more than eighty percent of subjects), and a little less frequently when they are heard (seventy percent of subjects).

Most of the tested synaesthetes noticed that certain aspects of graphemes influence the genders and personality traits attributed to graphemes. Among them, a determinant of gender or personality most often was listed the synaesthetic colour of a letter or a number. Less frequently participants thought that the shape, sound or number parity influenced gender or personality trait attributions to graphemes. Synaesthetes also reported experiencing personification in foreign languages they spoke.

The study conducted by Amin et al. (2011) is to date the only systematic group study that used a semi-structured questionnaire to explore in detail the phenomenology of personification in synaesthesia.

2.2 Aim of the study

The present study aims to verify previously published results on characteristics of personification in synaesthesia (Amin et al., 2011) and also to explore further the phenomenology of personification in synaesthesia.

To date, the study of Amin et al (2011) provides the only detailed account on the characteristics of personification in synaesthesia. In the study described in this work some of their questionnaire items are replicated, but the scope of investigation is extended by including additional sets of inducers (days of the week, months of the year, objects categories) and additional categories of concurrents include, such as personality traits, moods, human-like appearances, social roles and relationships. Therefore, the current study investigates a wider range of inducers than Amin et al (2011). Additionally, more concurrent categories are included in the scope of research of the current study In the previous investigation of Amin et al (2011), these were limited to two main categories only – gender and personality.

The study is motivated by the fact that, in the recent synaesthesia literature descriptions of personification of weekdays, months and objects are mentioned, but systematic investigation of those categories of inducers has yet not been carried out. Moreover, in further stages of this work, the neural correlates of synaesthetic gender, as well as personification of objects will be explored; therefore it is important to gain a detailed account of these phenomena.

2.3 Participants

27 participants were recruited Sean Day's The Synesthesia List, an internet based Google group for synaesthetes and synaesthesia researchers, from the Synaesthesia Database and also via advertisements on the Brunel University Campus and Royal Holloway Campus. Among the participants were 23 women and 4 men. Twenty-four subjects were native English speakers; two were Italian speakers and one was a native Japanese speaker. All participants not only personified graphemes, but also experienced coloured graphemes synaesthesia.

Participants gave a written consent. Subjects volunteered in the study and were not paid for their time.

2.4 Procedure

The structured questionnaire on sequence-personality synaesthesia was emailed to all synaesthetes who contacted us reporting experiencing this type of synaesthesia.

The questionnaire was emailed (posted) in two parts: one investigated personification of graphemes and inanimate objects and the second part explored phenomenology of month and weekday personification.

Completed questionnaires were returned by 27 participants by post or via e-mail. In the questionnaire subjects were asked to describe personified letters, numbers, objects, weekdays and months. They were also asked how frequently they experience personification, what influences pairings inducer-concurrent, whether attributed personalities change over the time and depend on the mood of personifying synaesthete. For more details on the questions asked see questionnaire in Appendix.

2.5 Results

2.5.1 What gets personified?

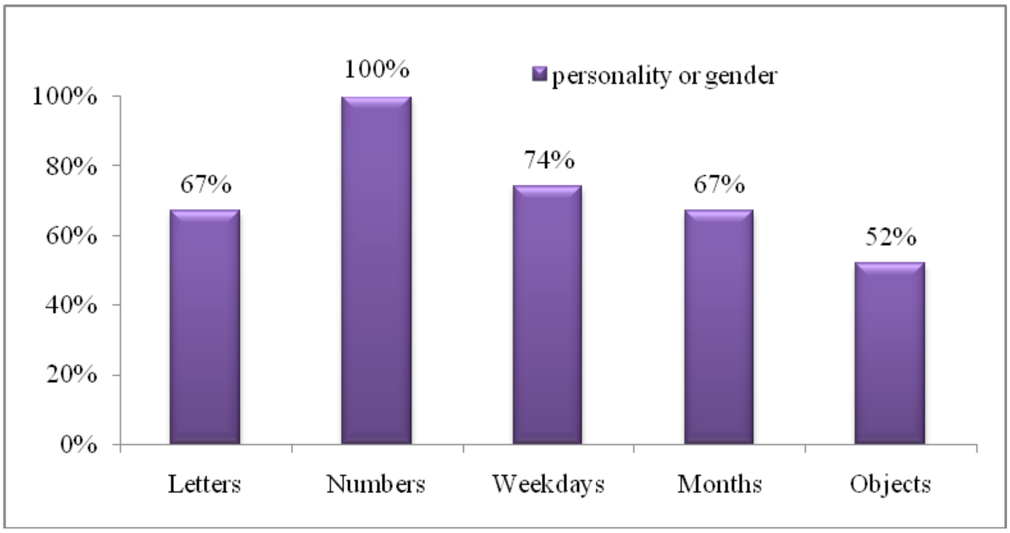

Figure 2.1 Frequency of gender or personality attribution to different sequences and objects

All subjects who completed the questionnaire also experience grapheme-colour synaesthesia. All of them attributed personality and/or gender to numbers and 71% attributed personality and/or gender to letters. Gender or personality was attributed to days of the week by 74% of synaesthetes, and to months of the year by 67%. About half of synaesthetes (52%) personified objects (see Figure 2.1). Individual participants also mentioned personification of violin strings, colours, spatial concepts (left-right) and musical notes.

2.5.1.1 Grapheme personification

Synaesthetes were asked to describe the personal characteristics and gender of graphemes. Personality description was divided into following subcategories: personality traits and moods, appearance, social role and relationships. Synaesthetes were also required to indicate whether or not they liked or disliked particular graphemes.

52% of synaesthetes reported that they attribute both personality and gender to graphemes. Only gender but not personality was attributed to letters and numbers by 3%. None of tested subjects reported experiencing only personality in response to letters and numbers. However, out of the participants who attributed gender only, letters and numbers were personified similarly frequently as inducers, as shown in Table 2.1, whereas, of those participants who attributed personality only, numbers were the inducer in all cases.

Table 2.1 Type of personification and class of stimuli

	Letters	Numbers	Both
Personality + Gender	14 (52%)	22 (78%)	14 (52%)
Gender	4 (14%)	3 (11%)	1 (3%)
Personality	0 (0%)	3 (11%)	0 (0%)

The description of subcategories of personality (see Table 2.2) shows that among synaesthetes who declared experiencing personality for graphemes, all of them think of letters and numbers as having personality traits. They also very frequently attribute to graphemes social roles and relationship (78% to letters; 68% to numbers). For 64% of synaesthetes letters have some sort of human-like appearance. In case of numbers, human-like appearance is attributed to them by 54% of the synaesthetes.

Table 2.2 Subcategories of synaesthetic personality for letters (N= 14 synaesthetes) and numbers (N=25 synaesthetes)

	Personality Traits & Moods	Appearance	Social Role & Relationship
Letters	14 (100%)	9 (64%)	11 (78%)
Number	25 (100%)	14 (56%)	17 (68%)

Descriptions of concurrents provided by synaesthetes were frequently very detailed and elaborate. The **personality traits and moods** of graphemes reported by individual synaesthetes included not only personality traits (“introversive”, “shy”, “optimistic”, “sociable”, “sensitive”, “hyperactive”), but also cognitive abilities (“smart”, “intelligent”, “great at planning and getting the job done”), moods (“apathetic”, “sad”, “rather jolly”, “happy”), attitudes (“helpful”, “pushy”, “bullying”, “arrogant”, “optimistic”), and references to specific mental states (“stressed”, “knows when to stop or say no”, “likes to be a centre of attention”, “thinks a lot about himself”).

Human-like appearance of graphemes was reported by synaesthetes in terms of age (old woman, a child), height (tall, short), race (African decent, black woman, “Moroccan or Indian”), facial features (blue eyes, grey-eyed, has a beard, wear glasses), hair (blond), body-build (chubby, slender, athletic), clothes (wears blue jackets, wears suit, jeans and shirt),

Social roles attributed to graphemes included work-related descriptions (“secretary”, “and technical field ”,“ professor ”,“ teacher”) and also education-related descriptions (“undergraduate”, “someone who just finished studies”), whereas perceived **relationships between graphemes** were described in terms of attitudes towards each other (“others like him”, “others rather frighten by her”, “not very liked by others”, “gives good advice to others”), the relation of power and leadership between them (“the others let him lead without objection”, “good leader”, “led by N”), and also familial and non-familial relationships (“A’s child”, “I’s girlfriend”, “mother to all numbers”).

2.5.1.2 Weekdays and months

74% of all synaesthetes who personify graphemes reported gender or personality for days of the week and 67% for months of the year. Almost all of these (94%) reported experiencing genders for days and months, whereas personality traits for months and weekdays were reported by 70% and 65%, respectively, as shown in Table 2.3.

Table 2.3 The frequency of gender and personality attribution for weekdays and months

	Gender	**Personality**
Months	16 (94%)	12 (70%)
Weekdays	16 (94%)	11 (65%)

Among the group of synaesthetes who personify weekdays and months, the majority of personifiers were English native speakers and two of the synaesthetes were Italian. English does not have grammatical gender, but Italian has masculine and feminine gender for nouns; genders of days and months are all masculine. The comparison of synaesthetic and grammatical genders shown that synaesthetic and grammatical genders for months and weekdays are in some cases incongruent (see Table 2.4).

Table 2.4 The frequency of synaesthetic gender congruent with grammatical gender for months and weekdays.

	Gender Congruent with Grammatical Gender for Days (N=7)	**Gender Congruent with Grammatical Gender For Months (N=12)**
Synaesthete 1	3 (43%)	6 (50%)
Synaesthete 2	4 (57%)	10 (83%)

2.5.1.3 Inanimate objects

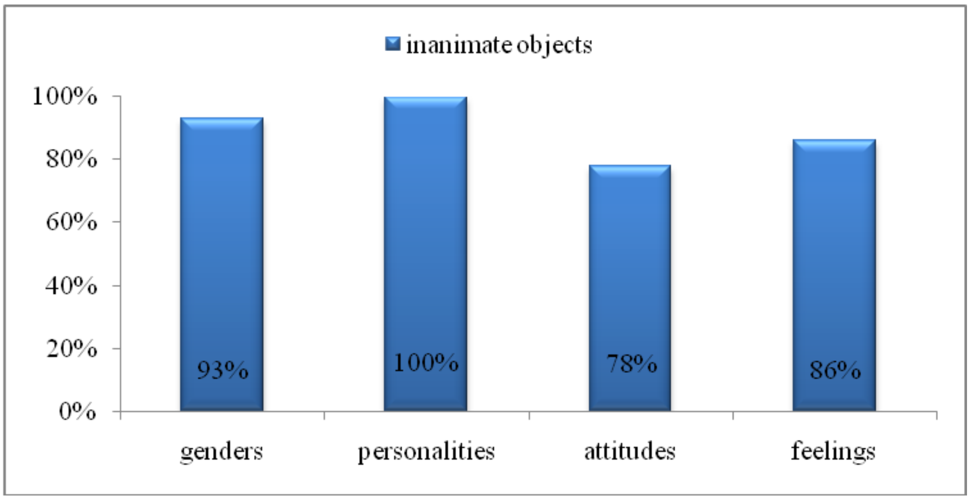

Figure 2.2 Types of concurrents attributed to inanimate objects

52% of all synaesthetes who personify graphemes also personify objects. All of them thought that objects have personalities, 93% attributed genders to objects. 86% of synaesthetes perceived inanimate objects as having personalities and 78% ascribed attitudes to them, as shown in the Figure 2.2.

Table 2.5 Categories of objects eliciting synaesthesia

Object category	**N=14**
Personal objects (including toys)	13 (92%)
Body parts	10 (71%)
Clothes	8 (57%)
Vehicles	7 (50%)
Furniture	10 (71%)
Tools	6 (43%)
Buildings	7 (50%)
Plants	10 (71%)
Food	4 (28%)

Natural objects	11 (78%)
Simple shapes	10 (71%)

The comparison of different categories of objects within this subgroup (see Table 2.5) shows that most of the synaesthetes (92%) personify personal objects, such as mobile phone, toys, pen, door key, paint brush, violin and so on. More than three quarters of synaesthetes who personify objects, thought of natural objects (e.g., rocks, sea) as having personalities, feelings or genders. For 71% of personifiers plants (trees, herb plants, flowers), furniture (e.g, armchair, chair, bed), body parts (e.g., hands, fingers, teeth, feet) and also simple shapes (e.g., triangle, square, circle) were inducing synaesthetic personification. 57% of synaesthetes personified clothes. Among personified clothing items were scarf, trousers, t-shirt. Vehicles (e.g., car, bike, truck) and buildings (e.g., house, university, library) were personified by 50% of synaesthetes, whereas buildings and vehicles were perceived as having gender or personality by half of the synaesthetes within this subgroup. Tools, such as cake mixer, scissors and vacuum cleaners were personified by 43% of all synaesthetes personifying inanimate objects. One of the synaesthetes described personification of vacuum cleaners as follow:

> *"I have a family of three vacuum cleaners. One is called Toby. He has somewhat portly character, very helpful but is forever falling over and bumping into things, so he is a bit accident prone. He can also, like both the other cleaners be prone to sudden vicious attacks on me. This is always from the hose to attachments which*

have a mind on their own, they trip me up, turn round and hit me and can be generally nasty and I get very cross!"

Food was the least personified category of inanimate objects; only 28% of synaesthetes thought of food (e.g., broccoli, onion, carrots) as having personalities and/or genders.

Synaesthetes were asked to indicate whether they associate more or less frequently personalities and genders with familiar objects. 71% of all synaesthetes who personify objects reported genders and personalities for more familiar rather than unfamiliar objects. The remaining 29% of synaesthetes indicated that the familiarity of the object does not impact their personification – they personify familiar and unfamiliar objects with similarly frequency.

2.5.2 When does personification occur?

All of the synaesthetes tested experienced personification of graphemes from childhood. A majority of them (59%) personified graphemes from a very early age, as long as they can remember (less than 5 years old). A further 26% reported experiencing synaesthetic personification from between the ages of 5 – 8 years, and 15% from when they were between 9 and 11 years old. For the majority of synaesthetes (74%), the personalities of letters and numbers have not changed over time, but for some (26%), the personalities of graphemes became more complex and more mature.

The vast majority of tested synaesthetes stated that they experience personification on a daily basis (85%). The remaining 15% personify letters and numbers sometimes, usually when they think about letters or numbers or when doing calculations.

For the majority of synaesthetes (67%) the strength of synaesthetic association of personification has remained unchanged during their lifetime, for 22% the experience of grapheme personification increased, whereas for 11% has decreased.

All of synaesthetes reported experiencing personification when graphemes are presented visually, 96% of participants personified when thinking about graphemes (see Table 2.6). 74% of synaesthetes were likely to experience personification when they hear a grapheme. 56% experienced gender or personality for letters when they are presented with a word, and 70% when seeing multi-digit numerals.

Table 2.6 Overview of conditions under which synaesthetes personify graphemes

N=27	Strongly Agree	Moderately or Mildly Agree	Moderately or Mildly Disagree	Strongly Disagree
When I see a (single digit) number/letter	19 (70%)	8 (30%)	0 (0%)	0 (0%)
When I hear a (single digit) number/letter	8 (30%)	12 (44%)	5 (19%)	2 (7%)
When I think about particular number/letter	23 (85%)	3 (11%)	1 (4%)	0 (0%)
When I see a word	7 (26%)	8 (30%)	7 (26%)	5 (18%)
When I see a multi-digit number	5 (18%)	14 (52%)	4 (15%)	4 (15%)

Synaesthetes answering an open ended question asking about regularities that in their opinion influence personalities or genders of graphemes listed shape (41%), font size (18%), biographical experience (15%), colour (4%) and also whether or not number was odd or even (4%) as factors that can influence personalities of letters or numbers (see Table 2.7)

Table 2.7 Characteristics influencing synaesthetic personification

Qualities influencing personification (self-reported)	**Number of synaesthetes**
Colour	1 (4%)
Shape or form of grapheme (e.g., roundedness, angularity)	11 (41%)
Biographical experience (e.g., friend’s name/date of birth)	4 (15%)
For numbers, whether they are odd or even	1 (4%)
Font case (capital versus lower letters)	5 (18%)

Individual synaesthetes reported that shape influenced the personality and gender of given grapheme describing it as follows: “If a number that doesn't have a definite gender is written fancy or in a ‘girly’ font, it might take a form of a girl, or if it is in big bold masculine font it might take a form of a boy”, “more rounded numbers are more likely to be female”, “different personalities for handwriting”, “personalities change slightly when with different fonts”.

Biographical experience that was also listed by synaesthetes as a factor having impact on personalities and genders of graphemes was expressed in following statements: “My birthday is on the second of August, so I came to love 8 and 2. 8 has similar personality to mine”, “genders and personality traits are associated with most common first names”.

One of the tested synaesthetes suggested that colour influences the personalities attributed to graphemes reporting: “If they are written in different colour, I will associate the personality of the colour to the personality of the letter. If, for example A is written in yellow, it will be happier.”

Another tested participant noticed that the knowledge of the mathematical rules also has impact on personality traits attributed to numbers: “Even numbers have receptive personalities because they can be divided by 2, whereas odd numbers are self-centered and independent.”

2.6 Discussion

The aim of the current study was to explore the phenomenology of personification in synaesthesia, including personification of graphemes, days of the week, months and objects. To date, there was only one group study that systematically examined characteristics of personification among synaesthetes (Amin et al. 2011), but it was limited to personification of graphemes and objects only.

The semi-structured questionnaire used in this study included many of the items previously included in the study by Amin et al (2011), but also comprised additional items investigating categories of concurrents attributed to graphemes. In the questionnaire linguistic sequences as graphemes, days and months were explored. Non-linguistic inducers of personification, such as different categories of inanimate objects, were also investigated.

The overall results show that most synaesthetes experience sequence-personality synaesthesia from childhood and on a daily basis. This is consistent with results of the previous questionnaire by Amin et al (2011), and provides additional evidence for classifying sequence-personality as a congenital variant of synaesthesia.

Furthermore, it was found that some linguistic inducers elicit personification more often and others less frequently: Synaesthetes with sequence-personality synaesthesia most frequently attribute gender or personality to numbers; nearly three quarters of them personifies weekdays and somewhat fewer attribute personality or gender to letters and months. Interestingly, the finding that numbers tend to be personified more frequently than any other linguistic sequences may be related to the fact that counting sequences are acquired early in life (usually earlier than the alphabet or months and days) and most children, when they are three years old, can count up to ten objects (Siegler, Deloache, and Eisenberg, 2003).

Similar results were previously reported by Calkins (1893). She noticed that numbers are more frequently personified than letters, but in her study numbers were personified twice as frequently as letters, whereas in our sample this difference is much smaller.

However, the results reported by Amin et al (2011) are inconsistent with these findings. In their study, the authors found that numbers and letters were personified with similar frequency. Additionally, there is also inconsistency regarding the proportion of synaesthetes who in addition to linguistic sequences also personified objects. In our sample, about half of the tested synaesthetes personified inanimate objects, whereas in the group studied by Amin et al. (2011), inanimate objects were personified by more than three quarters of all tested synaesthetes.

Further disparity between the results of the current study and Amin et al (2011) relates to the factors perceived by synaesthetes to influence personification. Colour of graphemes was reported to influence personalities the most frequently (Amin et al., 2011), whereas our study does not indicate that. Instead, shape of graphemes and autobiographical experiences appear to influence personalities more than colour, which is also in inconsistent with results reported by Amin et al (2011). Additionally, more synaesthetes tested by Amin et al (2011) than in our sample thought of numbers parity and sound of grapheme as shaping their personifications of graphemes.

The differences in results described above may be related to the rather limited sample size (27 and 34 synaesthetes in each of the studies), therefore in future studies it would be necessary to conduct a larger scale investigation comparing the types of personification in synaesthesia and their frequencies.

Analyses of various types of concurrents in synaesthetic personification show that gender and broadly-defined personalities were attributed equally frequently to numbers, whereas letters were more often perceived as having genders than personalities. Among synaesthetes who attributed personality to letters or numbers, all of them experienced graphemes as having personality traits and moods and about three quarters thought of letters and numbers as having social role, familial and non-familial, affective and power-based relationships between personified items within sequences. Additionally, more than half of the participants in the present study experienced graphemes as having human-like appearance, describing their age, facial features, body build, clothing and cultural origin. These social characteristics of graphemes have been previously mentioned in single case studies (Flournoy, 1893; Simner & Holenstein, 2007; Smilek et al, 2007), but this is first study to demonstrate this in a group of personifiers.

Social descriptions of graphemes provided by synaesthetes are not only culturally dependent, but are also shaped by their personal experience. Personalities of graphemes may sometimes alter, depending on the mood of a synaesthete. Moreover, the descriptions of graphemes' personalities sometimes include autobiographical experiences of synaesthetes, such as having similar personality to their friends or themselves. This supports a claim that personification synaesthesia could result from the misattribution of self-referential processing (Sobczak-Edmans and Sagiv, in press), at least in some cases.

The results obtained show that not only numbers and letters are frequently personified, but also weekdays and months. Among the personifiers tested here, nearly three quarters of them experienced the days of the week as having personality or gender. Most of them attributed gender to the weekdays and slightly less than three quarters thought of days as having personalities.

A similar effect was observed among those synaesthetes who personified months: gender was attributed to months more often than personality. The higher frequency in attribution of gender than personality to days and months may be related to the fact that in many languages these sequences (and other nouns) have grammatical genders. Could it be the case that synaesthetic gender is only a linguistic construct similar to grammatical gender? In our study, we tested not only native English speakers, but also two Italian native speakers. Italian has grammatical genders for nouns, including weekdays and months. The Italian speakers tested attributed to days of the week and months both personality and genders. Interestingly, their synaesthetic and grammatical genders differed in some cases. When asked about it in an interview, the tested synaesthetes explained that they know what the grammatical genders of days and months are, but at the same time, their synaesthetic gender is different, suggesting that the synaesthetic and grammatical genders of linguistic nouns are distinct phenomena that co-exist, even if their origin may be similar. For example, one of the tested Italian speakers noted that although Monday in Italian has a masculine gender, she 'experiences' it as a reflective, active and tidy woman. A similar disparity between grammatical and synaesthetic gender of some of the weekdays and months was observed in the second of tested Italian synaesthete. For example, she described the month of April as a proud woman and Sunday as a quiet girl. This phenomenon is analogous to '*alien colour effect*'. Alien colour effect occurs when in response to names of colours synaesthetes experience colours that are different from those that they named (Gray et al. 2006). Considering that similar effect occurs in sequence-personality synaesthesia for gender when synaesthetic and linguistic genders of sequences are in conflict, this phenomenon could be named '*alien gender effect*'.

Not only linguistic sequences are personified by synaesthetes, but also inanimate objects. About half of all personifiers reported personification of objects, which is about one third less than found by Amin et al. (2011). Synaesthetes attributed not only personalities and genders to objects, but personified also feelings and attitudes. Some of descriptions of personification of inanimate objects resemble animistic thought present in an early childhood, in which objects and other entities are imbued with life and consciousness. Similarly as in the developmental variant of personification (childhood animistic thought), in synaesthesia personified objects appear as alive, having not only distinctive personality traits but also attitudes, feelings and interactions with each other, as depicted in the description of the mushroom family (Sobczak-Edmans & Sagiv, in press) or the vacuum cleaners (Section 2.5.1.3).

2.7. Conclusion

In sum, the main conclusions are that:

- Personification in synaesthesia includes a variety of different inducers, which for the vast majority are linguistic (graphemes, weekdays, months, seasons, musical notes), but also non-linguistic, such as body parts and inanimate objects. Out of all linguistic sequences, numbers are likely to be the most frequently personified which may be linked with the early age of number acquisition. However, this hypothesis requires further investigation, considering lack of consistency with previous group study investigating the frequency of personified sequences.
- Co-occurring synaesthetic experiences include elaborate social and affective characteristics, such as personality traits, moods, human-like appearances, social roles and relationships. Concurrents are influenced not only by the physical qualities of graphemes but also by autobiographical experiences of synaesthetes. This means that the personality of a letter or number sometimes depends on the synaesthete’s previous experiences. For example, they may think of the personality of particular letter as similar to someone’s whose name starts with that particular letter. This implies that in synaesthetic personification social perceptions/concepts of the self and

others are (at least in some cases) attributed to graphemes, which provide support for the theoretical account explaining personification in synaesthesia as a result of misattribution of agency (Sobczak-Edmans and Sagiv, in press).

- Genders are more frequently attributed to days and months than personalities, which may be associated with the fact that in many languages these sequences have grammatical gender. However, synaesthetic and grammatical genders sometimes may be in conflict (‘*alien gender effect*’), which suggests that synaesthetic and grammatical genders of linguistic nouns are distinct phenomena.

CHAPTER 3 Neural correlates of grapheme personification

3.1 Introduction

In sequence-personality synaesthesia, linguistic sequences such as letters, numbers, weekdays and months have not only synaesthetic colour, but also rich and elaborate social characteristics, such as genders and personality traits, professions and relationships between them. For a synaesthete who personifies letters, the letter ‘X’ can be a young smart doctor, whereas ‘T’ can be a conservative, 20 year old male student who looks up to ‘K’ and ‘H’ (for more examples see Table 3.1). Since these biographical and social characteristics of letters and numbers are just like the descriptions used in everyday life to depict other people, is it possible that there are interactions between the mechanisms invovled in processing graphemes and general social cognition mechanisms for understanding others? Could it be the case that in sequence-personality synaesthesia, representations of mental states can be activated not only when interacting with or thinking about humans but also when perceiving non-human concepts such as grapheme? This would certainly be consistent with the extended version of the cross-activation theory of synaesthesia (Hubbard, Brang, and Ramachandran, 2011). The aim of this chapter is to evaluate these suggestions by examining the functional neuroanatomy of sequence-personality synaesthesia. To date, there has been only one case study which examined neural correlates of gender attribution to letters (Amin et al., 2011). AA is a synaesthete for whom some of the letters in alphabet have genders and others do not. She does not attribute personalities to letters, neither to numbers; therefore in the experimental design entailed a comparison of the responses to letters with gender and without gender. The synaesthetic gender of letters was irrelevant to the task (AA's task was to detect the presence of grapheme repetition) and it was therefore predicted that any changes in brain activation should result from automatic processing associated with synaesthetic personification. Increased activation in the precuneus was found when the participant viewed letters with genders. Based on this finding, Amin and her colleagues concluded that the precuneus activation in sequence-personality personification may be associated with the mental imagery thought to underlie grapheme personification; they also hypothesised that this activation may be related to the projection of one's own feelings onto graphemes.

Table 3.1 Example of letter inducer-concurrent associations in sequence-personality synaesthesia

A	f	Serious, dominating, tall. Looks after B	**N**	f	Tries to get along, middle age woman, M's wife
B	m	Playful, childish, chubby, A's child	**O**	f	Spiritual, in her twenties
C	f	Playful, short, D's child	**Q**	f	Middle aged woman
D	k	Serious, determined, tall, C's mother	**P**	m	Tall, formally dressed, scientific and highly educated
E	m	One of the boys, youthful, teen, F's brother	**R**	m	Boring, middle aged
F	m	Goal orientated, wears jeans and shirt, E's brother	**S**	m	Party animal, in his twenties, disco DJ
G	m	Charismatic and individual, wears suit from 70's	**T**	m	Student, looks up to H and K, 20 years old, conservative
H	m	Teacher, knowledgeable, old	**U**	m	Get's along with everyone, dancer
I	m	L's boyfriend, loner	**V**	m	Host, greater, in his 30's, neatly dressed

J	m	Cheerful, African decent, individual	**W**	m	Funny old man, uses cratches to walk
K	**-**	Wise old man, related to H	**X**	m	Young doctor, smart
L	f	More sociable than I. Girly, I's girlfriend	**Y**	f	Diva
M	m	Crowd pleaser, middle age man	**Z**	m	Story teller

Taking into account the extend of social and affective qualities of concurrents (see Chapter 2), in the current study we test a group of sequence-personality synaesthetes who endow graphemes not only with genders (as in AA's case), but often also personality, physical appearance, cognitive abilities, occupation, mental states, moods, attitudes, interests, inclinations, familial and non familial relationships, emotive and behavioural responses to other personified items (Simner and Holenstein, 2007; Amin et al., 2011; Sobczak-Edmans and Sagiv, in press). Comparison of social attributes to graphemes in the historical and contemporary literature and reports given by synaesthetes (for example, while describing the personality of 'Monday', one of tested synaesthetes noted that it '*is like a doctor I met in childhood*') suggest that even though synaesthesia is congenital, autobiographical experiences can influence the social characteristics attributed to graphemes (Simner and Holenstein, 2007; Sobczak-Edmans and Sagiv, in press). The social and autobiographical specificity of the features attributed to letters and numbers imply a possible functional overlap between the cognitive streams involved in the perception of graphemes and in processing information concerning other people.

To understand the mental states of others, people use different social-cognitive mechanisms. Simulation theory is currently one of the most investigated theoretical frameworks for understanding the minds of others (Buckner and Caroll, 2006; Goldman, 2008; Waytz and Mitchell, 2011). One of the theoretical approaches within simulation theory suggests that people use a self-projection mechanism to understand the mental states of others (in the absence of perceptual cues of another person's experience). This mechanism is also employed when judging another person's stable personality traits and dispositions. According to this theory, to understand the mental state of another person, one has to imagine (simulate) that mental state and after that assign (project) the re-created mental state to that person (Waytz and Mitchell, 2011). Self-projection is defined as a mechanism of switching perspectives between the immediate (self-centred) and an alternative one. In the context of understanding other minds, self-projection is understood as a mechanism that enables mental exploration of alternative perspectives by referencing them to one's own past experiences (Buckner and Caroll, 2006). The self-projection mechanism assumes that representations of one's own mental states that are stored in central nervous system can be activated by imagining one's own mental state or the mental state of another person. The crucial part of the process is to ascertain whether the mental state perceived in the other person is an observed state or a state imagined by the mind of the "perceiver", which requires understanding that the source of the mental state is in oneself and not in another, whether observed person or an imagined one. Hence it is necessary to correctly distinguish between the self and the other as the source of the simulated mental state. Otherwise, if an error occurs, it may lead to problems with attribution of the correct source of the mental state, and confusion between the creations of one's own mind and one's knowledge of other minds may occur. This may be the case in synaesthetic personification of linguistic and non-linguistic sequences.

The self-projection mechanism was investigated in neuroimaging studies of the general population with such testing paradigms as trait adjectives/statement judgment as to whether the trait or statement presented to the subject applies to the self or other (Saxe and Kanwisher, 2003; Saxe and Wexler, 2005; Saxe and Powell, 2006; Mitchell, 2008). Other studies looked at mental state attribution to randomly moving shapes or fictitious characters in cartoons (Castelli et al. 2000, 2002; Gallagher et al., 2000; Tavares, Lawrence and Barnard, 2008) and online games, which require simulation of another's person perspective (Gallagher et al., 2002; Cabe, K et al, 2001). Saxe and Kanwisher (2003) tested twenty five subjects using fMRI for the neural correlates of understanding minds of others, using theory of mind story judgment tasks. The mental inference stories were compared with mechanical inference stories and showed activations in regions of the default brain network, such as the precuneus and lateral parietal cortex. Tavares, Lawrence and Barnard (2008) used the animated shapes paradigm to investigate the functional neuroanatomy underlying the attribution of mental states to moving geometric shapes. They asked participants to focus their attention either on the spatial aspects of the moving shapes or on the social behaviour underlying the movement. Brain activity in response to social interactions between moving shapes also activated the default network regions – the lateral parietal cortex, posterior cingulated cortex and superior temporal sulcus. "Online" simulation of the mental states of others was tested by Gallagher and others (2002) by observing subjects playing a computerised version of the "stone, paper, scissors" game in the scanner. In the mentalising condition subjects believed that they played against the experimenter, and in the control condition, participants were let to believe that they were playing against the computer. But in fact, in both conditions, participants played against random sequences generated by computer. When the fMRI results of conditions for playing against the experimenter versus against computer were compared, activation of the anterior paracingulate cortex and right inferior frontal cortex was found.

Considering this body of research and other work into mentalising processes, Waytz and Mitchell (2011) argue that at the neural level this mechanism is processed by the regions of the brain's default network (Raichle et al., 2001) that include the posterior cingulate cortex (retrosplenial cortex), the precuneus, ventral and dorsal medial prefrontal cortex, the lateral temporal cortex, the inferior parietal lobule and the hippocampal formation. The regions of the human default network have been implicated in self-reflective processes together with imagery processes related to the self, as well as in recalling past experiences (Buckner, Andrews-Hanna, and Schacter, 2008). Besides the default network, the paralimbic regions implicated in processing internal states such as the insula may be crucial for processing self-reflective information in personification (Craig, 2009; Modinos, Ormel, and Aleman, 2009). Increased insula activation has been reported in many studies examining self-reference (Farrer and Frith, 2002; Fossati et al., 2004; Johnson et al., 2005; Kircher et al., 2000; Ruby and Decety, 2001; Takahashi et al., 2008) and its role in self-reflection has been emphasized by recent reviews and meta-analyses (Schmitz and Johnson, 2007; van der Meer et al., 2010).

3.2 Aims and hypotheses

The broad aim of the present study is to identify the neural correlates of grapheme personification using functional MRI in synaesthetes who attribute mental states not only to other people, but also to linguistic sequences and inanimate objects. It is assumed that automatic neural response in synaesthetes will be observed when presented with graphemes reported as having socially relevant characteristics (as was shown by Amin et al., 2011).

Could grapheme personification represent a kind of over-activation of mentalising processes co-occurs with misattribution of agency? It is hypothesized that the activations in response to graphemes in sequence-personality synaesthesia will overlap with the neural circuits underlying everyday mentalising. Specifically, I aim to establish whether involvement of the precuneus is a common occurrence in synaesthetes who personify graphemes (or was it peculiar to synaesthete AA; Amin et al., 2011)?

Finally, it is hypothesized that the activity in precuneus will increase with the increased intensity of reported grapheme personification, as suggested by Amin and her colleagues in their case study.

3.3 Method

3.3.1 Subjects

Five synaesthetes were recruited via advertisements on university campus and from the Synaesthesia Participants Database[5] who took part in the study for payment. Among the synaesthetes tested were 2 female and 3 male participants with a mean age of 28.4 years (SD = 4.16 years). Subjects reported no abnormal neurological condition, were right-handed and had normal or corrected vision. The study was approved by Brunel Ethics Committee and all participants provided written consent.

Variants of the inducers triggering genders and/or personality for tested subjects are described in Table 3.3. Four out of five participants reported that letters of the alphabet, numerals, days of the week, months of the year trigger experience of personalities and genders. One of the participants reported experiencing genders but not personalities for a few letters of alphabet and all numbers. Subjects stated that they have had these synaesthetic experiences as long as they can remember. In this study, following Amin et al. (2011) consistency scores were collected for sequence-personality synaesthesia and coloured graphemes synaesthesia as shown in Table 3.2.

[5] Synaesthesia Participants Database is a database of self-referred synaesthetes via synaesthesia research websites (www.syn.psy.ed.ac.uk; www.syn.sussex.ac.uk)

Table 3.2 Personification types and consistency scores of tested synaesthetes

Synaesthete	Sex	Type of personification	Gender consistency	Personality consistency	Colour consistency
CS	F	Gender only	100%	-	100%
GF	F	Gender + personality	85%	100%	100%
MF	M	Gender + personality	81%	88%	100%
SJ	M	Gender + personality	85%	73%	100%
OE	M	Gender + personality	85%	88%	100%
Mean	-	-	**87%**	**87%**	**100%**

Table 3.3 Summary of inducers triggering personality and gender among tested synaesthetes

Inducer	Concurrent	CS	GF	MF	SJ	OE
Letters	gender	x	x	x	x	x
	personality		x	x	x	x
Numerals	gender	x	x	x	x	x
	personality		x	x	x	x
Days	gender		x	x	x	x
	personality		x	x	x	x
Months	gender		x	x	x	x
	personality		x	x	x	x

3.3.2 Stimuli

Participants were presented with letters or numbers from the Roman alphabet. They also were presented with Hebrew letters, with which participants were unfamiliar and they attributed neither gender nor personality to them. A sample of these graphemes is as shown in Figure 3.1.

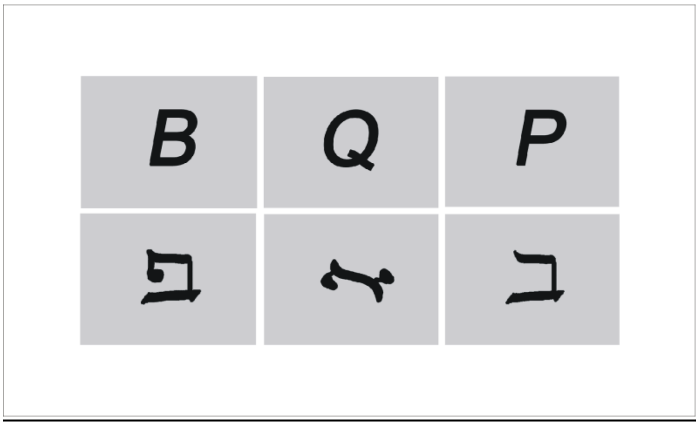

Figure 3.1 Example of the stimuli used in the experiment

All participants were presented with six different Roman letters or numerals and two Hebrew letters. These letters were previously rated by synaesthetes. Graphemes were written in black, in upper case and presented on a grey background. In the questionnaire completed by synaesthetes, they were asked to provide descriptions of the genders and personalities they associated with letters of alphabet and numbers and to rate the strength of these experiences. Synaesthetes indicated that some letters give more intensive experiences of personality traits and genders than others. Therefore, before going into the scanner, subjects were asked to rate the intensity of the perceived personification for each grapheme on a scale from 0 to 10. Graphemes rated as 0 were assigned to the group of non-personified graphemes; graphemes rated between 1 and 3 were designated weak personification, those rated between 4 and 6 designated medium personification and between rated from 7 and 10 were designated strong personification. Then graphemes chosen from each category were presented to participant while in the scanner. Participants were presented with two graphemes from each personification category. The set of graphemes used for each of the participants is shown in Table 3.4.

Table 3.4 Graphemes used in each experimental condition for each synaesthete

PARTICIPANT	STRONG PERSONIFICATION	MEDIUM PERSONIFICATION	WEAK PERSONIFICATION
CS	9, 1	4, 7	6,3
GF	E,A	V,J	G,W
MF	N,X	G,B	K,I
SJ	N,C	A,E	L,U
OE	Y,T	N,M	A,B

3.3.3 Experimental design

The experimental task employed a simple block design. Each experimental block with personified letters was 12 seconds long (6 repetition of letters presented for 1 second on and 1 second off). Each baseline block was 15 seconds long, to allow the haemodynamic response to recover. In the baseline blocks, participants were presented with fixation cross in appearing the middle of the screen. The experiment had four experimental conditions: Strong personification, medium personification, weak personification and non-personified graphemes.

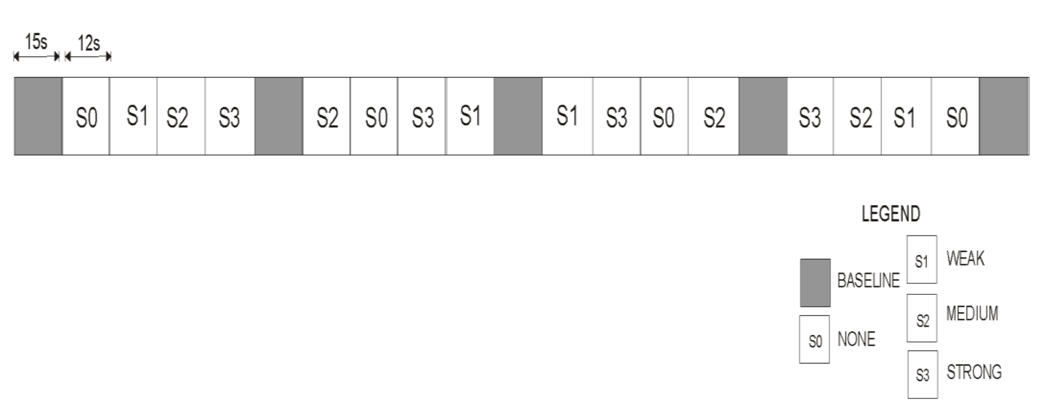

Figure 3.2 Schematic representation of experimental design. This pattern was repeated twice during the experiment. The baseline lasted for 15 seconds, followed by the experimental conditions, including: S0 (non-personified graphemes), S1 (weak personification), S2 (medium personification) and S3 (strong personification).

During the experimental task participants passively viewed pictures of personified letters and non-personified letters as shown in Figure 3.2. To maintain participants' attention, subjects were required to detect the presence of grapheme repetition and indicate it by pressing a button (one back task).

3.3.4 Imaging procedure

FMRI data was collected using a 3 Tesla Siemens Trio scanner. Firstly, the localising scans were performed. Then the experimental, functional images were acquired using a gradient-echo, echo-planar sequence (TR = 3s; TE = 33 ms; ip angle = 90; voxel size = 3*3*3 mm). Functional volumes were acquired continuously during each experimental run, which lasted about 6.5 min (8 blocks per condition of 12 seconds long). The functional run was followed by a high resolution T1-weighted structural scan. The Cogent 2000 toolbox for Matlab developed at the ICN[6] was used to project stimuli onto the screen, which participants saw via a mirror mounted above the head coil. The fMRI data was processed using SPM 8 (Wellcome Department of cognitive Neurology, London; http://www.fil.ion.ucl.ac.uk) with Matlab software (MathWorks, Natick, Massachusetts). Images were realigned to correct for head movement and transformed into a standard anatomical space based on the ICBM 152 brain template (Montreal Neurological Institute). Then, the normalised images were spatially smoothed (8 mm full-width-at-half-maximum [FWHM]) using a Gaussian kernel function.

[6] http://www.vislab.ucl.ac.uk/cogent.php

3.3.5 FMRI analysis

Two types of statistical analyses of data were performed based on the linear general model. In both analyses, trials were modelled using a canonical hemodynamic response function. Firstly, a conjunction analysis was conducted, in which whole-brain statistical maps were created. This was done by comparing the strong personification conditions with no personification condition. This analysis aimed to detect regions responsible for synaesthetic personification of graphemes.

Secondly, a parametric analysis with the personification intensity ratings as the modulation parameter was utilised. The aim of this analysis was to examine whether the activity of the precuneus increases as the personification of graphemes intensity became higher. In this analysis, we constructed the personification intensity regressor and assigned the values: 0, 1, 2, 3 to indicate strong personification trials, medium personification trials, weak personification trials and no personification trials respectively.

The analyses were performed individually for each participant. Then contrast images for each participant were utilised in a second-level analyses that employed the random-effects model (significance was assessed at the threshold of $p<0.001$, uncorrected) for parametric analysis and the fixed-effects model and significance was assessed at the threshold of $p<0.05$, FWE corrected.

3.4 FMRI results

3.4.1 Categorical analysis

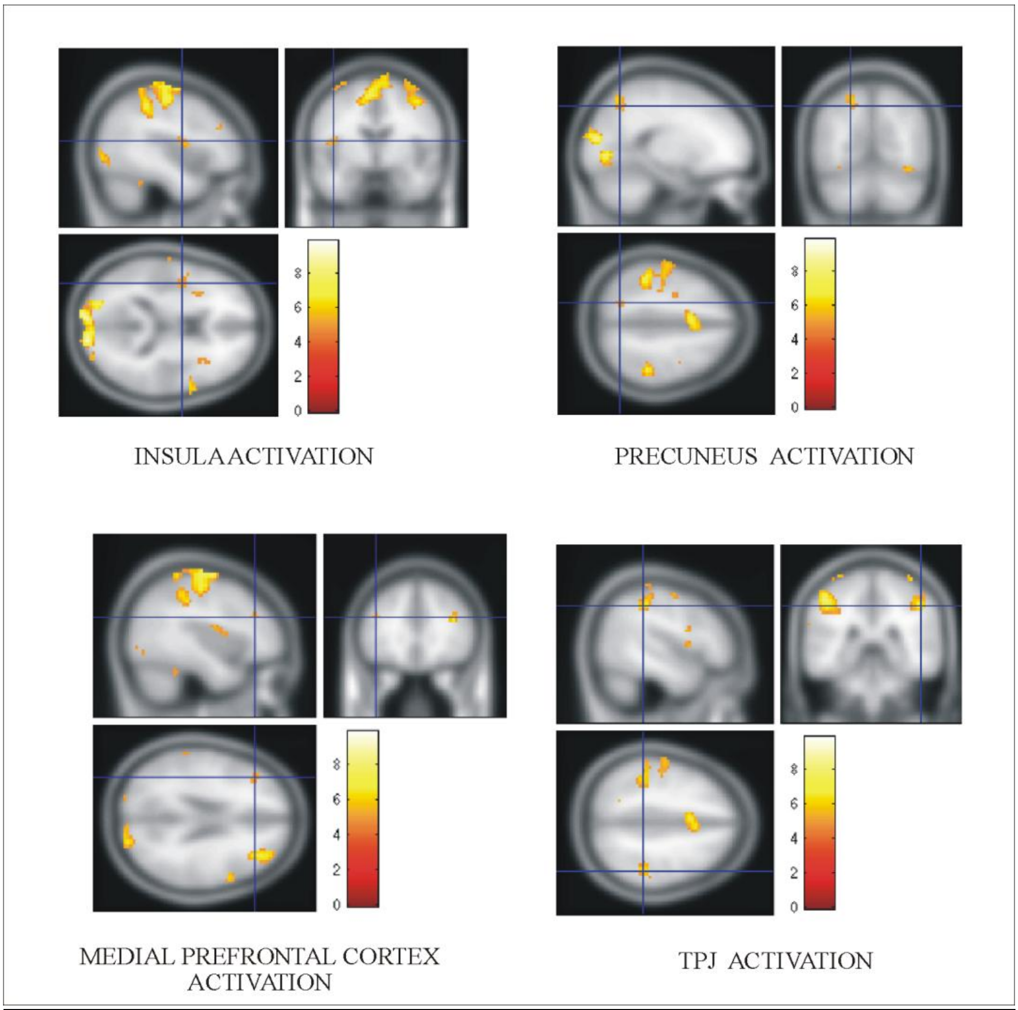

Figure 3.3 Brain regions with increased activation in response to all personified graphemes versus non-personified ones. Whole-brain, fixed-effects analyses ($p<0.05$, corrected) revealed increased activations for insula (top left), the precuneus (top right) and the medial prefrontal cortex (bottom left) and temporoparietal junction (bottom right).

In the whole-brain analysis, in the comparison of personified graphemes with no-personified graphemes we found significant clusters of activations in the mentalising network bilaterally, including: the precuneus, the insula, the medial prefrontal cortex and the right temporoparietal junction (Figure 3.3, Table 3.5).

We also observe the activation in the postcentral gyrus, the precentral gyrus, the lingual gyrus, the declive (a cerebellar region), cuneus, the inferior and middle occipital cortex. All activations are family-wise corrected at the threshold of p<0.05.

Table 3.5 Brain areas activated during personified letters conditions compared to non-personified letters condition (p<0.05; FWE corrected).

Anatomical Location	**Side**	**Cluster size**	**t-value**	**Coordinates**		
Precuneus	L	40	6	-21	-64	55
Precuneus	R	2	5.14	30	-70	28
Precuneus	R	4	4.95	27	-49	55
Precuneus	R	1	4.87	36	-43	55
Temporo-parietal junction	R	274	6.98	48	-37	43
Temporo-parietal junction	R	1	4.74	60	-40	16
Inferior parietal lobule	R	5	5.22	42	-46	58
Insula	L	32	5.49	-42	-4	13
Insula	L	12	5.19	-33	11	13
Medial prefrontal cortex	R	84	7.96	36	41	28
Medial prefrontal cortex	L	9	5.63	-39	32	25
Medial frontal gyrus	L	452	7.8	-6	-7	58
Inferior frontal gyrus	R	4	5.22	57	17	-5
Postcentral gyrus/TPJ	L	775	8.03	-45	-19	55
Postcentral gyrus	R	28	6.16	57	-19	55
Precentral gyrus/insula	R	184	6.39	60	5	16
Precentral gyrus	L	5	5.2	-54	11	-2
Precentral gyrus	L	1	4.78	-57	2	40
Cuneus	L	564	9.88	-9	-100	10
Culmen	L	41	5.79	-33	-49	-32
Culmen	R	7	5.1	9	-58	-8
Declive	R	71	6.18	39	-61	-17
Declive	L	1	4.72	-33	-64	-14
Inferior occipital gyrus	L	43	6.87	-45	-82	-2
Lingual gyrus	L	56	8.07	-21	-79	-2
Lingual gyrus	R	6	5.79	18	-82	-2
Lingual gyrus	R	1	4.82	36	-76	-5
Middle occipital gyrus	R	10	5.47	42	-82	1

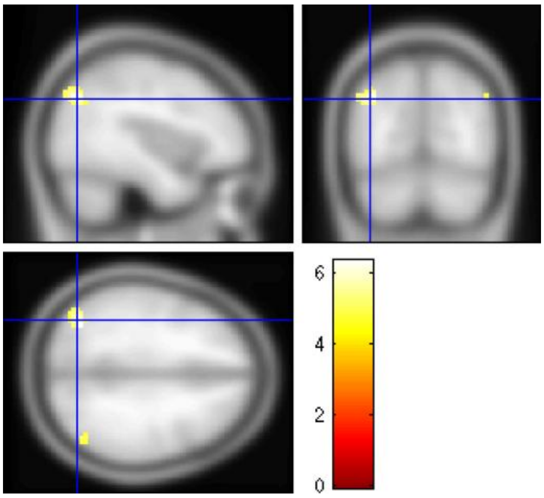

Figure 3.4 Brain regions with increased activation in response to the contrast comparing non-personified graphemes with personified ones (p<0.05, corrected)

In the opposite contrast, comparing brain activation in the response to non-personified graphemes versus personified graphemes, significant changes in brain activation were observed in the bilateral angular gyrus, the anterior cingulate, the inferior occipital gyrus and in the lingual gyrus as shown in Table 3.6 and Figure 3.4.

Table 3.6 Brain regions activated during non-personified letters conditions compared to all personified letters condition (p<0.05; FWE corrected)

Anatomical Location	Hemisphere	Cluster size	t-value	Coordinates		
Angular gyrus	L	64	6.35	-39	-70	34
Angular gyrus	R	12	5.37	48	-67	37
Anterior cingulate	L	11	5.33	-3	50	-5
Inferior occipital gyrus	L	3	5.23	-24	-97	-5
Lingual gyrus	R	2	4.96	24	-94	1

3.4.2 Parametric analysis

To determine whether activity in precuneus increases with the increased intensity of reported letter personification, the parametric modulation analyses were conducted next. The results of parametric analysis with the personification strength ratings as the modulation parameter are shown in Table 3.7 and Figure 3.5. The brain regions where activity increased when personification became stronger include the middle temporal gyrus and middle frontal gyrus, but not the precuneus.

With the decrease of the subjective intensities in experienced grapheme personification, no changes in the brain activity were observed.

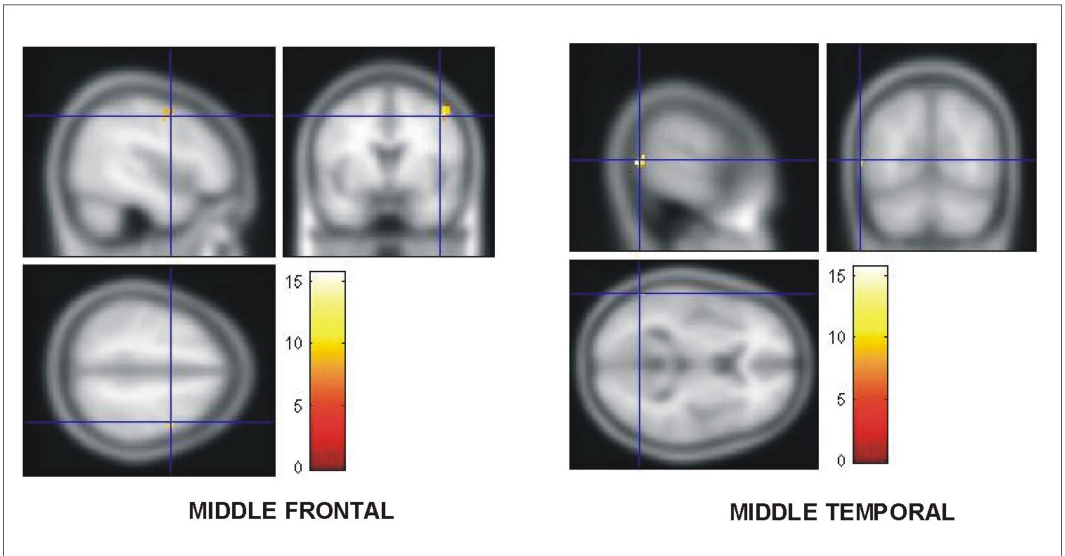

Figure 3.5 Changes in brain activity parametrically modulated by changes in intensity of grapheme personification reported by synaesthetes

Table 3.7 Brain regions parametrically modulated by the synaesthetic personification intensity (p<0.001; uncorrected; extent threshold: k=10 voxels)

Anatomical location	Side	Cluster size	t-value	Coordinates		
Middle frontal gyrus	R	19	15.72	45	2	49
Middle temporal gyrus	L	10	14.10 12.48	-60 -60	-67 -61	4 10

3.5. Discussion

In synaesthetic personification, letters and numbers are perceived as having such human qualities as personality traits, gender, profession, mental states and relationships between each other. Given the predominance of social characteristics attributed to graphemes and their similarity to everyday mentalising descriptions, this study aimed to assess whether the underlying neural mechanisms for personification in these synaesthetes are shared with general social cognition mechanisms for understanding other people. Specifically, the objective of the current study was to determine whether brain regions from the social cognition network - specifically, those implicated in the self-projection mechanism for understanding mental states of other people - are activated in synaesthetic personification. Since the subjects were not explicitly focusing their attention on the experienced synaesthetic personifications, but rather on the letter repetition task, these data also provide neural evidence of the reality and the involuntary nature of synaesthetic personification. Additionally, the study also investigated whether together with the increased intensity of reported grapheme personification, the activity in precuneus will increase, but the results obtained did not show that the strength of perceived personalities and genders of graphemes is associated with the activation of the precuneus, but instead with the changes in activation of the middle frontal and middle temporal gyros. However, in a group of five synaesthetes with grapheme personification, we found that brain areas associated with social cognition such as the precuneus, the temporoparietal junction, the insula and the prefrontal medial cortex were more active when synaesthetes saw personified graphemes in comparison with non-personified ones from the foreign alphabet, suggesting that in this group synaesthetic personification of graphemes is linked with universal mechanisms for social cognition. The precuneus, the temporoparietal junction and the prefrontal medial cortex have been previously identified as regions of default brain network and proposed by Waytz and Mitchell (2011) as mediating mentalising processes when other people are not physically present, namely when thinking about other people's mental states, predicting their moods and so on. Activation of the insula has been previously observed in mirror-touch synaesthesia (Blakemore et al., 2005), in which synaesthete C experienced touch on her own body while watching a video of person being touched. Based on this, it was suggested that this increase in the activation of insula is associated with the error of the misattribution of the source of the tactile sensation to the synaesthete's own body (Banissy, in press). It is possible that the increase in insula activation observed in the current study reflects an error in selecting the source of mental simulation of the personal characteristics, feelings and mental states that are attributed to graphemes. Additionally, insula activation has also been previously reported in grapheme-colour synaesthesia (e.g. Sperling, 2006). Given that all the tested synaesthetes in the current study experience grapheme-colour synaesthesia in addition to grapheme-personification synaesthesia, the observed activation in the insula could reflect the former. However, it should also be considered that studies examining brain function in grapheme-colour synaesthesia did not control for personification, therefore it is similarly possible that in that studies the observed activation of insula was induced by personification co-occurring with coloured graphemes.

Brain responses to non-personified graphemes were greater than to personified graphemes in the angular gyrus. It is possible that this effect is due to processing of spatial associations (number forms and alphabet form) that synaesthetes have greater ability to pay attention to when there is no personification to "distract" them.

In the study, it was predicted that increased intensity of grapheme personification will be associated with stronger activation of the precuneus. However, this effect was not observed in the precuneus, but instead in the middle frontal gyrus and middle temporal gyrus. Middle frontal cortex activation has been previously linked with self-related processing (Morita et al., 2008) and it is possible that in synaesthetic personification, self-related processing increases together with the subjectively perceived strength of grapheme personification. Changes in the middle temporal gyrus may reflect increased memory processing during self-projection in personification. This suggests that perception of strongly personified graphemes may involve retrieving more memory details from a synaesthete's personal past than perception of graphemes that are personified less strongly or not at all. The greater involvement of memory processes in strongly personified graphemes is reflected in phenomenological descriptions of these graphemes – they tend to have more elaborate and rich biographical descriptions than weakly personified graphemes, where descriptions may be limited to gender only.

The correspondence we observe between the social cognition network and personification in synaesthesia of graphemes is consistent with previous findings investigating personification of graphemes and inanimate objects (Amin et al., 2011; Sobczak, Sagiv and Williams, 2011). The social characteristics attributed to both graphemes and to objects in synaesthesia activate brain areas from the social network. Amin and colleagues (2011) tested a single synaesthete AA and found precuneus activation in response to personified graphemes when compared with non-personified ones, which is also the case in the current study. This confirms the importance of the precuneus in the implementation of personification in synaesthesia. In the case study of AA, her personification of letters was limited to the attribution of gender only, excluding other social characteristics. In the current study we also find increased activation in additional social brain regions (apart from the precuneus activation), which may be associated with the more elaborate personification features attributed to graphemes by participants.

A tentative explanation of these results might be that the changes observed in brain activation in response to personified graphemes (in areas involved in social cognition, self-reflective processes and autobiographical memory), are co-activated by the representations of graphemes resulting in the activation of self-related social processing that leads to subjective experiences of grapheme personification, including one’s own mental state representations, personality traits and other biographical experiences. These self-related mental contents are not recognised as one’s own, but rather they are projected onto graphemes and attributed to them. If this is true, the perceptual error occurs on the level of the selection of the source (agent) of mental states, personality traits and so on. This assumption is particularly relevant to the developmental explanation for personification in synaesthesia proposed by Sobczak-Edmans and Sagiv (in press) maintaining that personification may represent a universal human tendency to perceive the social reality using the self as a model (the roots of which are present in early childhood and manifests in animistic thought). Support for this interpretation comes from functional neuroimaging research and from neuropsychological studies. In social brain research, the insula, temporoparietal junction, the precuneus and medial prefrontal cortex have been implicated in mentalising, self-referential processing (Farrer and Frith, 2002; Fink et al., 1996; Fossati et al., 2004; Ruby and Decety, 2001; Takahashi et al., 2008), and in self-reflection (for review see Schmitz and Johnson, 2007; van der Meer et al., 2010). The medial prefrontal cortex is a crucial brain region for perceiving other people and understanding of the social aspects of other mental agents, such as other people and domesticated animals, but not inanimate objects (Mitchell et al., 2005).The insula is associated with processing involved in self-awareness. The increase in insula activation occurs during the rubber hand illusion, in which the participant experiences the artificial hand as their own (Tsakiris, 2008). This indicates the insula's importance in integrating information from diverse functional systems, including subjective emotions related to the body and emotional experiences (Craig, 2009; Kurth et al., 2010). Additionally, the temporo-parietal junction has been proposed to be a necessary brain structure for taking someone else's perspective, which was shown by, for example, Ruby and Decety (2004), who observed the increased activation in the temporo-parietal junction when comparing brain responses in subjects imagining how participants would feel in certain everyday social situations with imagining how another person would feel in similar situations. Moreover, Samson et al (2004) tested the capabilities for inferring mental states of others in patients with brain lesions in the left temporo-parietal junction and observed the impairment of these processes.

This cognitive capability was impaired in patients suggesting the necessity of the temporo-parietal junction for representing someone else's mental states. Furthermore, evidence from neuropsychology suggests that lesions of the right (and sometimes left) parietal cortex may produce misattributions of agency that itself sometimes involve animistic attributions. In particular, patients with parietal lesions are frequently characterised by delusional misidentifications of body parts. These patients think that their arm or leg does not belong to them and often attribute their limbs to other people - examiner, or their friend or family member. More importantly, some patients also attribute personalities to their limbs and give misidentified arms or legs nicknames such as "George", "Toby", "Silly Billy", "Floppy Joe" (Critchley 1955, p. 286), which has certain similarities with body parts personification in sequence-personality synaesthesia.

Although we provide supporting evidence for the conjecture that personification in the tested synaesthetes shares neural mechanisms with mentalising in general social cognition, the extent to which obtained results reflect the engagement of simulation processes and self-projection is unclear as we examine it only at the neural level. In sequence-personality synaesthesia, synaesthetes feel compelled to think of letters and numbers as if they were humans, but they know that this is not the case. A synaesthete can think that the letter 'B' is 'a playful chubby child' and be aware of distinction between 'real' experience and synaesthetic experience, but at the same time (s)he does attribute these qualities to the letter 'B'. However synaesthetes frequently remain unaware that social representations activated by graphemes reflect self-referential processes and autobiographical experiences. It is important to note that synaesthetes are not delusional: synaesthetic experiences of the social worlds of letters and numbers do not conflict with their understanding of the conventional meaning of graphemes and their linguistic/mathematical function; however it may ease or hinder it. This is analogous to colour-grapheme synaesthesia, in which synaesthetes see letters in both, printed and synaesthetic colour at the same time. Indeed, in grapheme personification, synaesthetes maintain conventional meanings of graphemes and attributed to them human-like qualities simultaneously.

This study raises a number of questions for future research. First of all, having gained supporting evidence for the involvement of the social brain regions in the implementation of synaesthetic personification in the tested group, it is important to find out whether this effect applies to the population of sequence-personality synaesthetes. Secondly, an intriguing avenue for future systematic investigation would be to explore the structural brain specificity of synaesthetes who personify graphemes, since the scope of the present study was limited only to functional neuroanatomy. Nevertheless, the current study is the first to provide insights into functional neuroanatomy for personification of graphemes showing that brain regions processing synaesthetic personification and mentalising in general social cognition partially overlap. While the initial findings are promising, it is important to remember that this is (apart from AA's case study) the only study examining neural correlates of grapheme personification and has a limited number of participants (five). For this reason future studies involving testing more synaesthetes for neural mechanisms of grapheme personification are necessary.

3.6 Conclusions

The present study examined the functional neuroanatomy of grapheme personification in synaesthesia and showed that:

1) Given that the synaesthetes' task was to detect letter repetition and grapheme personification which was task-irrelevant during the imaging procedure, the observed neural differences in response to personified and non-personified graphemes provide indirect evidence for the reality of synaesthetic experience.
2) The underlying mechanism for personification in synaesthesia and universal mechanisms for understanding other minds may be shared at the neural level, since the social brain areas such as precuneus, right temporoparietal junction, and insula are activated in response to personified but not non-personified graphemes.
3) Consequently, it is likely that the self-projection mechanism is activated when synaesthetes think about graphemes or perceive them. If this is the case, then misidentification of the source of the mental state and the personality traits perceived may underlie the attribution of human-like characteristics observed in sequence-personality synaesthesia.
4) The intensity of the subjectively perceived experienced is not associated with the strength of precuneus activation. However, it is associated with activations in the right middle frontal and the left middle temporal gyrus.

Chapter 4 Behavioural correlates of object personification

4.1 Introduction

Synaesthetes personify not only graphemes, but also attribute personalities and genders to inanimate objects, including fruit and vegetables, computers, household objects, body parts and other items as previously described in Chapters 1 and 2. For example, a synaesthete may think of a scarf as being a reliable, focused and good natured female, whereas a pair of trousers may be a young and childish, but cooperative man (for more examples of inanimate objects personification see Table 4.1). This phenomenon has been referred to in the synaesthesia literature as personification of inanimate objects (Amin et al., 2011; Sobczak-Edmans and Sagiv, in press) or object-personality synaesthesia (Smilek et al, 2007). Similarly to grapheme personification and other variants of synaesthesia, inanimate objects are reported to be personified on a daily basis from an early childhood (Amin et al., 2011; Smilek et al, 2007).

Table 4.1 An example of gender, personality traits and feelings attributions to various categories of inanimate objects (GF)

Object Category	m/f	Personified Object	Personality Traits & Feelings
Body Parts	f	skin	Sensitive, moody
	m	brain	My brain (which I call “Brain”) is completely independent from me, like another person living in my head. He is cynical, attentive, curious, and sarcastic. At the same time, though, he is also wise and caring toward me. He is honest, and tries to warn me anytime

			he can. Unfortunately, I don't always listen to him.
	m	feet	My feet are ugly – but totally unaware of that. In particular, they look different from each other. They are curious, funny, childish and shy. They don't like to be looked at by other people, but at the same time they can be very gregarious when they find someone they trust (i.e. someone that will not mind them being so asymmetric). Furthermore, they are clumsy: they are so busy looking around when I walk that make me fall all the time.
	f	Hands	Left hand is more feminine and creative than right hand. Right hand is like a peasant, I write with it, so it is practical one (never would wear rings on the right one).
	m	Fingers	Fingers are supportive, not very curious, and obedient. A thumb is older than the rest of them, and the little finger is the youngest – is childish and playful. The middle finger and the ring finger are brothers – the ring finger is romantic, whereas the middle one is practical and responsible. Forefinger is younger than middle and ring fingers, is more cheerful and intellectual than others. I would have different reactions depending on which finger got hurt – if it was thumb I will curse, but if it was the little one I will behave as a mother and say: ‘oh cutie’
		teeth	We have only functional relationship, sometimes they betray me, for example they plan to decay.
Clothes	f	scarf	Reliable, focused, good-natured, calm
	m	my light brown trousers	My trousers are young, childish and quite vain. They don't care about what's going on, unless it is something serious – in which care they shut up and stay at their place, without being as smiley as usual. Despite their young age, they are very cooperative whenever I need them to behave and let me climb stairs or hike hills.
Other everyday objects	m	Swiss knife	My Swiss knife is steady, serious and cooperative. He is helpful, reliable, focused, calm, and trustworthy. He doesn't complaint if I don't use him for a while or if I forget him somewhere. He's not vindictive and he

			never lets me down. He's like a perfect soldier, which can take initiative when needed but also carefully obey orders.
	m	My ipod	Punctual, reliable, cheerful, happy
	f	Bed	Reliable, stable, cooperative
	f	Bike	Cheerful, happy, reliable
Buildings	f	my house	My house is like an old, patient – but at times tired and absent-minded – lady. She takes care of me as much as she can. She tried to shelter me, but her old body cannot keep the cold outside or prevent wind and rain from falling in during the rainy season.
		university building	Not very friendly
		library	Very snobbish, has a lot of knowledge but does not interact with it
Plants	f	my plant	I'm not sure about the name, but I call her “Priscilla”. She is good-natured, humorous, vain, moody
	m	broccoli	Trustworthy, cheerful, happy
Simple Shapes	f	circle	Effective, consistent, professional, happy
	m	trapezium	Trapezium is a middle-age, steady, moustached shape. He is patient and humble, and well tolerates the vanity of the other shapes (e.g. triangles, rounds, squares). He knows he's not the most popular among students, but does not complaint about it. Narrow-minded.
		square	Similar to triangle, cool guy, handsome but quieter and more friendly
	m	equilateral triangle	Handsome, smart, young
	m	acute-angled triangle	Older woman, not ugly, smart
	fm	rectangle	Younger, more naïve than trapezium

Previous investigations into personification in synaesthesia focussed mostly on graphemes (for a review of these studies, see Section 1.3). To date the personification of inanimate objects has been examined empirically in only one study conducted by Smilek et al (2007). In this study, researchers aimed to provide empirical evidence of the reality of object–personality associations by studying the consistency of object-personality pairings in TE, a 17 year old female synaesthete experiencing personification of inanimate object. The first experiment consisted of initial test, intervening session and retest and included two types of images: object displays and test displays. Firstly, TE and control participants were presented with 32 images containing familiar objects (letter and number), or a novel object (shapes described as fribbles, geerbels and geons) and were asked to describe the personalities of those objects. Control participants were informed additionally about TE's experiences and presented with an example of her experiences, which they were expected to mimic. The intervening session, in which the testing procedure was repeated with new set of familiar and unfamiliar objects, was intended to disrupt memory based on the assumption that additional descriptions retroactively interfered with associations made in the initial testing session. In the re-test session, participants were shown images of the objects shown in the initial testing session together with four personality descriptions, unique for each subject. In each trial, one or two of the personality descriptions were previously given by subjects in the initial testing session. The study provided evidence that personality-object pairings for both familiar and novel objects are highly consistent over time in case of TE (91% consistency for familiar objects and 88% for non-familiar objects), but not in case of controls, whose average consistency score was 50%.

In the second experiment carried out by Smilek et al (2007) an eye tracker was used to test how the personalities attributed (positive versus negative) influenced TE's overt behaviour. TE claimed that she disliked seeing objects with negative personalities, but once she looks at them it is difficult for her to disengage her attention from these objects. For this reason, in the study the eye movements of TE's and 6 controls were monitored during free viewing of displays containing 12 graphemes rated by TE as either liked or disliked. Smilek and colleagues (2007) established that TE fixated more frequently on positive than negative graphemes, but the duration of her fixations was longer for negative than positive graphemes. This effect was not observed in non-synaesthetes. Therefore, besides providing evidence for the reality of personification of objects, Smilek et al (2007) showed empirically that the personification in synaesthesia is not limited to graphemes only and also includes inanimate objects. Although the researchers in the study described above noted that TE reports that personification of inanimate objects is involuntary, there is limited evidence to support it.

Personification of inanimate objects is present not only in synaesthesia, but also can be found in the general population, however more frequently among non-synaesthetic children than non-synaesthetic adults. Accordingly to Piaget (1929) children think of nearly all surrounding them entities as having human-like qualities, but the extent and strength of this tendency decreases with the age, although it still remains present among adults. People in everyday situations tend to personify non-randomly moving shapes (Heider and Simmel, 1944), computers (Nass et al., 1995), pets and gadgets (Epley et al., 2008), but also nationalities (e.g., mother Russia for Russia, Uncle Sam and Columbia for United States).

Personification occurs in metaphors, myths and religion (Guthrie, 1993). An interesting example of personification among non-synaesthetic adult is the propensity to personify body parts (Cornog, 1986; Ernster, 1975). For example, among adults tested by Martha Cornog (1986), sexual organs were named ‘Little Willy’, ‘Little Guy’ (designating male sexual organ) and ‘Little Joanie’, ‘Miss Muff’, ‘Myra and Myrtle’ (designating female sexual organs). Interestingly, some of the names given to sexual organs were variations of ‘owner’s’ names, such as in case of ‘Litle Willy’, where the owner’s name was Billy. Other names attributed to sexual organs include other unrelated human names (‘Myra and Myrtle’) or human designation (‘Guy’), but also variations of other words, such as in case of ‘Miss Muff’ (Cornog, 1986). Not only sexual body parts, but also sexually related body functions are personified, such as menstruation, which is frequently personified. Virginia Ernster (1975) conducted a study of American menstrual expression and found that personification designating menstruation can be found among various categories. The personification of menstruation often included references to a female visiting relative (e.g. ‘Aunt Sylvia is visiting me’, ‘Granny’s visit’, ‘my aunt from Redwood City’, etc.) or references to a male (‘Charlie just came to the door’, ‘Herbie is over’, ‘George monthly’, etc.). In the non-academic literature one can find examples of personification not only of sexual organs, but also personifications of different body parts. For example, f ingers that are commonly known by their names include traces of personification. For example, the ring finger in Polish is called the warm-hearted finger. Additionally, personification can be found in disorders, such as alien hand syndrome or Alzheimer’s disease (Zaitchik and Solomon, 2008). In alien hand syndrome patients do not recognise their own arms as belonging to them and report their involuntary movements. They also give their ‘alien hands’ names (Critchley, 1955), attributing to them intentions, thoughts and feelings.

Personification of body parts is also observed in synaesthesia. However, personifications reported by synaesthetes appear to be imbued with rich and elaborate human-like qualities (e.g. mental states, feelings, moods, etc.) that interact and have relationships within each other, whereas non-synaesthetic personification of body parts is much less elaborate and often limited to giving them human-like names (for main differences between synaesthetic and non-synaesthetic personification of inanimate objects see Table 4.2).

Table 4.2 Comparison of synaesthetic and non-synaesthetic personification

	SYNAESTHETIC PERSONIFICATION	**NON-SYNAESTHETIC PERSONIFICATION**
Types of personified objects	Inanimate objects; sequences (Amin et al., 2011)	Inanimate and animate objects; specific patterns of motion (Epley et al., 2008; Morewedg et al., 2007)
Type of description	Rich and elaborate descriptions (Smilek, 2007; Simner, Gartner and Taylor, 2011)	Short descriptions (Smilek, 2007; Simner, Gartner and Taylor, 2011)
Consistency	Stable over time (Smilek, 2007; Simner, Gartner and Taylor, 2011)	Tend to change over time (Smilek, 2007; Simner, Gartner and Taylor, 2011)

Given that personification is also commonly observed in general population, why should the personification of inanimate objects be considered a type of synaesthesia? As was previously established in synaesthesia research, cross-domain pairings that are specific for various types of synaesthesia are also present in the general population (Sagiv and Ward, 2006). For example, similarly as in colour-sound synaesthesia in which synaesthetes associate sounds with colours, non-synaesthetes associate high pitch sounds with bright colours and low pitch sounds with dark colours (Ward, Huckstep, and Tsakanikos, 2006). However, the observed cross-domain correspondences in non-synaesthetes do not fall under the definitional criteria of synaesthesia, broadly understood (e.g. Day, 2005; Rich and Mattingley, 2002). Broad definitions of synaesthesia require cross-domain pairings to be consistent over time, involuntary, automatic and idiosyncratic, which should be demonstrated by objective behavioural and/or physiological correlates that are not observed in the general population. Thereupon, it is necessary to determine if synaesthetic and non-synaesthetic personification of inanimate objects differ by comparing the cognitive processes underlying these phenomena. Limited information can be found in the synaesthesia literature on this question in relation to personification of inanimate objects. Smilek et al (2007) showed that synaesthetic personification of inanimate objects is more consistent over time than non-synaesthetic personification and that the synaesthetic descriptions of personifications are richer and more elaborated than in the general population. The personification of inanimate objects in synaesthesia sometimes co-occurs with a strong emotional component (Smilek et al., 2007; Sobczak-Edmans and Sagiv, in press), which can be illustrated with an anecdotal report. One of the synaesthetes tested in this study reported a past experience, in which she presented a very strong affective reaction - became sad and started crying loudly - after her mother made mushroom soup adding the ‘mushroom family’ (as personified by her) she was looking after when they were growing in a tray. Smilek et al (2007) also suggested that synaesthetic personification of inanimate objects is automatic and involuntary, however this was inferred from subjective synaesthetic reports and objective evidence to support this claim was limited.

4.2 Aim and hypotheses

The purpose of this study is twofold. Firstly, it aims to investigate empirically the involuntary character of object-personification synaesthesia, since to date there have been only one case study published confirming the lack of firm attentional control of inanimate object personification. The second aim of this study is to establish whether the same cognitive mechanisms underlie personification of inanimate objects in synaesthesia and in the general population. To test this, a behavioural Stroop-like paradigm was used in the experimental design. Stroop reaction time paradigms consist of tasks in which information processed in one cognitive dimension interfere with information processing in another dimension, for example, a subject asked to report the colours of words presented to them will give less accurate responses when the word presented is the name of a colour different from the colour in which the word is rendered (Stroop, 1935). In synaesthesia, the most frequently used variation of the Stroop paradigm manipulates the congruency of the synaesthetic pairings of inducer and concurrent. This paradigm was previously used in several investigations into synaesthesia, including synaesthetic personification of graphemes. In synaesthetic personification research using variations of Stroop-paradigm, it was shown that when synaesthetes who assign genders to letters are presented with faces preceded by a letter with congruent versus incongruent gender, they exhibit significantly slower reaction times than when responding to incongruent trials (Amin et al., 2011).

Since the Stroop effect is widely considered to be the most effective tool available for measurement of automatic processing (Smilek et al., 2001; Mattingley, Rich, Yelland, and Bradshaw, 2001), a variation of the Stroop paradigm is employed in the current study to test for automaticity of inanimate object personification in synaesthetes and in the general population. In order to answer the question whether or not personification of objects relies on voluntary processing or lacks firm attentional control, the present study examines whether the 'mood' of objects induces a Stroop effect in synaesthetic and non-synaesthetic subjects. This study differs from the previous investigation using Stroop-like paradigm into involuntary character of synaesthetic personification (Amin et al., 2011; Simner and Holenstein, 2007) in two ways. First of all, it examines different type of inducers – the previous investigations focused entirely on graphemes, whereas the current study examines personification of inanimate objects. Secondly, the current research involves inducing personification of objects by manipulating the setting in which objects are presented. The previous investigations into grapheme personification tested synaesthetic pairings between grapheme and gender which synaesthetes had experienced as co-occurring for a long time, in many cases as long as they can remember.

4.3 Method

4.3.1 Participants

Participants who took part in the experiment included synaesthetes and a control group. Five synaesthetes were tested (3 male, 2 female) who all attribute human-like qualities to objects. All of them also personify graphemes and report having grapheme-colour synaesthesia. Synaesthetic subjects were aged between 23 and

33 years old with the mean group age of 26.8 (SD=5.6) and all were enrolled as students at university.

The control group[7] included 44 participants that were drawn from a student participants pool (mean age: 19.9 years, SD = 3.1). Among them were 39 female and 5 male participants. Before undergoing the testing procedure, participants were screened for synaesthesia, to ensure that no participants in a control group had synaesthesia. Participants who gave any type of answers indicating synaesthesia were excluded from further testing in this experiment. All of the subjects had normal or corrected to normal vision and all gave written consent to participate in the study.

4.3.2 Stimuli and procedure

Stimuli used in the experiment consisted of images depicting household objects and images showing happy and sad facial expressions. Images of male and female faces with happy and sad facial expressions were created using an online application[8].

Images for presentation were created in two categories: those containing grouped objects and those containing 'lonely' objects. In the grouped objects condition participants were presented with images of a few household objects placed next to each other in a line (see Figure 4.2). In the 'lonely' objects condition, one object was placed on one side of the display, separated from the remaining of objects.

[7] The author is grateful to Ms Grace Wilkins for her help in collecting the data

[8] The online application used for creating cartoon faces can be found on the following website: http://www.magixl.com (Date last retrieved 29/09/2012).

This spatial separation was meant to induce personification of the separated objects, similarly as in a social situation where one person is separated from the others and feels lonely and isolated. The rationale behind using the ‘lonely’ objects paradigm for inducing personification in synaesthetes who personify inanimate objects on an everyday basis, comes from synaesthetes’ anecdotal subjective reports (in which they often described ‘feeling sorry’ for the objects that were left alone for one reason or another). The images of grouped and socially excluded objects were used in the current experiment were the same as used in the neuroimaging study (for details see Chapter 5).

During the experimental procedure, participants were seated in front of a computer running E-Prime software (Psychological Software Toolbox, 2002) at a distance of 50 cm away from a computer screen. The images with objects and faces were presented centrally. The subjects’ task was to press ‘Z’ whenever they saw a sad target face or ‘M’ whenever they saw a happy face. The task was exactly the same for both groups. The experiment consisted of 128 experimental trials and 8 practice trials. Half of all trials were incongruent and half congruent. In the congruent condition the ‘happy face’ followed a prime of ‘grouped objects’, whereas in the incongruent condition, the ‘happy face’ was presented after a ‘socially excluded object’ prime. Analogous trials were presented using images of sad facial expressions.

During each trial a fixation cross was presented for 400 ms, followed by the grouped object’ prime for 250ms and finally by a target face appeared on the screen until a response was made or for maximum 3000 ms (see Figure 4.1). The target face had either a happy expression or a sad expression.

Figure 4.1 Trial structure used in the study of personification of inanimate objects

Figure 4.2 Examples of images used in the study displaying 'lonely' objects (top) and 'grouped' objects (bottom)

A similar Stroop-like paradigm to the one employed in the current study, was used in testing synaesthetes with grapheme-gender personification (Amin et al., 2011):

The tested participants were presented with a fixation cross, a prime (letter with synaesthetic gender) and a target face. However, their task was different than in the present study – instead of determining the ‘mood’ of the face their task was to decide on the gender of the face. Furthermore, a different type of prime was used in the study of Amin et al. (2011) who used well established synaesthetic grapheme-gender pairings (pairings which synaesthetes reported experiencing as long as they can remember). In the current study, priming images designed to induce personification during the experimental procedure were in fact novel stimuli for all participants.

4.4 Results

4.4.1 Comparison of differences between mean results in the congruent and incongruent trials in personification of inanimate objects

Before data was analysed, all errors (incorrect answers about facial expression displayed on an image) and outliers (scores that were higher or lower than 3SD from the mean) were excluded. The resultant mean values of reaction times in congruent and incongruent conditions in synaesthetes and control group are shown in Figure 4.3.

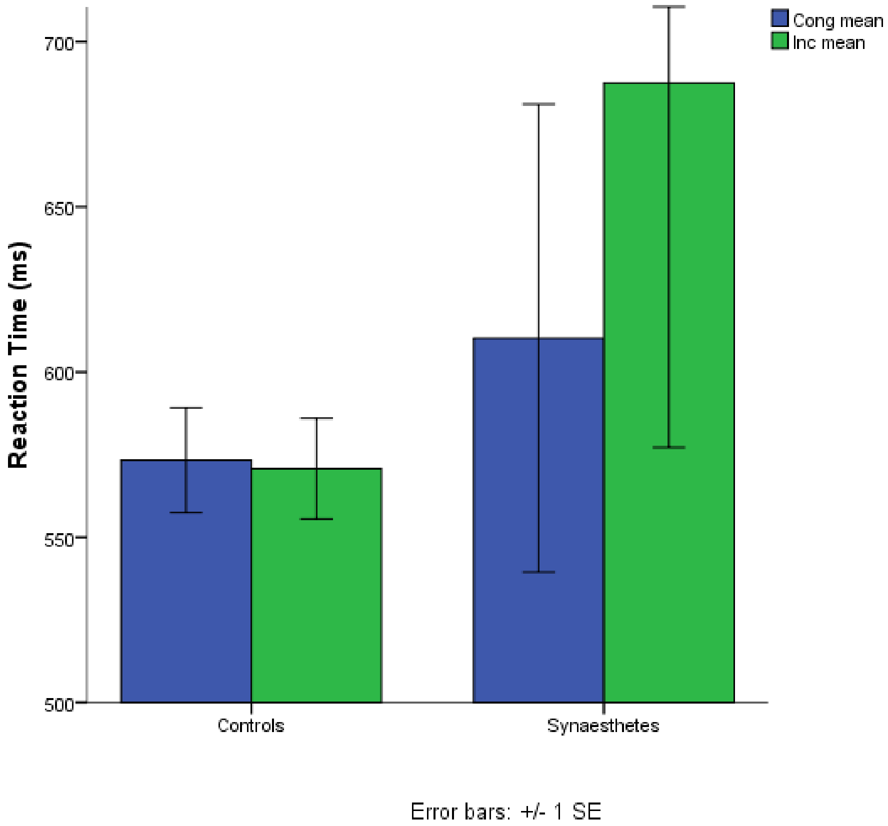

Figure 4.3 Mean reaction times in milliseconds for congruent and incongruent trials in both groups – synaesthetes and controls

Congruent and incongruent mean reaction times in the control group were analysed using a repeated measures t-test, which showed that on average, participants did not perform significantly better with the congruent condition (M = 573.29, SE = 15.85) than with the incongruent condition (M = 570.76, SE = 15.24): $t(43) = 0.56$, n.s.

In order to compare the difference between mean reaction times in congruent and incongruent trials in the group of synaesthetes, a nonparametric Wilcoxon test was employed for the reason that the group had only five subjects. It was found that on average, synaesthetes performed significantly faster in the tests with congruent (M

= 610, *SE* = 70.76) condition than in the tests with incongruent condition (*M* = 687.4, *SE* = 110.27): $z = 2.02$, $p < 0.05$.

4.4.2 Analysis of interaction effect between groups and congruency effect

In order to compare directly the reaction time congruity effect in synaesthetes and controls, a two-way mixed analysis of variance (ANOVA) test with congruency as a within-subject factor (congruent/incongruent) and group as a between-subject factor was carried out. The results of the Stroop paradigm for personification of inanimate objects for both groups (means shown in Figure 4.3) were entered into the analysis.

A two-way mixed analysis of variance revealed a significant main effect of Congruency, $F(1, 47) = 15.2$, $p<0.001$, but the main effect of Group did not approached significance, $F(1, 47) = 2.04$, n.s. This means that synaesthetes and non-synaesthetes do not differ in their average reaction times, but all of them on average performed slower on incongruent than congruent trials. ANOVA analysis also revealed significant interaction between Congruency and Group, $F(1, 47) = 17.3$, $p < 0.001$. The interaction effect shows that synaesthetes performed faster on congruent trials (*M* = 610.00, *SE* = 70.76) in comparison with incongruent ones (*M* = 687.40, *SE* = 110.27), whereas the control group was not affected by this factor, since their congruent (*M* = 573.29, *SE* = 15.85) and incongruent (*M* = 570.76, *SE* = 15.24) mean scores were similar (see Figure 4.3). I.e., the magnitude of the congruity effect is larger in synaesthetes.

This suggests that the moods synaesthetes associate with objects produce reliable interference with subsequent mood judgments, even when the objects remain task-irrelevant. These results provide evidence that the attribution of human-like qualities, such as an object's emotion is involuntary in synaesthetes who personify inanimate objects. This effect is present in all five synaesthetic participants whose mean RT differences range from 22 to 253 ms).

4.5 Discussion

The current study was designed to examine whether the processes underlying personification of inanimate objects in synaesthetes and non-synaesthetes are automatic or voluntary. This was tested using a specially designed variant of a Stroop paradigm with images of faces and inanimate objects.

The results obtained show that synaesthetes were slower in responding to incongruent stimuli than to congruent stimuli. This difference was not found in the non-synaesthetic group. This is consistent with the idea that there are qualitatively different processes underlying synaesthetic and non-synaesthetic personification of inanimate objects. People without synaesthesia sometimes do think of cars, computers and other objects as endowed with life, often call them names and attribute to them to human-like mental characteristics (e.g. Benfield et al., 2007), but it appears that non-synaesthetic personification of static objects is more voluntary and not automatic as in synaesthetic personification of inanimate objects, since the interference effect was observed only in synaesthetes and not in the controls.

Support for this interpretation comes from the results of previous studies examining the automaticity of personification of graphemes (Simner and

Holenstein, 2007; Amin et al., 2011; Simner). Amin et al. (2011) conducted an analogous Stroop-like paradigm to the one used in the current study to examine the automaticity of gender-grapheme associations. The researchers presented to synaesthetes and non-synaesthetes a target face preceded by a letter prime and the experimental task was to determine the gender of face presented. In this study, synaesthetes were found to have significantly slower average reaction times in incongruent trials compared with congruent trials and this effect was not observed in non-synaesthetes, a result which is consistent with the results of the current study. Similarly, results consistent with those of the current study were obtained in the experiment by Simner and Holenstein (2007) which assessed the involuntary character of letter-gender pairings. The authors presented a synaesthete AP with female and male names, designed in such a way that the synaesthetic gender of the first letter of the English names used was congruent or incongruent with the semantic gender of the words. Simner and Holenstein (2007) found that reactions times were faster in congruent than in incongruent trials, suggesting that automatic processing underlies the personification of graphemes in synaesthesia. This difference was not found in the general population.

Taken together, the previous studies in personification provide converging evidence that synaesthetic gender-grapheme pairings are involuntary and automatic, highlighting this as one of the traits defining synaesthesia and differentiating synaesthetic and non-synaesthetic personifications of graphemes. Consistent with this are the findings obtained in the current study. Synaesthetic personification of inanimate objects, similarly as personification of graphemes, is automatic and involuntary in a wider range of circumstances than those observed in the general population. By showing the involuntary character of object-personality sensations, this study provides new evidence for the reality of inanimate objects personification. Up to date, the empirical support for reality of inanimate object personification synaesthesia was limited to synaesthetic reports and the consistency over time of personality-inanimate objects pairings (Smilek et al., 2007), with limited empirical evidence to support the reports that these sensations are involuntary and automatic. The results of the current study, considered together with the previous findings provide objective evidence that personification of inanimate objects is a variant of synaesthesia, since it is automatic, idiosyncratic and relatively consistent over the time.

Although the results of the current study support the claim that synaesthetic personification of inanimate objects is involuntary and automatic, several limitations of the study need to be acknowledged. Firstly, this is the first empirical investigation into automaticity of inanimate objects personification with limited sample size (five synaesthetes were tested), therefore future studies on this topic should be carried out. Secondly, one plausible possibility is that non-synaesthetic personification of inanimate objects is automatic, but weaker than in synaesthesia or arises in a more restricted set of circumstances, and the paradigm used in the study may not be sensitive enough for the non-synaesthetic population. Future studies could examine this using different paradigm, such as, for example, a paradigm that included inanimate objects or body parts chosen by tested participants themselves, similarly as in the alternative version of the paradigm used for gender-grapheme attributions in the study of Amin and colleagues (2011). A further important issue worth attention is that this study does not examine the interactions between images of inanimate objects and the names of those objects. This is an interesting question for the future studies, given that personification of inanimate objects and personification of graphemes often tend to co-occur. Lastly, the current study did not examine the relationship between synaesthetic gender of objects and gender of the target face, since focus of investigations was on the ‘mood’ of presented objects and not their synaesthetic gender. A future extension of the current study should control not only for the objects’ ‘mood’, but also their synaesthetic gender.

4.6 Conclusion

In this chapter, it was examined whether personification of inanimate object in synaesthesia is involuntary and automatic as observed in other variants of synaesthesia. The results obtained with a Stroop-like paradigm show that only synaesthetes displayed the behavioural priming effect in which ‘lonely’ primed sad rather than happy facial expressions. This effect was not observed in non-synaesthetes. This finding provide converging evidence that personification of inanimate objects is a genuine type of synaesthesia and is consistent with the fact that synaesthetes personified from static images whereas controls did not.

Chapter 5 Neural correlates of object personification in synaesthesia

5.1 Introduction

Having established some of the behavioural correlates of synaesthetic personification of inanimate objects (Chapter 4), this chapter aims to examine the neural correlates of this phenomenon. As described in the previous chapters, personification of inanimate objects is not limited to synaesthesia only, but also occurs in the general population. Personification of non-human entities in the general population has sometimes been studied in psychology under the term anthropomorphism. Here, for clarity, the term personification will be used throughout the chapter[9].

Humans occasionally personify the entities surrounding them and this tendency appears to be much stronger in early childhood than in adulthood. Personification processes have been suggested to be an early, developmental mechanism reinforcing the development of theory of mind (Amin et al., 2011; Sobczak-Edmans and Sagiv, in press), and personification could be considered as a basic psychological mechanism underlying social cognition (Sobczak, 2009). The strength of the general tendency to personify varies. In some people, like for example young children, this tendency is stronger, whereas in others it may be much weaker. For example, patients with Asperger's syndrome have difficulties in giving human-like descriptions while watching animated shapes, and also do

[9] Term 'personification' is more appropriate to use than 'anthropomorphism' because the focus is on the attribution of mental states (such as feelings and attitudes), rather than any physical features or similarities.

not show activations in the brain areas involved in social cognition (Castelli, Frith, Happe and Frith, 2002). Similar deficits in the ability to personify are observed in patients with damaged amygdalas (Herberlein and Adolphs, 2004).

Personification of inanimate objects among synaesthetes and non-synaesthetes appears to be qualitatively different (see Discussion in Chapter 4). The main difference is that synaesthetic experience is involuntarily induced and without conscious effort, whereas non-synaesthetic personification appears to be rather voluntary and non-automatic, at least in some instances, such as the personification of static objects. In non-synaesthetes, there are three major factors that could increase the tendency to perceive non-human entities as human-like. The first relates to the knowledge elicited by the agent. As young children first develop a concept of the self and only later in development acquire more complex knowledge about different agents, they consequently exhibit an egocentric bias in reasoning when explaining less well-known stimuli, which increases their propensity to personify. The egocentric/homocentric knowledge is more easily accessible when the perceived stimuli looks like a human morphologically. People frequently attribute their own beliefs and desires to others that seem to be similar to them (Epley et al., 2004). Considering that the self often serves as a pattern for reasoning about unfamiliar others, Waytz and colleges (2010) hypothesised that is more likely to occur when perceiving unfamiliar agents. Social motivation is the second of the factors increasing personification. Humans have a basic need to affiliate and create social connections with others. Lack of social connections and social isolation can be compensated by personifying animals, gadgets and religious agents (Epley, Akalis, Waytz, and Cacioppo, 2008). Effectance motivation, defined as a need to understand, control and predict one's own environment has been proposed as a third cause of anthropomorphism. This account considers personification as a mechanism that enables fulfillment of the need to understand and control non-human, unpredictable agents by endowing them with human-like qualities (Waytz et al., 2010). Another important factor regulating the propensity to personify agents in the general population is movement, especially movement at a speed similar to human movement speed (Morewedge, Preston and Wenger, 2007), therefore many studies investigating personifying thought used stimuli in motion, like for example point-light videos of walking (e.g., Herberlain and Saxe, 2005) or classical moving geometrical shapes figures (e.g., Castelli, Happe, Frith and Frith, 2000; Castelli, Frith, Happe and Frith, 2002; Heider and Simmel, 1944;Tavares, Lawrence and Barnard, 2008). However, in synaesthesia, we see that even static objects can be personified. Also, in contrast to non-synaesthetes, many of the personifying synaesthetes perceive familiar objects as human-like with a greater frequency than they perceive non-familiar objects in this way, but in some cases familiarity of objects does not influence their personifications as reported in Chapter 2. On the other hand, lack of social connections – loneliness - could be an important factor increasing the tendency to create rich and elaborate personalities attributed to objects in synaesthesia, as could the need to control the objects, but to date this has not been empirically tested. The issue of loneliness in synaesthetic personification will be addressed in a later part of this thesis (Chapter 6). In the current fMRI study a personifying synaesthete (GF) and a group of non-synaesthetes will be tested to investigate the neural correlates of personification elicited by seeing 'lonely' inanimate objects. Testing a control group in addition to synaesthete GF - who personifies graphemes and objects on a daily basis - will allow a comparison of her brain responses with the brain responses of non-synaesthetes and identify the pattern of brain activation specific to synaesthetic personification.

The specificity of synaesthetic personification is highlighted by fact that it lacks firm attentional control, and synaesthetes report that throughout their life time they perceive inanimate objects and graphemes as endowed with social and affective characteristics, such as personality traits (e.g., a radiator is ‘an annoyed and frustrated moaner’, an accordion is ‘reliable friend, trustworthy’), genders (e.g., thin leaves are ‘young women’ and broad leaves are ‘old and middle aged women’), feelings (e.g., ‘sad’ bus) and attitudes (e.g., ‘easy going’ palm tree, ‘fun loving’ foot). There are two alternative ways of explaining synaesthetic personification. One of them is cross-talk hypothesis suggesting existence functional (or structural) cross-activations between the left angular gyrus and temporo-parietal junction and other brain regions associated with mentalising, such as the amygdala, somatosensory cortex, frontal and parietal brain regions (Simner and Hubbard, 2006). The second model implies that personification may result from the misattribution of agency due to lower threshold for brain regions implicated in mentalising (Sagiv and Frith, in press; Sobczak-Edmans and Sagiv, in press). To date, a functional neuroimaging study of AA provides evidence that synaesthetic attribution of gender to graphemes activates the precuneus, a brain area associated with self reflection, agency and imaginary processes. The precuneus activation is also found in non-synaesthetic personification, when people think of gadgets as unpredictable and ‘having mind on their own’ (Waytz et al., 2010), together with the preforontal cortex, temporoparietal junction, posterior cingulate, superior temporal sulcus and temporal poles adjacent to the amygdala. These brain regions are also known to be associated with in mentalising (Spreng et al., 2009), self-projection and egocentric perspective taking (Buckner and Caroll, 2007). Could this be the case (as previously suggested in relation to synaesthetic personification of graphemes in Chapter 3) that the misattribution of agency underlies synaesthetic personification of inanimate objects? The discrimination between one's own feelings and mental states and the feelings and mental states that are simulated is considered one of the challenges for the self-projection mechanism for any perceiver, not only for synaesthetes. Usually people can determine rather easily whether or not a particular mental state or feeling is simulated, but in some situations source attribution error may occur. This could takes place when one is watching a movie and experiences the same feelings as the main character, for example when one is crying along with the main character in the movie**.** It could be considered that in this situation the perceiver simulates the mental states of the main character and instead of projecting them, attributes them to themselves. In the case of imbuing letters with personalities and mental contents, one's own mental representations are attributed to entities outside the self - in this particular case - to graphemes. In accordance with this, personification would be understood here as a mode of thinking that is egocentrically biased by one's own mental contents that are projected onto non-human entities and attributed to them as feelings, intentions and beliefs etc. In this process of attribution of one's own mental contents to inanimate objects and other non-human entities the perceiver fails to monitor their own mental states, and misattribute them to externally located things.

5.2 Aim and hypotheses

This study sought to examine the neural correlates of the attribution of human-like characteristics to inanimate objects in the synaesthete experiencing personification of inanimate objects. To test this empirically, the synaesthete and a control subjects participated in functional magnetic resonance imaging (fMRI) experiment, in which they were presented with a series of pictures of inanimate household objects. The specially designed stimuli included images created in such a way as to induce feelings of social exclusion and loneliness. In half of these images one object was shown separated from the rest (this was intended to trigger experience of the social attribute of loneliness). Given the specificity of the stimuli used, it was aimed to establish if personification of inanimate objects automatically induces changes in the brain regions implicated in self-projection, namely the precuneus, temporo-parietal junction, the prefrontal medial cortex, the posterior cingulated cortex, the lateral temporal cortex and the hippocampal formation. Since the same stimulus was seen twice by the participants and, given that during the second viewing of the same objects participants were explicitly asked to think of objects as if they were humans, it was aimed to isolate and examine the personification processes that are voluntary and under strategic control. It was hypothesised that the changes in activation will include the same brain areas that are involved in implicit, pre-reflective personification, but the activations observed will be extended to larger regions of the brain. It was also expected to see differences in the neural responses to images presented between the synaesthete tested and a non-synaesthetic group and correspondingly to subjective reports, it was hypothesise that those responses will be more extensive in a synaesthete in comparison to non-synaesthetes.

5.3 Method

The stimuli used in the study consist of sets of images that were processed in Photoshop to produce images according to experimental requirements. Only the images that were rated by non-synaesthetic volunteers in a pilot study as the `most lonely' were included in the experiment.

In the experiment 90 pictures were used, 30 for each of the following groups (i) pictures of grouped objects (ii) picture where one object was separated from rest of objects, and (iii) scrambled images[10] (see Figure 5.1). Correspondingly, the experiment had three conditions: (i) grouped objects (ii) lonely objects and (iii) scrambled. Scrambled images were presented after each experimental of conditions ('lonely', 'grouped') to allow haemodynamic response to recover. This procedure was repeated for the entire duration of the study.

[10] Scrambled images were produced using a short Matlab code written by Dr Ben Edmans.

Figure 5.1 Example of stimuli used in the experiment: Top left – lonely object, top right – grouped objects and bottom – scrambled objects

During each condition, subjects were presented visually with pictures of grouped domestic objects, objects separated from others, or a random assortment of squares. The software used for this was Cogent 2000[11].

5.3.1 Design of the study

A block design was utilised in this experiment. Each block comprised of 4 images and every image was shown for 3 seconds. Participants were presented with images of objects placed together in a group, (the control condition) and similar images of the same objects where one of the objects was separated from the group. These formed the 'lonely objects' – experimental condition.

[11] The software used was developed by the Cogent 2000 team at the Functional Imaging Laboratory and the Institute of Cognitive Neuroscience at University College of London.

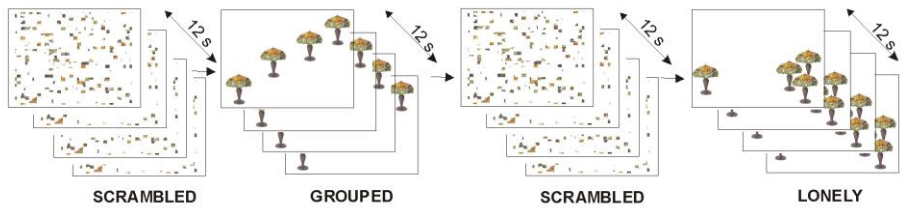

Figure 5.2 Stimulus sequences used in the experimental design. Blocked images of scrambled objects were presented first, followed by blocked images of grouped objects, then again blocked images of scrambled objects and blocked images of lonely objects. This sequence was repeated 8 times in both parts of the experiment – before and after priming.

During the experiment all subjects underwent the scanning procedure twice, without repositioning. In the initial part of the experiment, participants passively viewed the presented pictures. To maintain the participants' attention, subjects were asked to press a button every time they see an image in a green frame.

Then, before repeating this procedure, participants were primed to personify the objects. They were asked to imagine that "the objects they had just seen have feelings". Then subjects were told that "some of the presented images show objects that have been excluded from the rest of the group and these objects may feel lonely and isolated".

After the priming, participants were presented with exactly the same stimuli again. The participants' task remained the same as in the first part of the experiment (to press a button upon seeing an image with a green frame), but at the same time participants were instructed to try to imagine how the separated object from the other objects might feel. Therefore the key difference between the two parts of experiment is that in the second part the participants' attention was drawn to the possible interpretation of the stimuli as representing social relationship (such as exclusion) and the associated emotions. The aim of priming (through the use of verbal instructions and context) was to influence the control's group tendency to mentalise the shown images. The same set of stimuli was used before and after priming to minimise cognitive differences between two parts of the experiment and instead to try to influence the participants' subjective perception of the viewed objects.

5.3.2 Participants

One synaesthete, GF, and twelve non-synaesthetic volunteers (mean age 27 years ± 4.4 SD, range 18-33) participated in the experiment, among which were 6 females and 6 males, all right-handed. All participants had normal or corrected to normal vision and gave written consent to participate in the study. Before the scanning procedure, participants were screened in accordance with standard procedures and were informed that they can stop taking part in the experiment any time they wish. Participants also were reassured that their personal details will be kept confidential.

GF is a 26 years old female, postgraduate student in humanities, who experiences sequence-personality synaesthesia, co-occurring with colour grapheme synaesthesia. GF attributes personalities and genders to letters, numbers, and days of the week, months, simple shapes, cardinal directions, body parts and inanimate objects. Personalities and genders associated with graphemes, months and weekdays are discussed further in Chapter 2. Personalities for inanimate objects, including body parts, clothes, plants, shapes and other everyday objects are shown in Table 4.1 in Chapter 4.

5.3.3 Data analysis

Functional MRI data preprocessing and statistical analysis were implemented using SPM5 (Wellcome Trust Centre for Neuroimaging, http://www.fil.ion.ucl.ac.uk/spm). Before the statistical analysis was carried out, the standard preprocessing steps were conducted: realignment to the mean functional image in each session, co-registration of the functional images with a high-resolution anatomical image, normalisation into standard anatomical space using the Montreal Neurological Institute template provided by SPM5 and spatial smoothing with 8 mm full-width half-maximum (FWHM) Gaussian kernel.

Whole brain statistical analysis was performed using the general linear model (GLM) and all trials were convolved with the canonical haemodynamic response function. A high-pass filter with a cut-off of 128 s was applied to remove the low frequency drift in the data. To obtain statistical parametric maps we computed a t-test. In the group of non-synaesthetic controls, according to the random effects theory (Horowitz, Friston and Taylor, 2000), a second level analysis was conducted to analyse the data at a group level. All results (from a single synaesthete and a control group) were threshold at $p<0.05$, family-wise error (FWE) corrected.

5.4 Results

The first analysis evaluated the BOLD signal changes recorded during viewing of the ‘lonely objects’ condition compared to the ‘grouped objects’ condition in the synaesthete and the control group. Based on a previous study on the neural basis of personification of graphemes in synaesthesia that observed precuneus activation in response to personified graphemes, it was hypothesised that precuneus activation will be also observed during the personification of inanimate objects in synaesthesia, together with other brain regions involved in social cognition. Whole brain analyses of the tested synaesthete in a condition comparing neural responses to images of ‘lonely’ versus ‘grouped’ objects before priming (L1>G1) are displayed in Figure 5.3 and Table 5.1. As predicted, these results show a significant increase (FWE corrected) in activation in the precuneus, the temporo-parietal junction and the posterior cingulate gyrus, but not in the hippocampus, the prefrontal cortex and lateral temporal cortex. This effect was not observed in the control group, among whom we did not observed any FWE corrected activations.

In the opposite contrast, comparing brain responses to ‘grouped’ versus ‘lonely’ objects before priming (G1>L1), there was not significant (FWE corrected) changes in brain activations observed neither in the tested synaesthete nor in control group.

Next, we examined the differences in BOLD signal changes in response to viewing the same images, when subjects knew explicitly the ‘story behind the images’ and were trying to imagine how the ‘lonely objects’ could feel. This was done by comparing neural responses to images of ‘lonely’ versus ‘grouped’ objects after priming (L2>G2). This was meant to induce synaesthesia-like personification of inanimate objects in non-synaesthetic participants, but also it was also expected that the explicit focus of attention on imagining feelings of ‘lonely objects’ would increase the strength of previously observed activations in the synaesthete. The results of whole brain analysis of the L2>G2 condition in the synaesthete revealed bilateral precuneus activation and right temporo-parietal junction activation and the prefrontal cortex activation as described in the Table 5.2 and Figure 5.4. In the opposite contrast, comparing brain responses to ‘grouped’ objects versus ‘lonely’ objects after priming (G2>L2), there was not significant (FWE corrected) changes in brain activations observed neither in GF nor in control group.

In the control group, the analysis of the L2>G2 condition showed a significant increase in activity in the brain regions involved in social cognition and self-reflection, such as the precuneus and the insula. All other brain areas displayed significantly increased BOLD signal when participants were viewing the 'lonely' objects after priming, compared to the control condition - 'grouped' objects. These results are shown in Figure 5.5 and Table 5.3, which provides anatomical locations, coordinates, and t values of the statistically most active voxels for those brain regions consistently activated across subjects .

Table 5.1 Brain regions for L1>G1contrast, where viewing ‘lonely objects’ elicited more activity than viewing ‘grouped objects’ in the synaesthete GF before priming (FWE corrected)

Anatomical location	Cluster Size	t-value	Coordinates		
Temporo-parietal junction	5	5.16	69	-36	27
Precuneus	1	4.93	-18	-72	60
Posterior cingulate cortex	2	5.57	-3	-42	30
Fusiform gyrus	1	5.26	-45	-81	-9
Precentral gyrus	2	5.00	33	-3	69
Inferior occipital gyrus	9	5.71	-39	-87	-3
Culmen	3	5.07	51	-51	-30
Culmen	2	5.07	39	-54	-24
Declive	2	5.13	-42	-75	-21
Declive	9	5.59	45	-63	-18

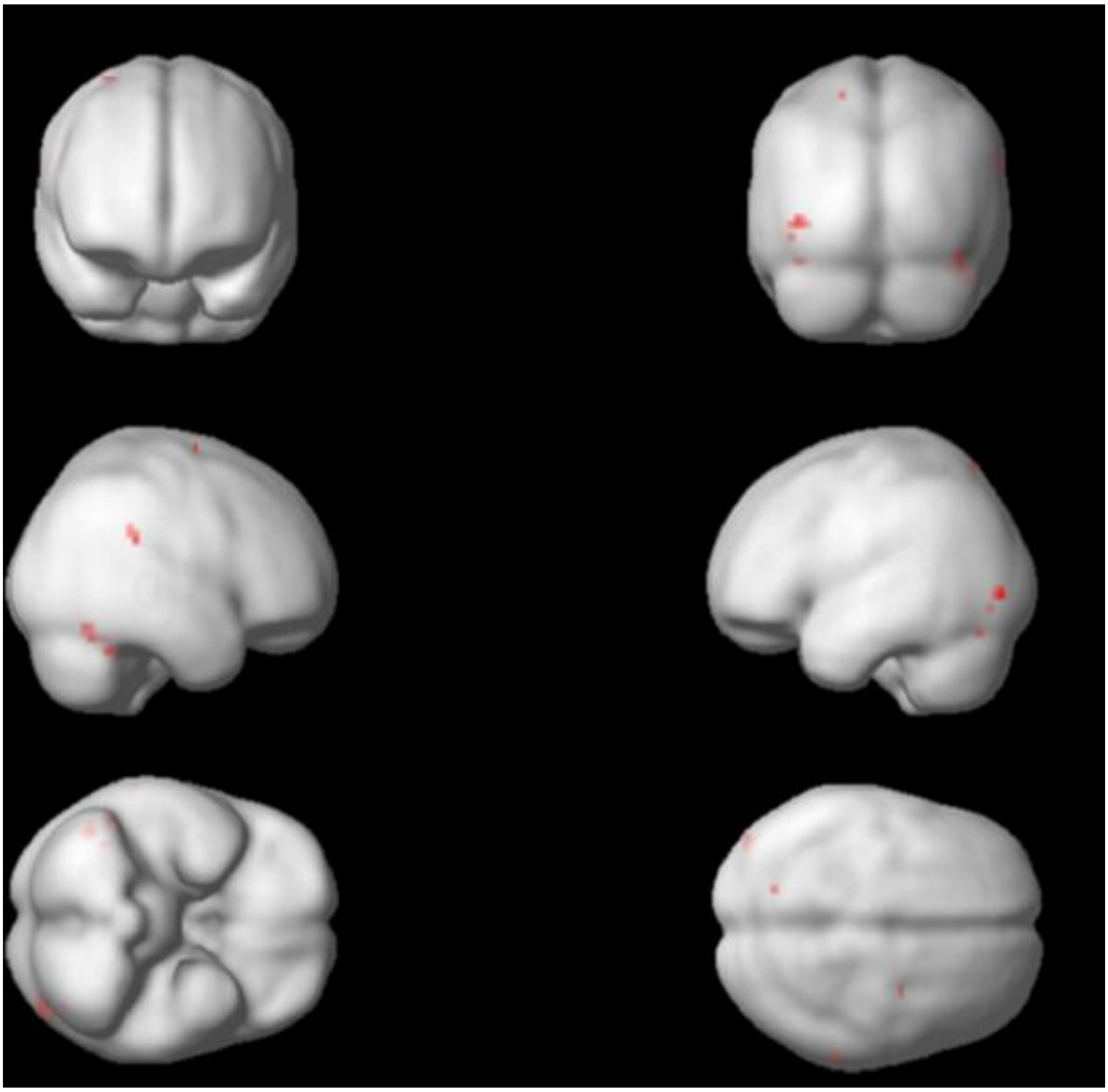

Figure 5.3 Regions of significant changes in activation when the synaesthete GF viewed images of lonely objects compared to when viewing 'grouped objects' before priming (L1>G1 contrast)

Table 5.2 Brain regions for L2>G2 contrast, where viewing 'lonely objects' elicited more activity than viewing 'grouped objects' in the synaesthete GF after priming (FWE corrected)

Anatomical location	Cluster size	t-value	Coordinates		
Precuneus	98	6.34	9	-75	60
Precuneus	15	5.80	6	-51	51
Precuneus	22	5.72	9	-51	78
Precuneus	7	5.30	-3	-78	54
Precuneus	1	4.92	6	-66	51
Superior parietal lobule	143	6.45	30	-57	66
Temporo-parietal junction	24	5.53	57	-39	36
Temporo-parietal junction	2	5.17	48	-36	45
Temporo-parietal junction	1	5.26	63	-36	21
Mid temporal gyrus	70	6.59	42	-66	18
Mid temporal gyrus	14	6.55	54	-69	12
Inferior temporal gyrus	3	5.37	-45	-48	-21
Superior frontal gyrus	15	6.02	30	-3	69
Inferior frontal gyrus (orbital frontal)	8	5.73	51	21	-6
Middle frontal gyrus	6	5.25	27	-12	54
Prefrontal cortex	4	5.16	42	30	33
Prefrontal cortex	1	5.02	36	30	54
Precentral gyrus	7	5.34	51	6	42
Precentral gyrus	1	4.95	-30	-15	57
Fusiform gyrus	5	5.28	42	-27	-18
Inferior occipital gyrus	39	7.39	-42	-87	0
Inferior occipital gyrus	1	5.02	51	-72	-9
Middle occipital gyrus	2	5.19	-36	-75	12
Cuneus	11	5.94	-15	-87	36
Culmen	16	5.86	48	-54	-27

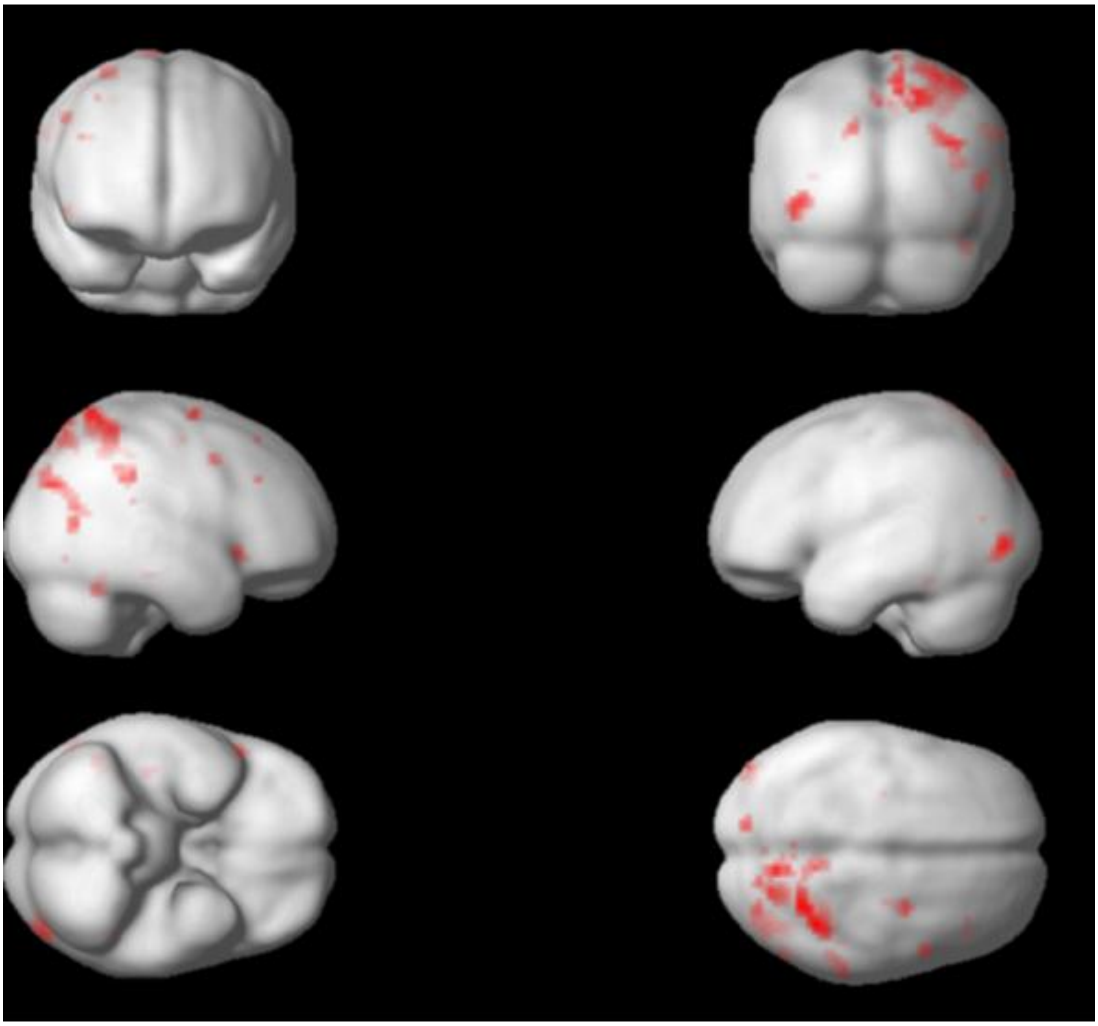

Figure 5.4 Regions of significant changes in activation for L2>G2 contrast, when the synaesthete GF viewed images of lonely objects compared to when viewing 'grouped objects' after priming

Table 5.3 Results for changes in brain activation for L2>G2 contrast, when non-synaesthetic group was viewing 'Lonely Objects' versus 'Grouped Objects' after priming (FWE corrected)

Anatomical location	Cluster size	t-value	Coordinates		
Precuneus	9	14.75	-21	-60	54
Insula	1	10.36	-33	24	3
Insula	2	9.97	-33	9	3
Middle occipital gyrus	1	9.91	-33	-84	24
Culmen	1	9.23	-15	-60	-3

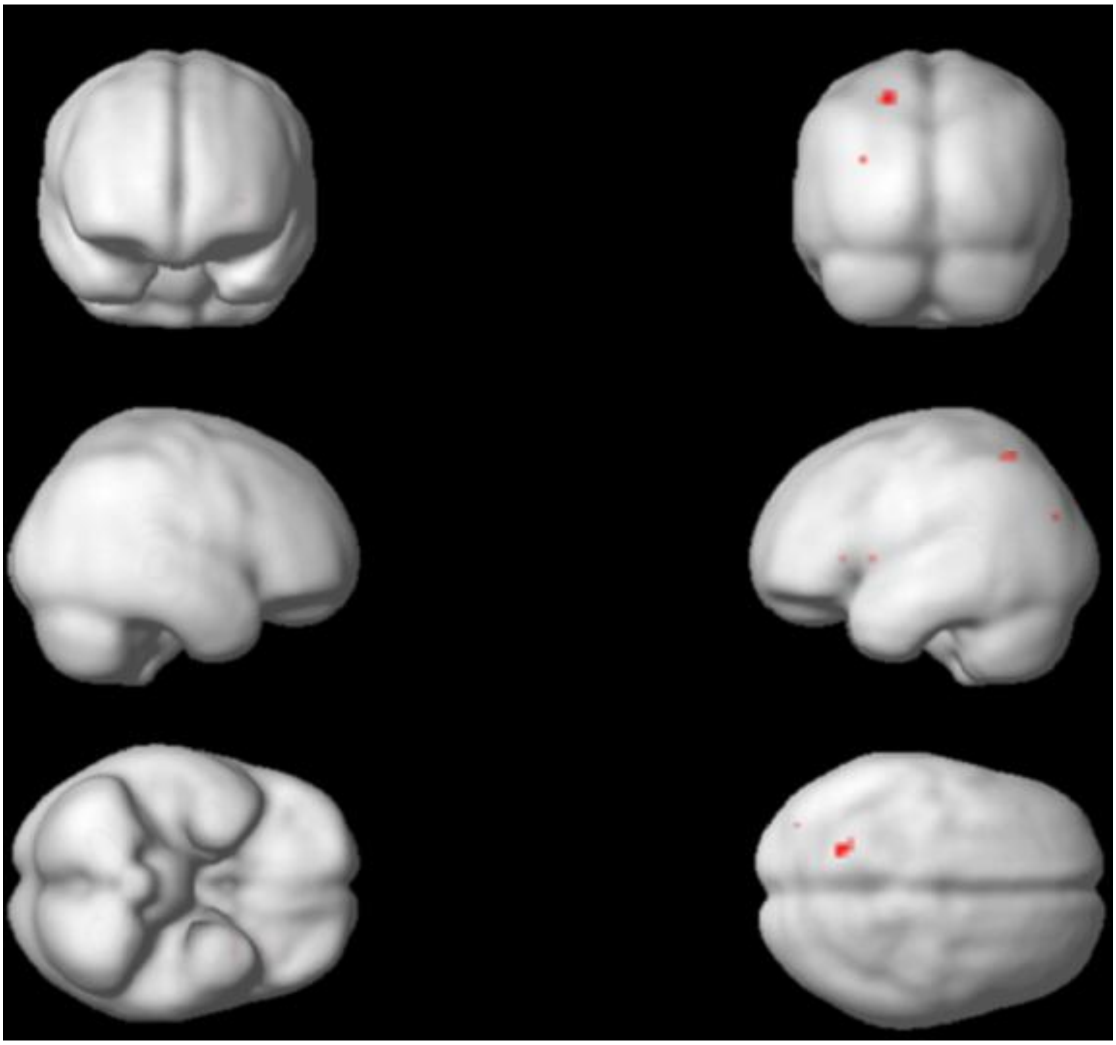

Figure 5.5 Regions of significant changes in activation when the non-synaesthetic group viewed images of lonely objects compared to when viewing ‘grouped objects’ after priming (L2>G2 contrast)

5.5. Discussion

The objective of the present study was to examine the neural correlates of involuntary object personification experienced by the tested synaesthete, to whom certain objects appear as having feelings, personalities, genders and relationships with each other. Using the ‘lonely objects’ paradigm, it was aimed to assess whether the objects presented can automatically induce personification, even when attention of the synaesthete was directed towards a different task. It was hypothetised that viewing images of ‘lonely objects’ will induce activation in the precuneus and other brain regions implicated in self-reflection and self-projection, including the temporo-parietal junction, prefrontal cortex and the posterior cingulated, the lateral temporal cortex and in the hippocampus. Additionally, the study was designed to examine whether similar patterns of activations will be observed in non-synaesthetic subjects in two different conditions - when they were naïve about the social meaning behind the pictures, and when they were prompted to focus their attention on the ‘social situations’ represented in the pictures.

The results of the study show significant changes in the brain areas implicated in social cognition and self-projection, such as the precuneus, the temporo-parietal junction and the posterior cingulate cortex, but not in the hippocampus and lateral temporal cortex when the synaesthete GF was naïve to the social context of presented images. This is consistent with previous studies on neural correlates of graphemes in sequence-personality synaesthesia (Amin et al., 2011; see also Chapter 3 of this thesis). In non-synaesthetes, no changes in activation were observed when participants were naïve about the ‘social situation’ in the pictures. However, after priming, when they focused their attention on the feelings of ‘lonely objects’ and tried to imagine what the objects feel, significant changes in the activation in the precuneus and in the insula were observed.

On the basis of these findings, could it be the case that the self-projection mechanism is activated in synaesthetic personification as previously proposed in Chapter 3? It is plausible that synaesthetic personification is due to a lower threshold for activation of social brain regions normally activated when thinking or perceiving other people. Perhaps the lower threshold for activation of this system in the synaesthete GF induces simulation processes of social contents and the associated mental states, moods and feelings are assigned to the perceived objects. In most people, the 'social brain' regions are usually activated when perceiving other people, but in synaesthesia it appears that these regions are activated not only by other people, but also by inanimate objects. This matches the phenomenology of the experience of the tested synaesthete, in which she reports that inanimate objects have social and affective characteristics. This suggests that she has increased sensitivity to perceive human-like qualities, not only in humans but also in objects, especially when they are arranged in the way that resembles social situations. Additionally, the results of the study provides converging evidence for the automaticity of social attributions to objects in synaesthesia, since the synaesthete GF was asked to focus her attention on an unrelated task and remained naïve about the social aspect of the images.

The lack of the activations to presented images of 'lonely' objects in non-synaesthetes is in line with their subjective reports given after the experiment, in which none of them reported thinking of the objects presented as having feelings or any other human-like qualities before priming, and instead being surprise at the suggestion that the objects presented might have feelings. However, after priming, when non-synaesthetic participants focused their attention on the feelings of 'lonely objects' and tried to imagine what the objects feel, changes in activation of the brain regions associated with mentalising and self-reflection, namely in the precuneus and in the insula, were observed. These results slightly differ from the previous neuroimaging studies into non-synaesthetic personification, in which personification processes activated prefrontal cortex, temporo-parietal junction, the precuneus, superior temporal sulcus and temporal poles adjacent to the amygdale (Castelli, Happe, Frith and Frith, 2000; Castelli, Frith, Happe and Frith, 2002; Herberlain and Saxe, 2005; Tavares, Lawrence and Barnard, 2008). This may be due to the fact that the current study differs from previous investigations into non-synaesthetic personification in several ways. Firstly, instead of testing personification induced by animate stimuli (e.g., point-walkers, moving shapes etc), the element of movement was excluded from the study to be able to examine attribution of human-like qualities to inanimate objects. Secondly, the social meaning of the images shown was not made clear to the tested subjects who, instead, were directed to focus their attention on a different, unrelated task (participants were asked to press a button after noticing a green frame appear) to investigate automatically occurring personification. Thirdly, the stimuli used were primarily designed to investigate synaesthetic personification and therefore could be less effective in inducing personification in the general population.

Nevertheless, the results of the current study suggest that the underlying neural mechanisms for automatic personification of objects in the synaesthete GF and for voluntary personification of inanimate objects in non-synaesthetes are not exactly the same. In non-synaesthetes, the voluntary personification of objects also activates the precuneus (similarly to the tested synaesthete) and additionally the insula, but not other brain regions implicated in mentalising. It is worth noting that the control participants reported greater difficulty in ‘inferring’ personality traits of inanimate objects, in comparison with the tested synaesthete. This is consistent with the behavioural results (see Chapter 4) showing that synaesthetes who personify objects, were significantly slower in responding to incongruent than congruent trials when presented with an image of a happy facial expression preceded by an image of ‘lonely objects’ (incongruent trial) or the same image preceded by sad face (‘incongruent trial). Given that this effect was not observed in non-synaesthetes (see Chapter 4), it was suggested that that personification in synaesthesia is automatic, whereas personification in non-synaesthetes require a more deliberate effort. The relevance of this is noticeably supported by the current findings, since the changes in activations of the ‘social brain’ regions (when subjects were naïve about the social aspect of presented images) were observed only in the synaesthete GF and not in non-synaesthetes. However, taking into account the fact that when non-synaesthetes voluntarily focused their attention on the feelings of ‘lonely objects’, the observed changes we in the activation were in the precuneus and in the insula – brain regions implicated in self-reflection and thinking about other people. Therefore the possibility that personifications in synaesthesia and in general population are governed by the same self-projection mechanism cannot be excluded. The limitation of the current study is that personification in general population was not probed under conditions that are known to facilitate this process (in the situation of social isolation, when perceived entities are ambiguous and unpredictable and when they are showing movement resembling the speed of human movement; Epley et al., 2008; Morewedge et al., 2007; Waytz et al., 2010), when people are more likely to assign their own mental contents to the perceived entities. Future studies could seek to compare synaesthetic and non-synaesthetic personification under these conditions. Furthermore, the present study could be extended by adding additional analysis providing a more detailed picture of the neural correlates of personification. For example, the brain areas identified in Chapter 3 as involved in grapheme-personification, could serve as functional ROIs for the current study to analyse changes in GF's brain activation for personification of inanimate objects. This would allow finding brain regions that mediate cognitive processing specific for synaesthetic personification that is independent of the type of inducer.

5.6 Conclusion

- The present study has shown that images of inanimate objects can induce personification processes in a synaesthete experiencing sequence-personality synaesthesia. In the tested synaesthete, viewing specially designed images revealed activations in the brain areas implicated in mentalising, such as the precuneus, the temporo-parietal junction and the posterior cingulate.

- This effect is not observed in the general population, unless non-synaesthetes explicitly focus their attention on the feelings of the inanimate objects. Then, similarly as in the tested synaesthete, the increased activation in the precuneus is observed.

- Based on these results it is proposed that synaesthetic and non-synaesthetic personification utilises partially overlapping neural mechanisms with general social cognition; however control participants reported having a greater difficulty in attributing personality traits of inanimate objects, in comparison with the synaesthete GF. A possible, but tentative explanation for this might be that the brain regions implicated in mentalising and self-projection have a lower threshold for activation in subjects with sequence-personality synaesthesia than in the general population and therefore inanimate objects and linguistic sequences are perceived as having social and affective characteristics.

Chapter 6 Psychological correlates of synaesthetic personification

6.1 Introduction

Considering the fact that in sequence-personality synaesthesia, synaesthetes perceive graphemes, weekdays, months, inanimate objects, body parts (among others) as being endowed with personalities, feelings, mental states and interactions with each other, it is important to ask what is the relationship between synaesthetic personification and such aspects of psychological functioning, as empathy and mentalising. Empathic and mentalising skills vary in general population. Given that synaesthetes appear to have increased sensitivity to social cues (see Chapter 5), think of graphemes in social categories and often feel sympathy for inanimate objects, is it possible that they exhibit increased ability to mentalise and empathise with other people? Amin and colleagues (2011) proposed two alternative answers to this question. Firstly, they suggested that personification could lower empathic abilities, given that the empathic resources are allocated not only to social interactions with other people, but also appear to be involved in thinking of graphemes and inanimate objects. Secondly, the authors proposed that personification may be limited to the domain of grapheme processing only and therefore may not affect the empathic abilities used in general social cognition. In their study, Amin and colleagues (2011) assessed empathy in ten personifying synaesthetes using the Empathy Quotient (EQ; Baron-Cohen and Wheelwright, 2004). Their findings suggested that synaesthetes do not differ in empathy from the general population; however they pointed out the variability in individual scores: a few participants scored very low, whereas one participant scored much higher than average. Therefore, they were unable to provide a definite answer concerning the relationship between synaesthetic personification and empathy. They concluded, however, that an increased ability to empathise is not necessary for synaesthetic personification. To investigate this relationship further, in the current study a group of personifying synaesthetes were also tested on their empathic abilities using the EQ test. In contrast to Amin et al (2011), in this study, the Eyes Test was also included. This is a test that requires the tested individual to recognise mental states from images of a person's eyes and surrounding areas was used to assess mentalising processes in synaesthetic personification. It is important to include mentalising processes in the current study given that empathy and mentalising processes are known linked with each other (de Vignemont and Singer, 2006).

One interesting aspect of personification in synaesthesia is the difference in the types of inducers eliciting it. In some of the synaesthetes, only letters or numbers induce personification, whereas in others personification is elicited not only by letters, numbers and other linguistic sequences, but also by various inanimate objects, as well as body parts. Could it be the case that more widespread personification across various categories of linguistic and non-linguistic sequences is linked with lower empathy (as previously suggested by Amin et al; 2011), whereas in case of more selective personification (e.g., limited to letters only), empathic skills are not affected by personification? Could this be also the case with mentalising processes? To date, this hypothesis has not yet been empirically investigated; this is the first study to test empirically for the presence of differences in empathy/mentalising abilities between synaesthetes with a different extent of personification.

It is important to note that objects are personified not only in synaesthetes, but also in the general population. One of the proposed explanations for personification among the general population emphasizes that humans have a strong need for social connections with others and that in situations of social isolation or loneliness people instinctively compensate for this and perceive non-human-entities as human-like (Epley et al., 2008). In fact, Epley and colleagues (2008) induced experimentally subjective feelings of loneliness in tested participants by presenting to them life predictions, which participants were told were based on their personality profiles, but in fact were tailored to induce feelings of loneliness. To increase feelings of loneliness in the participant, they were told they will end up alone in life. In result, the induced feeling of loneliness led to a higher tendency to think of non-humans as they were human-like. Could feeling lonely or isolated be correlated with personification of objects in synaesthesia? If this were the case, it is possible that synaesthetic personification is also linked with loneliness.

6.2 Aim and hypotheses

The aim of the current study was to examine the relationship between synaesthetic personification and psychological dispositions such as empathy, mentalising and loneliness. It was expected that synaesthetes are more empathic and have higher than average mentalising skills, but also experience increased levels of loneliness.

These predictions were motivated by the fact that synaesthesia is associated with enhanced sensory processing in the modalities of the concurrent (Bannisy et al., 2009). For example, synaesthetes who experience colour in response to grapheme are better at perceptual discrimination of colour in comparison to non-synaesthetes (Yaro and Ward, 2007), whereas synaesthetes with mirror-touch synaesthesia are better than non-synaesthetes in recognising facial expressions (Bannisy et al., 2011) and also exhibit heightened empathic ability (Banissy and Ward, 2007). In the synaesthesia literature there has already been one attempt to establish a relationship between emphatic abilities and synaesthetic personification (Amin et al., 2011), but due to the small sample size and heterogeneous results the conducted study did not provide conclusive results.

6.3 Method

6.3.1 The UCLA Loneliness Scale

The revised version of UCLA Loneliness Scale (University of California, Los Angeles) consists of 20 items measuring subjective feeling of loneliness and satisfaction/dissatisfaction with relationships with other people (Russel, Peplau and Cutrona, 1980). The participants are asked to indicate on a scale (ranging from 1 to 4) how often they feel in the way described by each of the given statements. In the current study, the electronic version of the UCLA Loneliness Scale was distributed using the online survey software Survey Monkey (http://www.survey monkey.com/).

6.3.2 Reading the 'Mind in the Eyes' Test

Reading the 'Mind in the Eyes' Test (referred to in this as the Eyes Test) is a measure of mentalising processes at the stage of recognition and attribution of mental states. The Eyes Testoriginates in autism research, but it also has been used in testing of social intelligence in the general population. The revised version of the test consists of 36 images illustrating human eyes obtained from images of actors' faces. Half of the faces are male and half are female. In the test there are also printed four descriptors of mental states: one correctly describes the expression depicted by the eyes, and three that are incorrect. This testrequires subjects to identify the mental state of the person in the photograph (Baron-Cohen et al., 2001). Participants are also provided with a glossary explaining all the mental state terms included in the task, to which they could refer while completing the test. In the current study, an online version of the test was used, an example of which is shown in Figure 6.1.[12]

Figure 6.1An example of a question used in the online version of the Eyes Test

6.3.3 The Empathy Quotient (EQ)

The EQ was initially designed to test empathic skills in adults with high functioning autism and Asperger' s syndrome, but it can be also used to test empathy in the general population. The EQ is a self- report questionnaire that

[12]An online version of the Eyes Test can be found at http:// glennrowe.net/BaronCohen/ Faces/EyesTest.aspx (Date last retrieved 14/11/2012).

comprises 40 questions exploring empathy and 20 filter questions that are included to distract subjects from the overall focus on empathy (Baron-Cohen and Wheelwright, 2004).An online version of EQ test was used in this study.[13]

6.4 Subjects

Eleven synaesthetes (mean age 31.5, SD±13.9) who reported personifying graphemes participated in the study, 6 of whom were female and 5 male. Some of the participants reported personifying not only graphemes, but also inanimate objects, as shown in Table 6.1. Participants were not chosen randomly – they were self-selected. Participants were recruited via advertising on Brunel University campus and Royal Holloway campus, and also via the Synaesthesia Research Database. All participants completed the Personification Questionnaire described in Chapter 2.

Table 6.1 List of synaesthetes with types of personification experienced

Synaesthete	**Sex**	**Grapheme Personification**	**Object Personification**
RP	M	YES	NO
FM	M	YES	YES
SM	F	YES	NO
SJ	M	YES	YES
GF	F	YES	YES
CS	F	YES	NO
CG	F	YES	YES
UL	F	YES	NO
DL	M	YES	NO
YG	M	YES	YES
DL	F	YES	NO

[13] The EQ used test is located at http://glennrowe.net/baroncohen/empathyquotient/ empathyquotient.aspx (Date last retrieved 14/11/2012).

6.5 Procedure

Participants who previously completed the Personification Questionnaire (see Chapter 4) were invited to participate in online study using the EQ, the Eyes Test and the UCLA Loneliness Scale to measure psychological aspects of personification in synaesthesia. The eleven participants who agreed to take part in the study were emailed links to online versions of the questionnaires. Once they completed EQ and the Eyes Test, resulting scores for individual participants were generated automatically and participants emailed them to the researcher. The results of UCLA Loneliness scale were directly accessed online.

6.6 Results

6.6.1 The Empathy Quotient

Table 6.2 An overview of results from the EQ test

Empathy Quotient	Mean EQ Score	Min EQ Score	Max EQ Score	SD
All	48	23	62	10.3
Male	44	23	62	14.3
Female	52	49	59	3.6

Mean total EQ, standard deviation, minimum and maximum scores are presented for all synaesthetes, and for male and female synaesthetes separately in Table 6.2. Personifying synaesthetes scored an average of 48 points, which is above the average EQ score of 42.1 for the general population that was found in the study of Baron-Cohen and Wheelwright et al (2004); however, this difference is not significant statistically ($t(10) = 2.01$, n.s).

Female participants scored on average 52 points, which is above the average EQ score of 47.2 found in females (Baron-Cohen and Wheelwright, 2004), and this difference is significant statistically (t(5) = 3.3 , $p<0.05$). The individual scores of all female participants (see Figure 6.2) give a consistent picture – all of the tested female synaesthetes scored above the female average score (scores ranged from 49 to 59).

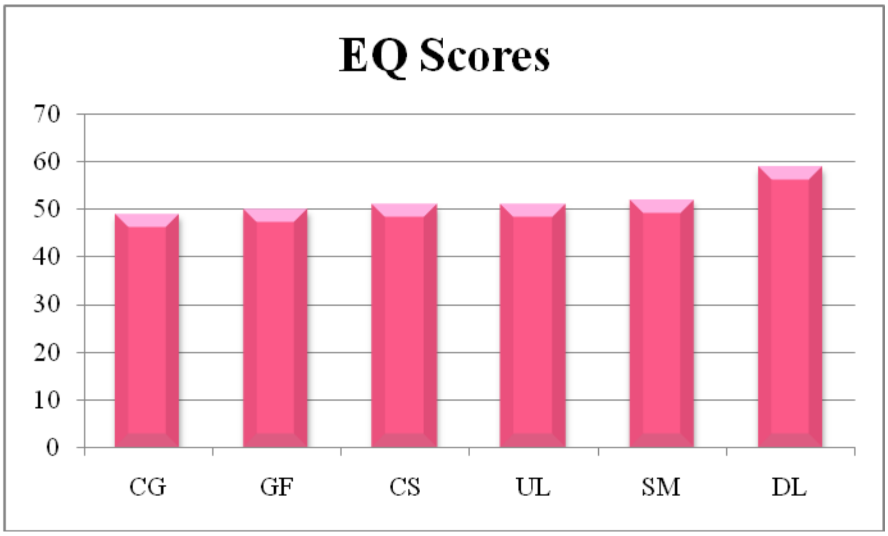

Figure 6.2 Individual EQ scores for female synaesthetes

Male participants scored on average 44 points, which is higher than the male average of 41.8 found by Baron-Cohen and Wheelwright (2004), but this difference is not statistically significant (t(4)=0.81, n.s). The individual male scores (see Figure 6.3) show that most of the tested male synaesthetes scored above the average male score (ranging from 23 to 62); however two of the tested male synaesthetes scored lower than average male score, one of them about 1.5 SD below normal male average.

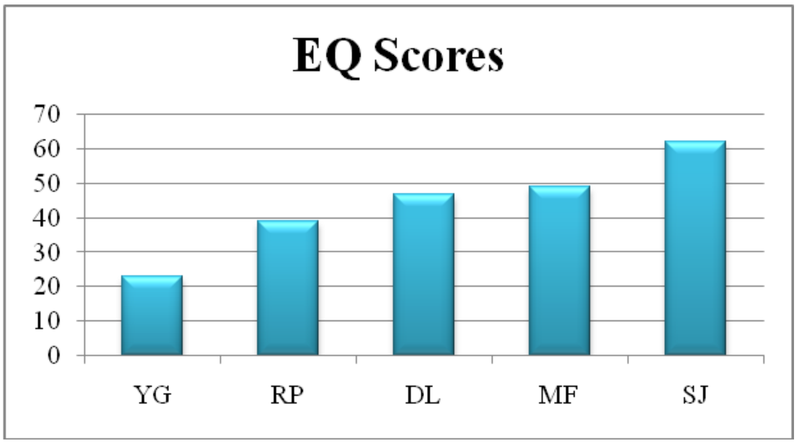

Figure 6.3 Individual EQ scores for male synaesthetes

6.6.2 The Eyes Test

Table 6.3 Mean scores, standard deviations, minimum and maximum scores in the Eyes Test for females, males and all synaesthetes

The Eyes Test	Mean	Min	Max	Std
All synaesthetes	25.3	18	33	4.6
Male	22.6	18	31	5.03
Female	27.5	24	33	3.01

The average scores for all synaesthetes and both genders separately, together with standard deviation, minimal and maximal scores are shown in Table 6.3. On average the synaesthetes scored 25.3, which is only slightly below the average Eyes Test score for the general population of 26 reported by Baron-Cohen *et al.*, (2001). This difference is not statistically significant (t(10) =-0.67, n.s.).

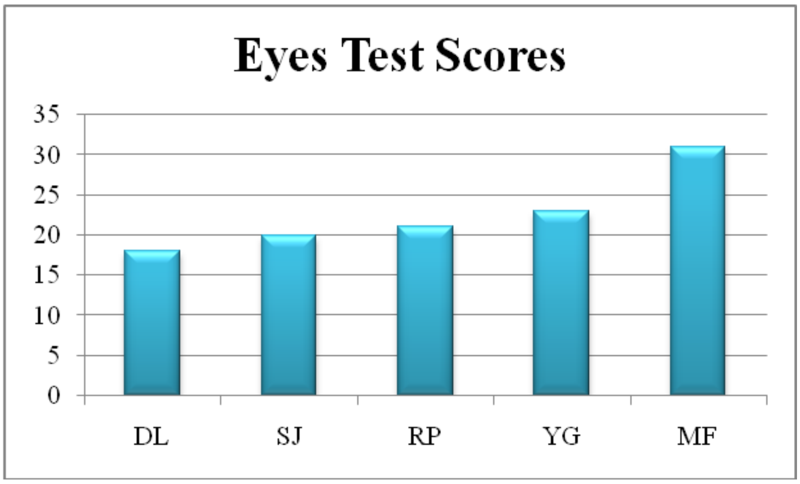

Figure 6.4 Individual scores in the Eyes Test for male synaesthetes

Male participants scored an average of 22.6, which is about 0.8 SD below the normal male average of 26 reported by Baron-Cohen and colleagues (2001), but this difference is not statistically significant (t(4)= -1.5, n.s.). However, individual male scores do vary (the highest score being 31, which is 1.2 SD above the male average).

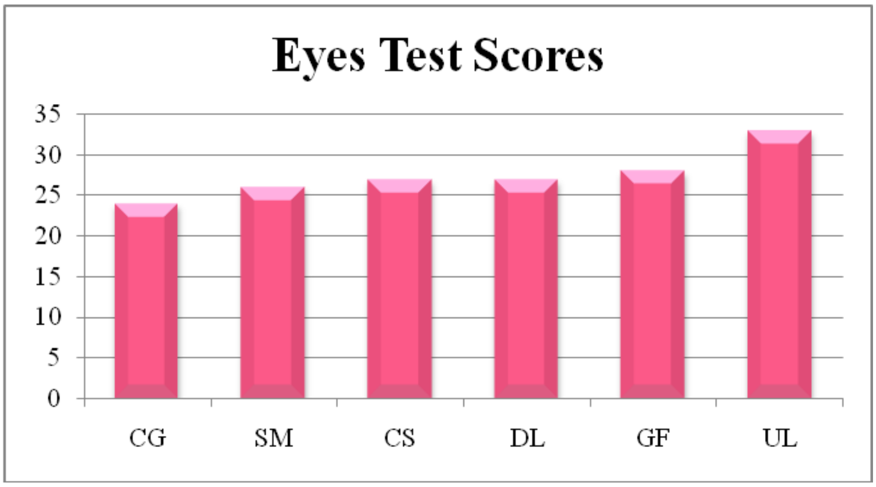

Figure 6.5 Individual scores in the Eyes Test for female synaesthetes

In the case of female synaesthetes, their average score was 27.5, which is above the female average of 26.4 reported by Baron-Cohen and colleagues (2001), but this difference is not statistically significant (t(5)=0.89, n.s.). However, individual scores presented in Figure 6.5 show variability in results – four out of six tested female synaesthetes scored slightly below the normal female average with the lowest score being 24 (about 0.7 SD below the female average), whereas two synaesthetes scored higher than average with the highest score being 33 (about 2 SD above the female average) .

6.6.3 The relationship between synaesthetic personification and aspects of social functioning such as empathy and mentalising

A non-paramteric test Mann-Whitney was carried out to investigate whether synaesthetes who personify linguistic sequences and inanimate objects differ in their empathic and mentalising skills from synaesthetes who personify linguistic sequences only but not inanimate objects. Synaesthetes were grouped according to the extent of their personification. Synaesthetes who personify graphemes or inanimate objects only were in a one group and synaesthetes who personify both graphemes and inanimate objects were in the second group. The results show that these two groups do not differ significantly in empathy (U=6.0; n.s.) and in mentalising (U=16.5; n.s.), suggesting that synaesthetes who personify graphemes and inanimate objects have similar empathy and mentalising skills as synaesthetes who personify graphemes only.

6.6.4 UCLA Loneliness Scale and synaesthetic personification

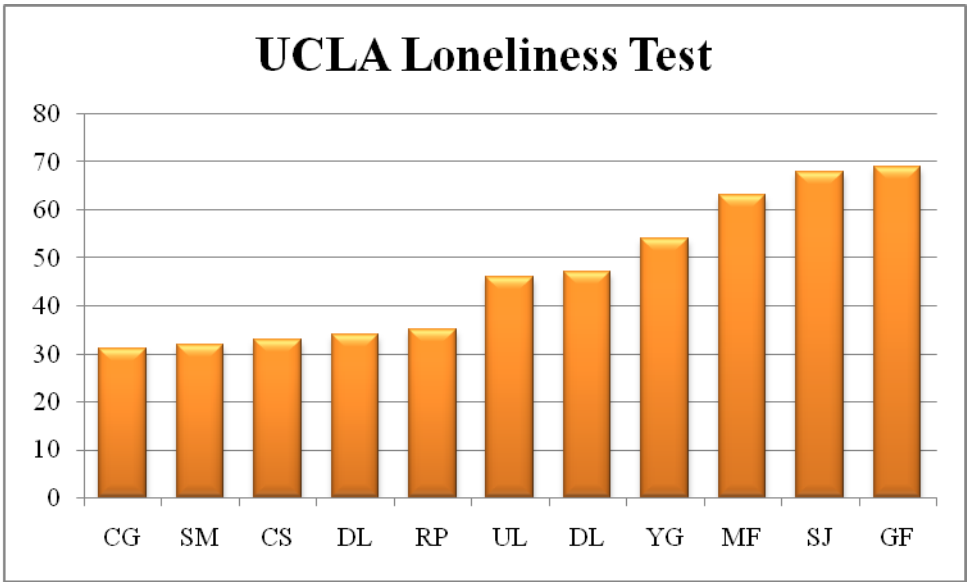

Figure 6.6 Individual scores in the UCLA Loneliness Scale for all synaesthetes

Personifying synaesthetes scored on ULCA Loneliness Scale on average 46.5, with minimum score 31 and maximum score 69 (for individual scores see Figure 6.6). The average score of synaesthetes is above the normal female (36.06) and male (37.06) scores reported by Russel, Peplau and Cutrona (1980). To assess whether the average score of all synaesthetes was significantly different than average scores of the general population, relative loneliness scores were calculated by subtracting the average mean score for the participant's gender from the individual loneliness scores. Analysis of the relative scores using a one sampled t-test showed that there was statistically significant difference in the loneliness of synaesthetes and average loneliness in general population ($t(10)=2.3$, $p<0.05$).

A non-parametrical test Mann-Whitman was used to test for differences in loneliness among personifiers. It was hypothetised that synaesthetes who personify graphemes and inanimate objects feel lonelier and more socially isolated than synaesthetes who personify graphemes only. The results show that synaesthetes who personify more categories of inducers (linguistic sequences and inanimate objects) feel lonelier than synaesthetes who personify linguistic sequences only ($U=25$, $p<0.05$).

6 .7 Discussion

The aim of the current study was threefold: Firstly, I sought to investigate whether empathy and mentalising skills in synaesthetes who personify graphemes and inanimate objects differ from those in the general population. It was predicted that increased tendency to perceive objects as having human-like mental contents and feelings would be associated with heightened empathy and ability to recognise the mental states of other people. Secondly, the study aimed to assess the relationship between synaesthetic personification and social isolation, predicting that personification may be correlated with increased feelings of loneliness and social isolation. Thirdly, I sought to examine the relationship between the range of personification (i.e. whether synaesthetes personify graphemes only or both graphemes and inanimate objects) and degree of social skills shown, such as empathy and mentalising. Specifically, it was aimed to investigate whether empathy and mentalising skills decrease with more extensive personification. These investigations were carried out using following questionnaires - the EQ, the Eyes Test and the UCLA Loneliness Scale.

6.7.1 Is personification in synaesthesia associated with heightened empathy and heightened recognition of mental states?

The results obtained in the study revealed that personifying synaesthetes do not have higher than average ability to recognise mental states from the information received from observing images of the eyes and surrounding areas. However, the results support the prediction that synaesthesia is associated with heightened empathy, but only among female synaesthetes. Male synaesthetes do not differ on average from the general population. Interestingly, a similar trend was observed in the mental states recognition task: Female synaesthetes were slightly better than non-synaesthetic women at recognising mental states, whereas male synaesthetes performed slightly worse than the general male population on this task; however neither of these differences were statistically significant. The results of the current study are congruent with previous findings demonstrating that heightened empathy is not necessary for personifying in synaesthesia (Amin et al., 2011) and provide some additional evidence supporting their hypothesis that there may be two alternative mechanisms underlying personification. The first involves heightened sensitivity to social cues derived from a lower threshold for mentalising and detecting intentionality, which may result in the benign side-effect of also personifying non-human things. The other involves inadequate mentalising processes resulting in a difficulty to read social cues in human interactions as well as application of the mentalising schema in inappropriate contexts (e.g., when thinking about graphemes and objects), perhaps due to reliance on superficial cues. One open question is whether these mechanisms are gender specific, given that the results observed in the current study shows that synaesthetic women but not synaesthetic men have heightened empathic abilities and are slightly better than non-synaesthetic women at mental state recognition. Larger samples will be required in order to establish this, as well as careful control of sampling biases that plague many synaesthesia surveys (e.g., Simner et al, 2006). Another interesting question is why extent of inducers eliciting personification in synaesthesia varies. The results from the current study examined the differences between mentalising and empathy skills in synaesthetes with more and less widespread personification. The results show that these skills are similar in both groups of personifiers. This suggests that regardless of whether synaesthetes personify only graphemes or graphemes and inanimate objects, both groups are equally good at mentalising and sharing affective states with other people.

6.7.2 Loneliness and personification

The results of the current study indicate that synaesthetes who personify graphemes and inanimate objects feel lonelier and more withdrawn from social interactions than non-synaesthetes. Additionally, the findings provide evidence that the level of loneliness experienced increases with the extent of synaesthetic personification. This is consistent with previous findings on personification in non-synaesthetes, in which was shown that lonely individuals are more likely to think of surrounding entities in human-like categories, a tendency whose purpose has been explained as compensating for their lack of social connections with others (Epley et al., 2007; 2008). Presumably, having fewer social interactions gives synaesthetes time and opportunity to ‘interact’ with perceived objects and to endow them with personalities, mental lives, and also with social-like relationships. In fact, greater loneliness may encourage the creation of personalities and social-like relationships among graphemes and inanimate objects, a hypothesis supported by the findings of the current study, which show that the extent of synaesthetic personification increases with the experience of loneliness. The increased feeling of loneliness in personifying synaesthetes and the fact that lonely people react stronger to the negatives (Hawkley and Cacioppo, 2010) corresponds with previous findings in this thesis (Chapter 4), in which the 'lonely objects' paradigm used sad rather than happy facial expressions as primes and was effective in inducing personification in synaesthetes.

An important limitation of the measurement of loneliness in the current study is that loneliness was measured in personifying synaesthetes at the current time of their life and lack information about the childhood experiences of synaesthetes, i.e. whether as a child they felt lonely and isolated. To investigate this further, it would be important to determine whether feelings of loneliness is a relatively stable disposition in synaesthetes or rather related to more situational factors. Future studies on this topic could include investigations that would examine how satisfied/dissatisfied synaesthetes were from their social interactions in childhood and examine environmental factors facilitating social interactions, such as number of siblings, parental educational attitudes and so on. Importantly, the measure of satisfaction/dissatisfaction of social interactions in childhood should be supported by the measures of the time that synaesthetes used to spend with friends, attendance to various additional classes and participation in various peer activities.

6.8 Conclusion

- Empathic abilities among female and male synaesthetes differ – female personifiers have heightened, whereas male personifiers have average emphatic abilities. However some of the male synaesthetes score very low on empathy measures, therefore it is suspected that there may be two different mechanisms underlying personification as previously suggested by Amin et al (2011) and that these mechanisms may be gender specific, but this hypothesis requires further testing. Furthermore, synaesthetes do not differ from the general population in mentalising skills, and mentalising skills in synaesthetes do not change with the increased range of personified inducers.
- Loneliness is associated with personification in the general population, and this same is true for synaesthetes who personify graphemes and inanimate objects. Synaesthetes who feel more socially isolated exhibit a tendency to personify not only linguistic sequences such as graphemes, but also inanimate objects. The similarity between synaesthetes and non-synaesthetes in increased levels of loneliness and tendency to personify suggests the possibility that personification of inanimate objects may be secondary to grapheme personification, arising from the increased need to create social connections with others from the genetic basis for grapheme personification.

Chapter 7 General discussion and conclusion

All human individuals are embedded in the social worlds of others; in the same way other people are part of our social world. Being able to infer what other people think, feel and intend are fundamental social skills. In a variety of situations, mental attributes are ascribed not only to humans but also to inanimate objects and other non-human entities. This happens in sequence personality synaesthesia, a variant of synaesthesia in which mental states and other human qualities are attributed to letters, numbers, time units or inanimate objects. Examining brain function that occurs during synaesthetic personifications of graphemes, ordinal sequences and objects provides a promising means to test theories concerning the neural bases of social cognition, particularly mentalising. In this work, the more specific issue of the identification of the cognitive and neural mechanisms involved in synaesthetic personification and its relation to normal cognition is addressed.

The investigations in this thesis began with an attempt to characterise and explore personification in synaesthesia using a structured questionnaire concerning the nature of experienced personification. Having established from the first study (Chapter 2) that synaesthetic concurrents include rich and elaborate human-like characteristics, in the second study it was aimed to examine whether neural changes in synaesthetes correspond to their subjective reports. This second study is described in Chapter 3. Given that synaesthetes perceive graphemes as if they were people, the results were expected to show changes in brain regions associated with the processing of social stimuli that are usually active when people think of other people in their absence (mentalising system). This examination took the previous case study of neural correlates in synaesthetic personification (Amin et al., 2011) a step further by examining a group of synaesthetes rather than a single synaesthete, but also by testing more elaborate forms of synaesthetic personification than grapheme-gender attribution only. Since the automaticity of synaesthetic pairings is considered to be one of criteria defining synaesthesia, an additional purpose of the study in Chapter 3 was to investigate the type of cognitive processing associated with these inducer-concurrent pairings – whether their processing is under strategic control or lacks firm attentional control. Previous research examined the automaticity of grapheme-gender pairings only, whereas this study extended this investigation by including all social and affective characteristics attributed to graphemes. It was expected that the involuntary character of grapheme-personal characteristics pairings will be reflected in neural responses when synaesthetes focus their attention on an unrelated task. The same argument was employed in Chapter 5, in which the neural basis of object personification was investigated together with the type of processing (voluntary versus involuntary). However, before examining this at the neural level, a further behavioural study was conducted using a Stroop-like paradigm (Chapter 4), in order to provide initial evidence for the lack of firm attentional control in processing of inanimate object personification in synaesthesia. In the final empirical study (Chapter 6), it was examined whether heightened empathy and mentalising skills (as well as social isolation and loneliness) also contribute to personification in synaesthesia (c.f., Epley et al. 2008).

The findings suggest that processes regulating personification of graphemes (Chapter 3) and personification of inanimate objects (Chapter 4 and Chapter 5) lack firm attentional control and appear to be involuntary. At the neural level, the brain regions involved in processing synaesthetic personification of graphemes (Chapter 3) and inanimate objects (Chapter 5) were found to partially overlap with functional anatomy known to be involved in mentalising and other aspects of social cognition, but not with all of them. At the psychological level, neither heightened empathy nor mentalising skills were found to be necessary for synaesthetic personification; however synaesthetes do feel lonelier than average person (Chapter 6).

7.1 Should synaesthetic personification be considered as a type of synaesthesia?

Given that attributions of personality to graphemes and objects do not take the form of simple sensations, but instead include rich biographical descriptions, can synaesthetic personification be considered a variant of synaesthesia? When synaesthetes talk about letters being in love with each other, having jobs, children or blue eyes, how can it be established that this is not purely metaphorical description? Previous studies into this phenomenon have provided some empirical support for classifying such personification as a new variant of synaesthesia. This thesis provides additional evidence showing that such personification satisfies a number of commonly cited criteria for synaesthesia, if not all. To verify the genuine character of synaesthetic personification, a variety of behavioural and neuroimaging methods were used.

In Chapter 3, by using a test-retest method, it was shown that grapheme-personality and grapheme gender pairings in synaesthesia are relatively consistent over time, although in the questionnaire (Chapter 2) some of the synaesthetes reported that the personalities of graphemes may be influenced by factors such as shape, colour or biographical experience of the synaesthete. For example, one of the synaesthetes tested in this study reported that the personality of the letter 'A' will be happier when written in yellow. These results are consistent with previous studies into personification in synaesthesia, which confirm that personal characteristics attributed to graphemes (Simner and Holenstein, 2007; Amin et al, 2011; Simner, Gartner, and Taylor, 2011) and objects (Smilek et al., 2007) do not change over time.

Even if consistency of reported inducer-concurrent pairings is treated as the gold standard in synaesthesia research, to be included in the spectrum of synaesthesia, the synaesthetic correspondences have to be not only consistent over time, but also involuntary and idiosyncratic (Cytowic, 1997; Cytowic and Eagleman, 2009). Previous studies on grapheme-personification established the automaticity of grapheme-gender attribution using Stroop-like interference paradigms, including name-gender discrimination (Simner and Holenstein, 2007) and face-gender discrimination (Amin et al., 2011). A cognitive process is considered automatic when it is goal-independent, non-conscious, load-sensitivity and fast (Moors and De Houwer, 2006). In this thesis, the experiments conducted provided evidence for two of these criteria for automatic processing – that the process is goal independent and non-conscious.

The involvement of attentional control of personal attributions to graphemes was investigated in the functional neuroimaging study reported in Chapter 3. In this study, personifying synaesthetes were visually presented with personified and non-personified graphemes. Participants were asked to press a button whenever they noticed the same letters being presented consecutively. The aim was to see if any personification-related changes in the brain could be observed, even when participants' attention was focused on aspects of presented letters other than their personalities (showing automaticity of personification). Since the stimuli involved in synaesthetic perception of graphemes include social and affective characteristics, the results were expected to show changes in brain regions that were previously reported to be implicated in thinking about mental contents of other people not physically present (Waytz and Mitchell, 2011), but also in anthropomorphic processing (Castelli et al., 2000) when non-synaesthetes think of non-human entities as if they were human. The findings of the study show that even when synaesthetes were instructed to engage in tasks other than focusing their attention on the personifications induced by graphemes, there are changes in brain activations in regions that overlap with the brain regions associated with mentalising and self-projection, including the temporo-parietal junction, precuneus, posterior cingulate and prefrontal cortex. This finding is consistent with the notion that specific synaesthetic inducer-concurrent pairs induce changes in the brain regions known to be involved in processing of those pairs. The results demonstrate that seeing grapheme induces personification even when synaesthetes are engaged a in different task, which implies that grapheme personification in synaesthesia is non-intentional.

In this thesis, it was proposed that inanimate object personification is involuntary; this was investigated in a functional neuroimaging experiment, as well as by using a variation of the Stroop paradigm.

In Chapter 4, synaesthetes who personify inanimate objects and graphemes and a group of controls were presented with images of a ‘lonely’ objects. The images presented showed several identical objects, the majority of which were positioned together in a group but one of which was separated from the rest (imitating a social situation of loneliness and/or rejection). This was followed in the presentation sequence by a target face expressing sadness (the congruent condition) or happiness (the incongruent condition). Synaesthetes also viewed images of grouped objects that were followed by a happy (congruent condition) or sad (incongruent condition) target face. This experiment was designed as a reaction time task, in which synaesthetes were required to decide whether the face presented was happy or sad. The results of the experiment showed that synaesthetes were significantly slower in their responses to incongruent than to congruent trials, suggesting that the feelings attributed to inanimate objects interfere with the process of judging others people’s feelings (at least those indicated by facial expressions). This congruency effect was not observed in controls.

This finding demonstrates two aspects of automaticity in synaesthetic personification of inanimate objects: The observed congruency effect in synaesthetes occurred without conscious monitoring of presented letters moods. Secondly, the congruency effect occurred even though synaesthetes did not focus on similarities between face/object moods correspondences, but instead their task involved discrimination of the facial expression. This strongly suggests that synaesthetes personify objects without intending to do so, but also that they cannot prevent personifying objects. Although the paradigm used did not examine the fastness criterion for automaticity (primes were displayed for 250ms) or load-insensitivity criterion, this experiment provides converging evidence that synaesthetic personification of inanimate objects is, at least in some aspects, automatic and involuntary. It is important to note that in this experiment the personification of inanimate objects in synaesthetes was induced via subtle social cues contained in the separation of one object from the rest rather than being pre-existing association, and synaesthetic attributions of human-like characteristics to inanimate objects formed during the study. This is consistent with the previous case study of TE in which was shown that personalities of objects can be formed following a single encounter with them (Smilek et al., 2007). The formation of new inducer-concurrent pairs is not specific to synaesthetic personification only, it also occurs in grapheme-colour synaesthesia when synaesthetes learn new language they report acquiring colours for new letters (Bergfeld Mills, 2002).

Additional evidence for lack of firm voluntary control of inanimate object personification is provided in Chapter 5. In the functional neuroimaging experiment, a synaesthete and a control group were presented with the same two sets of images displaying the same objects that were used in the Stroop-like experiment conducted in Chapter 4: in some images one object was separated from the other objects, while in the other images all objects were presented grouped together. Initially, all participants were kept unaware as to the real aim of the experiment and were asked to perform an unrelated task (to press a button when they saw a green frame around the images). This was meant to show whether a limited cue (spatial separation versus clusterring) could induce involuntary personification that is reflected in changes in neural activity in the brain areas associated with mentalising and anthropomorphic thought. Indeed, such changes were observed in the temporo-parietal junction, the precuneus and the posterior cingulate in the tested syanesthete GF, but not in the control group. It is important to note that even when control participants were asked to think of objects as if they had feelings, the observed activations in GF who was focusing her attention on unrelated task, were still greater than in controls. This provides additional evidence that the resulting activations in the tested synaesthete are likely to be due to processing that lacks firm attentional control rather than intentional or deliberate strategies.

Furthermore, GF showed a similar pattern of activations and even more extended activations when asked specifically to consider the feelings of objects. It is possible that this pattern of activation was observed because GF focused her attention on the 'social aspects' of the situation in the images. This is a reasonable conclusion, since GF was not engaged in performing any additional, unrelated task and she was allowed to focus her attention on the 'feelings of objects'. Therefore it is not surprising that the activations were larger than when GF was performing another cognitive task, unrelated to the objects personification task. This indicates that personification of inanimate objects can be modulated by attentional load, which is not uncommon in social cognition. For example, when we walk to work and pass other pedestrians, we do not necessarily think about their mental states, feelings or personality traits, and may only process the most salient cues (e.g., an angry face, or loud laughter). However, when we decide to focus our attention on the mental contents of those people, then we are able to infer more about their mental states.

In general, the findings obtained in this work provide converging evidence that personification can be considered as a variant of synaesthesia (or at the very least, share many features with other types of synaesthesia). The investigation showed that synaesthetic social and affective characteristics of graphemes are consistent over time, vary across synaesthetes and have involuntary character, thus fulfilling the definitional criteria of synaesthesia, according to which synaesthesia is a neurological phenomenon, in which a stimulus either evokes a perceptual experience in another sensory modality or triggers processing in another cognitive domain/stream and the inducer-concurrent pairings are consistent over time, involuntary and idiosyncratic (Hubbard, 2007).

7.2 Synaesthetic personification and its relationship to normal cognition

Two aspects of the relationship between normal cognition and synaesthetic personification were investigated. It was aimed to examine the neural correlates of synaesthetic personification and their relationship to brain functions, and also the relationship between development and synaesthetic personification.

7.2.1 Neural correlates of synaesthetic personification and brain functions

The functional neuroimaging studies described in Chapter 3 and Chapter 5 investigated which brain regions are involved in personification of graphemes and inanimate objects. The precuneus and temporo-parietal junction were found to be activated in synaesthetic personification of both graphemes and inanimate objects. Additional brain regions activated during grapheme personification included the insula and the medial prefrontal cortex, and for inanimate objects personification, the posterior cingulate cortex. These brain areas overlap with regions known to be involved in mentalising and self-reflection, suggesting that common mechanisms implement both synaesthetic personification and social cognition.

The precuneus has been previously implicated in synaesthetic attribution of gender to graphemes (Amin et al., 2011). This brain region also is known to be involved in the processing of mental imagery (Cavanna and Trimble, 2006) and has been proposed to be a nodal structure for self-reference (Abu-Akel and Shamay-Tsoory, 2011), given that it has functional connections with the inferior parietal lobule and medial prefrontal cortex. The precuneus, together with the posterior cingulate cortex and medial prefrontal cortex, have been associated with explicit and implicit self-referential processing (Rameson, Satpute and Lieberman, 2010). The medial prefrontal cortex is a crucial brain region for the perception of people and understanding of the social aspects of other mental agents (Mitchell et al., 2005). This area is active not only when participants listen to stories testing mentalising, for example, the ‘burglar story’ (Happe, 1994), but also when they are shown a set of objects and asked to assess whether a particular person, for instance Christopher Columbus, would know how to use them (Goel et al., 1995). Studies that used purposefully moving shape stimuli (following Heider and Simmel, 1944) showed that viewing induces spontaneous attribution of intentions and other mental contents to those shapes and that this is associated with activation in the medial prefrontal cortex and temporo-parietal junction (Castelli et al., 2000). Similarly as with the medial prefrontal cortex, the temporo-parietal junction is considered to be a key brain region involved in mentalising (e.g., Frith, 2007). The temporo-parietal junction has been proposed to be necessary in perspective taking (Ruby and Decety, 2004) and necessary for inferring the mental states of others since lesions in the left temporo-parietal junction impair this process (Samson et al., 2004). The insula is implicated in empathy, but is also active during the ‘rubber hand’ illusion indicating the insula’s importance in integrating information from diverse functional systems (Craig, 2009; Kurth et al., 2010). Furthermore, evidence from neuropsychology suggests that lesions of the right (and sometimes left) parietal cortex may produce misattributions of agency that itself sometimes involves animistic attributions expressed in delusional misidentifications of body parts and attribution of personalities to limbs, giving the misidentified arms or legs nicknames names such as “George” or “Floppy Joe” (Critchley 1955, p. 286).

Given that synaesthetic percepts in personification are not limited to the ‘mental states’ of graphemes (e.g., G likes to be in the centre of attention; 5 is stressed), but also include elaborate biographical information such as age, profession, gender, relationships, etc, can it be still claimed that common mechanisms implement synaesthetic personification and mentalising? The results of the studies described in this thesis suggest that all these various aspects of concurrents in personification rely on the same set of brain areas. In fact, these brain regions are implicated in the processing of episodic memory, which is known to have autobiographical reference (Tulving, 1983). This makes sense in the light of the fact that some of the tested synaesthetes reported that their graphemes' personalities reminded them of people they knew in the past (for details, see Chapter 2), suggesting that even though synaesthesia is congenital, autobiographical experiences can influence characteristics attributed to graphemes. In this thesis, the brain changes observed to occur in response to synaesthetic personification are explained as being induced by the co-activation of self-related social processing that is not recognised as originating in one's self; rather they are projected onto graphemes or objects and attributed to them. This, in turn, leads to subjective experiences of personification of graphemes and objects that comprise of one's own mental state representations, personality traits and other biographical experiences. In view of the fact that, in most people, 'social brain' regions are activated generally rather than selectively in response to the perception of other people, it is reasonable to assume that synaesthetes have a lower threshold for activation of the social brain regions and this facilitates simulation processes of social contents in response not only to people, but also to graphemes and objects. This assumption is rooted in the simulation theory, particularly in its consideration of the self-projection mechanism - a type of simulation that is used to infer mental states of others when they are not physically present. This mechanism is used when people cannot rely on using observable perceptual cues, such as bodily movement or facial expressions to infer the mental states of others, and instead imagine themselves inhabiting the mind of another person (Mitchell, 2009). Its relevance for synaesthetic personification lies in fact that personification is induced by inanimate non-human things, which do not provide real observable social behaviour that would allow an observer to endow them with mental contents. Instead, the (induced by them) self-referential processing is not recognised as constructed by their own minds and attributed to graphemes and inanimate objects. Therefore, the misidentification of the source of the mental state and personality traits perceived may underlie the attribution of human-like characteristics that occurs in sequence-personality synaesthesia. This is consistent with the developmental explanation for personification in synaesthesia proposed by Sobczak-Edmans and Sagiv (in press) maintaining that personification may be an excessive manifestation of the general human tendency to perceive social reality using the self as a model.

However, it is important to note that this interpretation of the neuroimaging results collected for personification of graphemes (Chapter 3) and inanimate objects (Chapter 5) is limited by the fact that the brain areas activated by synaesthetic personification are found to be activated not only in mentalising processes but also in the processing of various other functions. For example, the precuneus and temporo-parietal junction, the posterior cingulate and medial prefrontal cortex have been implicated in attentional processes (Small et al., 2003; Cavanna and Trimble, 2006; Young, Dodell-Feder and Saxe, 2010). Therefore, it is possible that the observed activations are not only driven by the self-projective mentalising, but may be related to attentional processes (see Chapter 5), such as attentional shift towards more engaging stimuli, namely graphemes and objects endowed with personal attributes. This does not contradict the hypothesis developed in this thesis that the self-projection mechanism underlies synaesthetic personification. In fact, this supports the hypothesis, given that it was proposed that the distinction between the self and other in mentalising is mediated by attention systems (Abu-Akel and Shamay-Tsoory, 2011).

7.2.2 The relationship between synaesthtic personification and development

Synaesthetic personification is similar to animistic thought in childhood, the phenomenon of children thinking of non-human things as endowed with life and consciousness. Similarly, to synaesthetes, graphemes are not only linguistic units but appear as alive, having various personality traits, racial backgrounds, body-build and facial features, social roles, attitudes, mental states, moods and cognitive abilities. Moreover, as described in detail in Chapter 2, letters and numbers are perceived as being part of communities, having social roles (e.g. ‘secretary’, ‘teacher’, ‘undergraguate student’), various attitudes towards each other, power-based relationships (e.g., ‘the others led him lead without objection’), belong to families (`A is mother to all numbers’) and have romantic relationships (e.g., ‘G is I’s girlfriend’). Given that animistic thought has been suggested to be a type of indiscriminate mentalising, in which the source of mental states is attributed to external things and not to the self (Rappoport and Fritzler, 1969), it is possible that, analogously to animistic thought, personification in sequence personality synaesthesia manifested in indiscriminate mentalising is a residual expression of developmental animistic perception. This is in line with Meltzhoff’s hypothesis that “recognition of self–other equivalences is the foundation ….of social cognition” (2007, p.126), which, together with the recognition that the people are ‘like me’, consitutes the basis for development of mentalising.

In most children animistic thought diminishes in intensity when they become older, however, as shown in this thesis, synaesthetes (even in adulthood) still show a tendency to see non-human things as human-like, suggesting that personification in synaesthetic adults is a tendency to perceive that other things are 'like me' (Sobczak-Edmans and Sagiv, in press). This is in agreement with the results from the study in Chapter 3 showing overlapping brain activations for grapheme personification, mentalising and autobiographical memory. These results suggest that graphemes induce in synaesthetes self-related social processing (e.g. representations of one's own mental states, personality traits and biographical experiences) that is not recognised as one's own, and the outcome of this processing is projected onto graphemes and attributed to them. If this is true, this 'like me' processing in synaesthetic personification results from misattribution of agency from the self to graphemes and objects, similarly as observed in developmental animism. The elaborate and detailed anthropomorphic descriptions of graphemes and inanimate objects presented in Chapter 2, together with findings of the functional experiments in Chapter 3 and Chapter 5 provide converging evidence supporting the claim that synaesthetic personification constitues a residual expression of animistic thought observed in the development of social cognition (Sobczak-Edmans & Sagiv, in press). This is consistent with the neonatal hypothesis of synaesthesia, according to which all people are born as synaesthetes. Typically developing adults lose synaesthesia as result of increasing functional specialisation in the brain, whereas in synaesthetes this process is interrupted and leads to synaesthetic sensations (Maurer, 1997).

7.3 Implications for synaesthesia research

Implications for synaesthesia research that emerge from the studies on synaesthetic personification in this thesis are that synaesthesia includes not only purely perceptual concurrents, but also concurrents from the social cognition domain. Synaesthetic inducer-concurrent pairs are not necessarily pure perceptual stimuli, but instead are higher-level concepts. They are constant over time, involuntary and idiosyncratic. Therefore, as previously suggested by Simner (2011), the definitional criteria of synaesthesia should be revised to include higher order concepts as possible inducers and concurrents in synaesthesia.

Concurrents in sequence-personality synaesthesia are drawn from autobiographical experience, which demonstrates that synaesthesia is not completely genetically pre-determined and can be influenced by environmental factors. This explanation emphasizes the role of associative learning in acquiring synaesthesia during development; therefore future studies could investigate personification in children. These could try to establish what determines the initial genders and personal characteristics being attributed to graphemes and objects, whether they arise from the childhood's animistic thought and how they relate to the linguistic gender acquisitions.

Personification in synaesthesia and mentalising share a neural basis and it is likely that they utilise the same self-projection mechanism. This suggests that personifying synaesthetes have increased sensitivity for noticing social cues in the environment than non-synaesthetes, which is manifested on phenomenological, behavioural and neural levels.

7.4 Implications for social cognition

One way of looking at the mentalising problem is examining anthropomorphic thought. Given that the tendency to perceive non-human entities as human-like is much stronger in sequence-personality synaesthesia than in the general population, testing synaesthetes could provide clearer insight into these processes and also shed light on the relationships between social functions and anthropomorphic thought. As shown in this thesis, synaesthetic and non-synaesthetic personifications differ. However, testing personifiers of different ages and comparing them with non-synaesthetes could potentially inform how we develop understanding of the minds of others. This could be done by using age-related social cognition tasks, together with a longitudinal investigation of functional neuroanatomy. Object personification seems to be more common and elaborate with familiar objects and personal belongings, rather than with novel objects. Similarly, reduplicative paramnesia often involves places, people, objects and body parts. Considering this similarity, it is suggested that further examination of synaesthetic personification could also shed light on these types of disorders and help us to understand better why people with brain dysfunction reduplicate only things ‘belonging’ to the patient.

7.5 General limitations and future research

One major limitation of the studies in this thesis is the limited number of participants, which is mainly due to the fact that personification in synaesthesia is not very frequent in the population (about 1.4%; Simner and Holenstein, 2007). Despite this limitation it is still possible to gain increased understanding of the cognitive and neural processes underlying this phenomenon. However, the small number of synaesthetes tested gives rise to the question of whether these findings can be generalised to other synaesthetes. The best way of determining this will be to test more personifying synaesthetes in the future using the same or similar paradigms.

Further limitations of the studies testing the involuntary character of graphemes and inanimate objects were that only two aspects of automaticity were tested: goal independence and non-conscious character, but not fastness and load-insensitivity. Despite the fact that the findings of the studies provide enough evidence to draw a clear conclusion for automaticity of personification in synaesthesia, it would be interesting to see whether or not all of these criteria are satisfied. Future experiments could include testing of additional conditions, in which primes will be displayed for shorter times (e.g., 80 ms, 60ms) to examine whether synaesthetic personification affects the very early stages of information processing. To test whether personification is insensitive to the cognitive load, neuroimaging studies could include conditions in which unrelated to personification tasks have an increasing level of difficulty (e.g., 1, 2 and 3 back task).

Finally, the scope of the current study did not include many important aspects of general social cognition in synaesthetes. This was due to the fact that priority was given to the examination of the cognitive and neural processes underlying synaesthetic personification, since empirical investigations into sequence-personality synaesthesia have to date been rare. Nonetheless, drawing on the findings from this thesis indicating the involvement of mentalising processes in sequence-personality synaesthesia, future investigation could probe the various aspects of social cognition, including perspective taking and self-other processing in personifying synaesthetes.

7.6 Concluding remarks

The work presented in this thesis has provided evidence that synaesthetic experience goes beyond the exclusively perceptual inducer-concurrent pairings. Instead, synaesthesia can include conceptual concurrents, such as social characteristics of graphemes and objects. This has predictable behavioural consequences and identifiable neural correlates consistent with the phenomenology, as in classical synaesthesia variants. This provides a broader perspective of how synaesthesia can be understood and poses new questions about the criteria accordingly to which synaesthesia should be defined.

Given that this peculiar phenomenon of graphemes having ‘mental lives and relationships’ shares some of the underlying neural mechanisms with ordinary social cognition, it is proposed that the tendency to personify non-human agents may reflect a developmental process that facilitates the acquisition and practice of the skills necessary for understanding the minds of other people. Thus, the study of synaesthetic personification provides scientists with a window into normal social cognition.

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Appendix A: Consent Form

CONTACT DETAILS:

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***Dr Noam Sagiv**, Centre for Cognition and Neuroimaging, Brunel University, Uxbridge UB8 3PH. Tel: +44 (0)1895 265341, e-mail:* noam.sagiv@brunel.ac.uk

Synaesthesia, cross-modal correspondences and individual differences in perception and imagery

What is synaesthesia?

We rarely stop to think about it and typically assume that everyone sees the world just like we do, but some people's mental imagery is richer than others'. People with synaesthesia experience a 'mixing' of the senses. For example some people think about numbers of time as having a particular pattern in space or have other associations (e.g., thinking about odd numbers as male and even numbers female). Synaesthesia is not harmful or disruptive and seems to be more common that previously assumed. About 1 in 10 individuals reports one variant of such phenomena but many do not realise it is unusual in any way.

What are the aims of the research?

The aim of the research is to understand the cognitive, developmental and biological basis of synaesthesia. This might also tell us more about ordinary perceptual experiences and its relationship to thinking, memory and language.

What is involved with taking part?

First of all, you will be asked to fill in a general questionnaire and to describe synaesthetic experiences that you may have. We would appreciate your participation even if you don't think you may have synaesthesia. We also ask about other individual differences and will try to find out if such differences are more common in synaesthetes than in non-synaesthetes.

You do not have to answer all the questions if you feel uncomfortable about it. However, it is useful for our research to gain as complete a picture as possible and all information you give will be treated in confidence. Following this, we may contact you again (by either phone, e-mail or letter) to invite you to take part in further behavioural and neuroimaging studies. These will involve basic tests of memory or perception. None of the tasks are harmful or stressful. You are under no obligation to take part, and you may refuse to take part for whatever reason and without giving any explanation.

Will my data be kept confidential?

Your personal details (name, address, etc.) will not be passed on to anybody else outside of our research group without first gaining your written consent. You will be referred to in our records and in any publications by your initials (or another code such as participant number), in accordance with the data protection act.

Please fill in the following :

Name of participant ***:***

Address :

____

____

Telephone number :

____

E-mail :

____

I have read the information above and I agree to take part in the study. I understand that I may withdraw at any point in the future.

Signed (by participant) : ___________________________ Date : ___________________

If I have any concerns or complaints regarding the way in which the research is or has been conducted I may contact Professor Taeko Wydell, Chair of the Psychology Research Ethics Committee, at taeko.wydell@brunel.ac.uk

Appendix B: DEBRIEFING FORM

CONTACT DETAILS:

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Supervisor of this experiment:

***Dr Noam Sagiv**, Centre for Cognition and Neuroimaging, Brunel University, Uxbridge UB8 3PH. Tel: +44 (0)1895 265341, e-mail:* noam.sagiv@brunel.ac.uk

Synaesthesia, cross-modal correspondences and individual differences in perception and imagery:

Information for participants

We rarely stop to think about it and typically assume that everyone sees the world just like we do. However, we may be wrong about this. There are substantial individual differences in mental imagery. Such differences are not immediately apparent because we hardly ever talk about it. Perhaps the most striking phenomenon is synaesthesia. People with synaesthesia experience a 'mixing' of the senses. For example, visualising colours when thinking about letters of the alphabet, days of the week or when listening to music. Other sensory combinations are possible (e.g., involving taste, smell or touch). Some people think about numbers or time as having a particular pattern in space or more rarely people may have other associations (e.g., thinking about odd numbers as male and even numbers as female). Synaesthesia is not harmful or disruptive and seems to be more common than previously assumed. About 1 in 10 individuals reports one variant of such phenomena but many do not realise it is unusual in any way. The spatial associations are most common, followed by colour associations.

The aim of our research is to understand the cognitive, developmental and biological basis of synaesthesia. This might also tell us more about ordinary perceptual experiences and its relationship to thinking, memory and language.We are also interested in other individual differences in mental imagery and whether they are more common in individuals who have synaesthesia than in the rest of us. Thus, even if you don't have synaesthesia, we are interested in your responses.

If you would like to hear more about our finding or you have synaesthesia and would like to participate in future studies, please feel free to contact us (see contact details above; in the subject line of your e-mail please state: SYNAESTHESIA RESEARCH). The following information sources may be of interest:

Internet resources

Synesthesia Resource Center (including audio/video links) http://www.bluecatsandchartreusekittens.com/

Dr. Noam Sagiv's homepage http://people.brunel.ac.uk/~hsstnns/

Journal articles on synaesthesia

Sagiv N & Ward J (2006). Cross-modal interactions: Lessons from synesthesia. *Progress in Brain Research* 155, 263-275. Available online at: http://eprints.assc.caltech.edu/224/

Martino, G. & Marks, L.E. (2001). Synesthesia: Strong and weak. *Current Directions in Psychological Science* 10, 61-65. Available online at: http://www.psychologicalscience.org/members/journal_issues/cd/CDIR1027.pdf

Books on synaesthesia

Ward J (2008). The Frog Who Croaked Blue: Synesthesia and the Mixing of the Senses. *Routledge*

Patricia Lynne Duffy (2001). *Blue Cats and Chartreuse Kittens: How Synesthetes Color Their Worlds*. New York: Henry Holt.

Appendix C: Personifications Questionnaire

SECTION1

1. **Do you think about letters and/or numbers as having personalities, moods, genders, appearance or social interactions/functions? (please circle or underline)**

Letters:

genders yes no **personalities** yes no **feelings** yes no

Numbers:

genders yes no **personalities** yes no **feelings** yes no

↓ In the column marked '**Gender**', we would like you to write the gender of the letter/number, as either m (= male) or f (= female) or leave a dash if you don't feel strongly either way.

↓ In the columns marked '**0-9**', please indicate how confident do you feel about each letter's (number's) gender, personality, physical appearance, and/or social role on a 0 to 9 scale (where 0 = no feelings, and 9 = a very strong feeling). You can use the entire range of numbers (if some feelings are stronger than others) or repeat the same numbers (if the intensity doesn't vary much).

↓ In the columns marked **'Personality Traits & Moods'**, '**Appearance'** and **'Social Role & Relationships'** we would like you to describe succinctly and to the best of your ability the personality traits (e.g. bossy), physical appearance (e.g. tall, old), social role (e.g. brother, king, leader) of any of the letters and numbers below, and relationships/interactions between them. If you don't experience anything at all then just put a dash in the column.

↓ In the column marked '**Liked/Disliked'**, please indicate whether you like or don't like particular letter/number. Write either (**+**) when you like or (**-**) when you don't like number/letter. Leave space when letter/number is neutral to you.

Letter	Gender (f/m)	0-9	Personality Traits & Moods	0-9	Appearance	0-9	Social Role & Relationships	0-9	Liked/ Disliked
A									
B									

C									
D									
E									
F									
G									
H									
I									
J									
K									
L									
M									
N									
O									
P									
Q									
R									
S									
T									
U									
V									
W									
X									
Y									
Z									

No	Gender (f/m)	0-9	Personality Traits & Moods	0-9	Appearance	0-9	Social Role & Relationships	0-9	Liked/ Disliked
0									
1									
2									
3									
4									
5									
6									
7									
8									
9									

2. Are these properties stable? Do they ever change? For example, if you are feeling sad, do the moods exhibited by letter and/or number reflect that or change a bit? Please explain
……
……
……
…….

3. **Do you think about** OBJECTS **as having personalities, genders, human-like appearance or social interactions/functions? (please circle or underline)**

Objects:

genders	yes	no	**personalities**	yes	no
attitudes	yes	no	**feelings**	yes	no

↓ In the column marked **'Personified Object',** we would like you to write an example of particular object from each category to which you attribute genders and/or personalities (e.g. your mobile in the category 'personal objects'). N B 'Personal Objects' refer to small objects that you use every day e.g. personal mug at work etc.

↓ In the column marked '**Gender'**, we would like you to write the gender of the object. Write either m (= male) or f (= female) or leave a dash if you don't feel strongly either way.

↓ In the columns marked '**0-9**', please indicate how confident do you feel about each object's example gender, personality, physical appearance, and/or social role on a 0 to 9 scale (where 0 = no feelings, and 9 = a very strong feeling). You can use the entire range of numbers (if some feelings are stronger than others) or repeat the same numbers (if the intensity doesn't vary much).

↓ In the columns marked '**Personality Traits & Moods**', '**Appearance'** and **'Social Role & Relationships'** we would like you to describe succinctly and to the best of your ability the personality (e.g. bossy), physical appearance (e.g. tall, old), social role (e.g. brother, king, leader) of any of the numbers and objects below, and relationships/interactions between them. If you don't experience anything at all then just put a dash in the column.

Please see an example below…

Object Category	**Personified Object**	**m/f**	**0-9**	**Personality Traits & Feelings**	**0-9**	**Appearance**	**0-9**	**Social Role & Relationships**	**0-9**
Personal Objects	*my mobile*	*f*	*4*	*Cooperative, sad etc*	*8*	*Girly, young*	*9*	*Like an elder sister*	*7*

Table3

Object Category	Personified Object	m/f	0-9	Personality Traits & Feelings	0-9	Appearance	0-9	Social Role & Relationships	0-9
Personal Objects									

Body Parts									
Clothes									
Vehicles									
Furniture									
Tools									
Buildings									
Plants									
Food									
Natural Objects (e.g. rocks)									
Toys									
Simple Shapes									

SECTION 2

1. **Do certain numbers and letters have characteristics that influence your personification, and have you noticed any patterns? (something that makes it more likely for you to personify the form, or assign a gender to the form, for example the shape of a letter, it's position in the alphabet, it's the first letter in a familiar person's name, the sound it evokes, it's colour etc.)**

....

....

....

....

....

....

....

2. **Under what conditions do you feel alphanumeric forms and objects have genders and/or personalities? (If yes to a condition, please indicate how strong this feeling is on a 6 point scale)**

	Strongly agree	Moderately agree	Mildly Agree	Mildly disagree	Moderately disagree	Strongly Disagree
When I see a number/ letter/ object	1	2	3	4	5	6
When I hear a number/ letter/object's name	1	2	3	4	5	6
When I think about particular letter/number/ object	1	2	3	4	5	6
When I see a word	1	2	3	4	5	6
When I see a multi-digit number	1	2	3	4	5	6
When I see a group of objects	1	2	3	4	5	6
When I see an object for the first time	1	2	3	4	5	6

Other (please give details)

…..………..…...
………………………………….

………
………
………
……………………………………………………………………………………………………..

3. **How often do you experience this type of synaesthesia? (circle or underline)**

   (a) On a daily basis…

   (b) On a weekly/monthly basis…

   (c) Sometimes…

   (d) Rarely…

   (e) Other (please give details) ……………………………………………………………………

   ………..

4. **Please complete this item if you speak more than one language or read more than one alphabet. Do you personify letters in all languages/alphabets? Please list languages below and circle (underline) the appropriate number.**

LANGUAGE	Strongly agree	Moderately agree	Mildly agree	Mildly disagree	Moderately disagree	Strongly disagree
1st=__________	1	2	3	4	5	6
2nd=__________	1	2	3	4	5	6
3rd=__________	1	2	3	4	5	6
4th=__________	1	2	3	4	5	6

Similarly looking letters in different alphabets have the same personality/gender (e.g., P in English and Russian) YES NO

Similarly sounding letters in different alphabets have the same personality/gender (e.g., R in English and P in Russian) YES NO

Further details: ……

5. Do you personify other symbols, e.g., Greek letters, Roman numerals etc…?

Yes No

If yes, please give details
……
……
…………

6. Do your personifications of letters/numbers change with a size/style or colour of the font?

Yes No

If yes, please give details
……
……
…………………………………………………………………….

7. Do you associate genders and/or personalities with objects depending on the familiarity of the particular object to you (e.g. you associate personality/gender to your personal pen but not to every pen). Please circle (or underline):

[personal object = unfamiliar object]

[personal object>unfamiliar object]

[personal object<unfamiliar object]

8. How old were you when you first began feeling that letters, numbers and/or objects had genders and/or personalities? ………….

Has this feeling become stronger or weaker with age? …………………………..

9. Have letters, numbers and/or objects personalities changed since, for example matured a bit? Did they behave more like children?

Please explain…….

SECTION 3 – ADDITIONAL INFORMATION

We are very interested in synaesthetes subjective experiences. Please use this section to give us any further information about your experience of genders and/or personalities that is not covered above (e.g. for moths or the days of the week), or to add more detail to your answers.

Week Days & Months

Do you think about week-days as having personalities or genders? (please circle)

Genders? YES NO Personalities? YES NO

Do you think about months of the year as having personalities or genders? (please circle)

Genders? YES NO Personalities? YES NO

↓ under '**m/f'** write the gender of the week day, month, as either m (= male) or f (= female) or leave a dash if you don't feel strongly either way.

↓ under '**0-9**', please indicate confident you feel about each gender or personality on a 0 to 9 scale (where 0 = no feelings, and 9 = a very strong feeling).

↓ under '**personality**', please describe succinctly and to the best of your ability the personality of any of the week days and months

	m/f	**0-9**	**personality**	**0-9**
Monday				
Tuesday				
Wednesday				
Thursday				
Friday				
Saturday				
Sunday				

	m/f	**0-9**	**personality**	**0-9**
January				
February				
March				
April				
May				
June				
July				
August				

September				
October				
November				
December				

Thank you very much for your time!

Please Note: Your personal details will not be passed onto anybody else outside of our research group without first gaining your written consent. You will be referred to in our records and in any publications by your initials (or other code), in accordance with the data protection act. You are under no obligation to take part, and you may refuse to take part at any point for whatever reason and without giving any explanation.

Appendix D: INITIAL SCREENING FORM

ROYAL HOLLOWAY, UNIVERSITY OF LONDON
MAGNETIC RESONANCE IMAGING UNIT

INITIAL SCREENING FORM

NAME OF PARTICIPANT ……………………………………………………   Sex: M / F

Date of birth………………………   Approximate weight in kg…………   (one stone is about 6.3 kg)

Please read the following questions CAREFULLY and provide answers. For a very small number of individuals, being scanned can endanger comfort, health or even life. The purpose of these questions is to make sure that you are not such a person.

You have the right to withdraw from the screening and subsequent scanning if you find the questions unacceptably intrusive. The information you provide will be treated as strictly confidential and will be held in secure conditions.

	Delete as appropriate
1. Have you been fitted with a pacemaker or artificial heart valve?	YES/NO
2. Have you any aneurysm clips or shunts in your body, or a cochlear implant?	YES/NO
3. Have you ever had any metal fragments in your eyes?	YES/NO
4. Have you ever had any metal fragments, e.g. shrapnel in any other part of your body?	YES/NO
5. Have you any surgically implanted metal in any part of your body, other than dental fillings and crowns (e.g. joint replacement or bone reconstruction)	YES/NO
6. Have you ever had any surgery that might have involved metal implants of which you are not aware?	YES/NO
7. Do you wear a denture plate or brace with metal in it?	YES/NO
8. Do you wear a hearing aid?	YES/NO
9. Do you use drug patches attached to your skin?	YES/NO
10. Have you ever suffered from any of: epilepsy, diabetes or thermoregulatory problems?	YES/NO
11. Have you ever suffered from any heart disease?	YES/NO
12. Is there any possibility that you might be pregnant?	YES/NO
13. Have you been sterilised using clips?	YES/NO
14. Do you have a contraceptive coil (IUD) installed?	YES/NO
15. Are you currently breast-feeding an infant?	YES/NO

Please enter here the name and address of your doctor (general practitioner):

I have read and understood the questions above and have answered them correctly.

SIGNED…………………………………   DATE…………………………

In the presence of …………………………………. (name) …………………………………..(signature)

Address of witness, if not the experimenter: