# Towards a Synergistic Understanding of Synaesthesia

## Combining Current Experimental Findings With Synaesthetes' Subjective Descriptions

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ABSTRACT: In synaesthesia, ordinary stimuli elicit extraordinary conscious experiences. For example, standard black digits may elicit highly specific colour experiences and specific tastes may elicit unusual tactile sensations. The growing interest in synaesthesia has led to numerous experimental studies of this phenomenon. The purpose of this paper is to review these recent studies and to discuss the relationship between the results of these experimental investigations of synaesthesia and the subjective descriptions reported by synaesthetes. It is argued that when the experimental investigations of synaesthesia are interpreted in the context of synaesthetes' subjective reports, the experimental investigations synergistically advance our understanding of synaesthesia. Ultimately we suggest that a more complete understanding of this fascinating phenomenon will require a clearly articulated combination of well-designed experimental studies and the subjective reports of synaesthetes.

## 1. Introduction

Imagine for a moment, that every time you heard a particular sound or viewed an ordinary black digit, you experienced an accompanying perception of a highly specific colour. Although for most people such experiences are completely beyond the realm of normal, for some, such occurrences characterise their typical day-to-day experiences. The term given to these extra-ordinary experiences is *synaesthesia.* For some synaesthetes the stimulus and the elicited experience occur in the same modality (e.g., printed digits or letters trigger colours called photisms). For others the inducing stimulus and the elicited experience cross modalities. For example, taste can elicit tactile experiences (e.g., Cytowic, 1989; 1993), or sounds can elicit colours (e.g., Wheeler, 1920).

Since the first formal description of synaesthesia in 1812 by Dr. G. T. L. Sachs (cited in Dann, 1998), a number of approaches have been used to investigate synaesthetic experiences. Early studies focused on *introspective reports* of synaesthetes in order to investigate the phenomenology of their experiences (see Wheeler, 1920 for a review). Numerous studies have also focused on the *psychophysical relationships* between inducing stimuli and the resulting synaesthetic qualia (see Marks, 2000; 1975 for reviews). Although both approaches have been very successful in providing insight into this fascinating phenomenon, the most recent investigations of synaesthesia have used a different method. This novel approach constitutes a growing body of literature focused on *experimental* investigations of synaesthetic experiences.

One purpose of the present paper is to review these recent experimental investigations. Accordingly, the first section of this paper discusses the recent experimental studies of synaesthesia and the theoretical implications of these studies. A second, and equally important purpose of the present paper is to discuss the relationship between the results of experimental investigations of synaesthesia and the subjective descriptions reported by synaesthetes. This issue is discussed in the second section of the paper. Ultimately, we argue that when the experimental investigations of synaesthesia are interpreted in the context of synaesthetes' subjective reports, the experimental investigations synergistically advance our understanding of synaesthesia. Furthermore, we argue that a complete understanding of synaesthesia will require *combining* experimental investigations of synaesthesia with the subjective reports of synaesthetes.

# 2. Experimental Studies of Synaesthesia

## 2.1 Consistency

Experimental investigations of almost all psychological phenomena are fundamentally based on the assumption that the phenomena show some consistency or regularity over time. Experimental investigations of synaesthesia are no exception. It is not surprising, therefore, that one of the first steps towards subjecting synaesthesia to experimental scrutiny has been to document the consistency with which particular stimuli elicit specific synaesthetic experiences. The available evidence suggests that while the pairings between eliciting stimuli and the resulting synaesthetic experiences differ widely between synaesthetes, for any given synaesthete, there appears to be high consistency of the pairings between eliciting stimuli and synaesthetic experiences over time (e.g., Baron-

Cohen, Harrison, Goldstein, & Wyke, 1993; Baron-Cohen, Wyke, & Binnie, 1987; Dixon, Smilek, Cudahy, & Merikle, 2000; Mattingley, Rich, Yelland, & Bradshaw, 2001; Odgaard, Flowers & Bradman, 1999 ; Svartdal & Iversen, 1989).

A good example of a study showing how the pairings between inducing stimuli and synaesthetic experiences are consistent over time is a study reported by Baron-Cohen et al. (1987). Baron-Cohen et al. (1987) tested the synaesthete EP who reported experiencing specific colours upon hearing words, letters and numbers. In an initial session EP and a non-synaesthetic control participant were asked to give detailed descriptions of the colours of 103 auditorily presented stimuli that consisted of meaningful words, names and alphanumeric characters. This initial session was then followed by a similar session completed ten weeks later by the synaesthete and two weeks later by the non-synaesthete. The results showed that EP's pairings between the eliciting stimuli and colours were 100% consistent across the initial and subsequent sessions. In contrast to the high consistency shown by EP, the non-synaesthete showed only 17% consistency across the initial session and a similar session conducted only two weeks later. These results suggest that the EP's pairings between the eliciting stimuli (i.e., words, names and alphanumeric characters) and synaesthetically experienced colours are highly consistent across time and that this consistency is much higher than would be expected based on normal memory performance alone. This high consistency shown by EP and many other synaesthetes described in the literature indicates that in synaesthesia, there are strong enduring associations between eliciting stimuli and the corresponding synaesthetic experiences.

As we review the different experimental studies of synaesthesia, it will become readily apparent that the consistency of the pairings between eliciting stimuli and synaesthetic experiences is a fundamental cornerstone of each of these studies. Because the same inducers invariably elicit the same synaesthetic experiences in a given synaesthete, researchers have been able to systematically explore how synaesthetic experiences influence cognition.

## 2.2. The Automaticity of Synaesthetic Experience

Synaesthetes often claim that their synaesthetic experiences occur independent of their intentions. For example, C, a digit-colour synaesthete, claims that as soon as she sees the digit 2, she experiences the colour red, whether she wishes to or not. In fact, the prevalence of such subjective reports has led some to speculate that the involuntary nature of synaesthetic experiences is one of the main diagnostic criteria of synaesthesia (e.g., Cytowic 1993; Dann, 1998). Subjective reports of synaesthetes regarding the involuntary nature of their synaesthetic experiences are interesting because they suggest that the processes underlying synaesthetic experiences may be automatic.

Investigations of the automaticity of synaesthetic experiences have typically been conducted with alphanumeric-colour synaesthetes using a variant of the Stroop task

(Stroop, 1935). For example, Wollen and Ruggiero (1983) presented the letter-colour synaesthete AN with cards containing either coloured disks, or letters painted in colours that were either congruent or incongruent with AN's photisms for the letters. The idea was that if a photism was an automatic consequence of letter identification, then the photism should interfere with naming the ink colour of these letters on incongruent cards. Consistent with this hypothesis, AN's colour-naming reaction times (RTs) were significantly longer for cards containing incongruently coloured letters, than cards containing congruently coloured letters or coloured disks. Similar results were reported by Mills, Boteler and Oliver, (1999), who tested a digit-colour synaesthete (GS) using an almost identical methodology. Like AN, their synaesthete took significantly longer to name the colours of incongruently coloured digits than cards containing either congruently coloured digits or cards containing coloured disks. Similarly, Odgaard, Flowers and Bradman (1999) demonstrated that a digit-colour synaesthete took significantly longer to name cards containing incongruently coloured digits than cards containing coloured Xs (a baseline condition). These findings have been taken to "support the idea that synaesthesia is an automatic process" (Mills, et al., 1999 pg. 186).

Ardent critics of these results may point to a number of methodological flaws of these studies. In all of these studies, the stimuli in each of the critical conditions were grouped on cards, and reaction times were recorded by stopwatch upon completion of an entire card. With such a methodology it is unclear what effect individual errors had on overall reaction times. Also, because the different conditions in the experiments were blocked (i.e., on different cards), participants' expectations may have led them to implement different strategies across conditions. Finally, the unreported error rates in Wollen and Ruggiero (1983) make it impossible to rule out the possibility that speed-accuracy tradeoffs contributed to their results. These methodological problems make it difficult to draw any firm conclusions from these studies.

Recently, we corroborated the previous findings using a methodology that circumvented the problems inherent in the previous studies (Dixon, Smilek, Cudahy, & Merikle, 2000). In our experiment, C, a digit-colour synaesthete was presented with either coloured squares (baseline condition) or an incongruently or congruently coloured digit (incongruent and congruent conditions respectively) on a computer screen. C's task was to name the video colour of the presented stimulus into a microphone as fast as possible while maintaining high accuracy. Colour-naming reaction times were recorded with millisecond accuracy and errors were also recorded for each trial. Baseline, congruent and incongruent trials were randomly intermixed. The results showed that C's colour naming RTs for incongruent trials (797 ms, 2.8% errors) were significantly slower than her RTs for congruent trials (552 ms, 1.4% errors) and baseline trials (545 ms, 0.0% errors). Similar results were found when the experiment was repeated with C, indicating the reliability of this phenomenon (Dixon, Smilek & Merikle, submitted). The markedly slower reaction times noted when C attempted to name the colour of incongruently coloured digits suggested that photisms could not be inhibited. C's results were also compared to a group of eight non-synaesthetes who showed no differences in their responses to stimuli that, for C, were congruent or incongruent. These results corroborate previous findings and suggest that synaesthetic colour experiences do indeed occur automatically.

Whereas each of the Stroop studies discussed thus far investigated only one synaesthete, Mattingley, Rich, Yelland and Bradshaw, (2001) studied the automaticity of synaesthetic experiences in a group of 15 synaesthetes. The synaesthetes who participated in this study reported experiencing colours to letters, digits and words. Mattingley et al. (2001) conducted two separate experiments in which 15 synaesthetes and 15 non-synaesthetes named the colour of alphanumeric stimuli that were presented individually on each trial. As in previous studies, the colours of the stimuli were either congruent or incongruent with the synaesthetes' photisms. In one experiment congruent and incongruent trials were presented in separate blocks and in the other experiment the congruent and incongruent trials were randomly intermixed and a baseline condition, which consisted of non-alphanumeric symbols that did not induce photisms, was added. The results of both experiments showed that the synaesthetes were slower at naming the colours of alphanumeric characters on incongruent trials than congruent trials. In contrast to the synaesthetes, the group of non-synaesthetes showed no differences in their responses to stimuli that were congruent or incongruent for the synaesthetes. Thus, the results from this group study corroborate the previous single subject investigations of synaesthesia and suggest that for those with digit- and letter-colour synaesthesia, photisms are an automatic consequence of viewing externally presented alphanumeric stimuli.

Taken together, six studies have shown that synaesthetes demonstrate large Stroop effects when they attempt to name the colour of congruently or incongruently coloured digits whereas, non-synaesthetic controls fail to show any congruent/incongruent RT differences when naming the colour of these stimuli. Most would agree that the often large Stroop effects shown by synaesthetes clearly demonstrate the general idea that in alphanumeric-colour synaesthesia, an alphanumeric stimulus automatically elicits a representation of a colour. However, often a more specific claim is implied, namely, that the Stroop effects shown by synaesthetes are caused by automatically elicited *perceptual experiences* of colour rather than automatically elicited *semantic* representations of colour. But, can one reasonably believe that the large Stroop effects shown by synaesthetes are the result of *perceptual experiences* of colour rather than automatically elicited *semantic* representations of colour?

An important finding that must be considered when answering this question is that non-synaesthetes that have been specially trained to associate colour labels with uncoloured forms can also show large Stroop effects. MacLeod and Dunbar (1988) trained non-synaesthetic observers to associate novel nonsensical uncoloured shapes with colour labels (i.e. each time a participant saw an elliptical shape they would say "blue"; each time the participant saw an amoeba-type shape they would say "red" etc.). Following thousands of such training trials participants were once again presented the shapes they encountered in training, only now the shapes appeared in colours that were either congruent or incongruent with the labels used in the training regimen. Thus, the shape that was associated with the label "red" would be presented either in red (a congruent trial) or in blue, green, or yellow (incongruent trials). Participants were asked to ignore the shape and concentrate on naming the video colour of the shapes as quickly as possible. Importantly, these participants demonstrated large Stroop effects characterized by slower reaction times on incongruent than congruent trials.

The finding that non-synaesthetes can be trained to associate colour labels with uncoloured forms and that this training can lead to large Stroop effects, has important implications for the interpretation of the Stroop effects shown by synaesthetes. Most would agree that the Stroop effects shown by individuals trained to associate colours with shapes are likely the result of trained *semantic* associations between colour labels and shapes. In Macleod and Dunbar's (1988) study it was presumably the trained semantic associations between colours and shapes rather than synaesthesia-like perceptual experiences of colour that interfered with colour naming on incongruent trials. Therefore, the results of MacLeod and Dunbar's study, taken together with the results of the synaesthesia Stroop studies indicate that both synaesthetes who perceptually experience synaesthetic colours as well as specially trained non-synaesthetes who likely did not have such synaesthetic experiences can show equally large Stroop effects. Because the Stroop effects shown by synaesthetes and non-synaesthetes can be equivalent, one might argue that the Stroop effects shown by synaesthetes could be attributed solely to the semantic associations between alphanumeric stimuli and colours rather than to the interference effects of perceptually experienced photisms.

We believe that before concluding that the Stroop effects shown by synaesthetes are simply the result of semantic associations between alphanumeric stimuli and colours, there is another piece of data that must be considered, namely, the subjective reports of the synaesthetes regarding their experiences during the Stroop experiments. For example consider the digit-colour synaesthete C. When C describes viewing a black 2, she says she sees a black digit with a red overlay sitting atop the black 2. When C is presented with an incongruently coloured digit, she claims that she has the perception of two different colours (i.e., the physical colour and her photism), and that this dual perception is a *subjectively jarring experience.* Furthermore, C also reports that digits have induced these colour overlays as far back as she can remember and that unlike the participants in the study of Macleod and Dunbar (1988), she reports never undergoing a formal external training regimen in which digits were associated with colours. We suggest that if these subjective reports are taken at face value, they indicate that C's large colour-naming Stroop effect is not merely due to trained semantic associations, but is, at least in part, a result of the perceptual colour overlay that C experiences as part of her synaesthesia. We stress the point that Stroop results should be interpreted in light of participants' subjective reports. For synaesthetes like C, digits elicit a conscious, externally projected *percept* of colour. For the subjects in MacLeod and Dunbar's (1988) study we doubt this would be the case. Thus, although both synaesthetes and extensively trained non-synaesthetes might show equivalent Stroop effects, if the subjective reports are considered, it can be concluded that the Stroop effects shown by synaesthetes and non-synaesthetes are the result of markedly different processes.

## 2.3. Synaesthetic Colour Experiences and Normal Perceptual Colour Experiences

How do the processes underlying synaesthetic colour experiences compare to normal perceptual colour experiences? Although subjective reports of synaesthetes have proven invaluable in interpreting many experimental findings, some aspects of synaesthetic experiences may be less amenable to subjective insights than others. One aspect of synaesthesia that is likely *not* amenable to subjective insight is the *relative* degree of automaticity of the processes underlying synaesthetic and normal colour experiences. While synaesthetes have useful insight into the fact that perceiving a digit "automatically" leads to a colour experience in much the same way as perceiving a colour patch "automatically" leads to a colour experience, it may be too much to ask for synaesthetes to make accurate judgements pertaining to the relative degree of automaticity of these processes. Because subjective reports are not likely to be useful in assessing the relative automaticity of the processes underlying synaesthetic colour experiences and normal colour experiences, researchers must draw upon the patterns of data that accrue when synaesthetes participate in various experimental paradigms. Based on these data patterns it is possible to gauge the relative automaticity of synaesthetic and normal colour experiences.

To date, only one study has assessed the *relative automaticity* of the processes underlying synaesthetic colour experiences and normal perceptual colour experiences (Dixon et al., submitted). To assess the relative degree of automaticity, the digit-colour synaesthete C performed two different Stroop tasks. In one task, C named the *colours* of squares (baseline condition) and the colours of coloured digits. In the other task, C named the *photisms* that she associated with black digits (baseline condition) and with coloured digits. In both tasks, the coloured digits were presented in colours that were either congruent or incongruent with the colours of C's photisms for the digits. The critical comparison in this experiment was the magnitude of the RT difference between congruent and incongruent trials when C named colours (i.e., the magnitude of the colour naming Stroop effect) relative to the magnitude of the RT difference between congruent and incongruent trials when C named her photisms (i.e., the magnitude of the photism naming Stroop effect). The assumption underlying this comparison was that the relative sizes of C's colour naming and photism naming Stroop effects would reflect the relative degree of the automaticity of both her synaesthetic experiences and her normal perceptual experiences of colour. Concretely, if C's synaesthetic photisms are more automatic than her normal colour experiences, then the synaesthetic photisms elicited by the digits should be harder to ignore than actual colour of the digits appearing on the computer screen. In other words, the interference produced by an incongruent photism on colour naming should be greater than the interference produced by an incongruent colour on photism naming. In this case the observed Stroop effect should be larger when C names the colours of digits than when she names the photisms associated with each digit.

The results showed that the difference in RT between congruent and incongruent trials was much larger when C named the colours of the digits and attempted to ignore the photisms than when C named the photisms associated with the digits and attempted to ignore the physical colours the digits were presented in. In other words, the results showed that C's photisms elicited by the digits interfered more with her colour naming than the colours of the digits interfered with her photism naming. The fact that there was greater interference when C named colours and ignored photisms than when C named photisms and ignored colours strongly suggests that the processes underlying C's synaesthetic photisms are more automatic than the processes underlying C's normal perceptual colour experiences.

The relative degree of automaticity of synaesthetic photisms and the processes underlying normal colour perceptions may be an important individual difference between synaesthetes and may correlate with individual differences in the subjective experiences of synaesthesia. For example, synaesthetic photisms may be more automatic than normal perceptual colour experiences only in cases such as C's, where the synaesthetic photisms are experienced as being projected externally onto the presented digit. For synaesthetes who experience their photisms in the "mind's eye", it may very well be the case that the processes underlying their normal colour perceptions are more automatic than their synaesthetic colour experiences. Preliminary evidence from a number of synaesthetes in our laboratory suggest that this is indeed the case, however, greater numbers of "mind's eye" and "projector" type synaesthetes must be tested before we can firmly establish whether such individual differences in the relative automaticity of synaesthetic photisms and normal colour perceptions occur and whether they correlate with individual differences in the subjective experiences of synaesthesia.

While the relative automaticity of the processes underlying C's synaesthetic experiences and her normal colour perception appear to differ, the same is not true for the relative speeds of these processes. We evaluated the relative speeds of the processes underlying C's synaesthetic colour experiences and her normal perceptual colour experiences by using naming speeds. Specifically, we compared the speed with which she named her photisms associated with black digits to the speed with which she named the colours of coloured squares. We measured C's speed of responding using a single-trial methodology where reaction times were recorded with millisecond accuracy and errors were recorded for individual trials. The results showed that the RTs and errors for naming colours and photisms did not differ.

The available evidence from two other cases of synaesthesia also suggests that photism and colour naming speeds do not differ (Mills et al., 1999; Wollen & Ruggiero, 1983). Wollen and Ruggiero (1983) compared the letter-colour synaesthete AN's RTs for photism naming (cards containing black letters) to the RTs for colour naming (cards containing coloured disks). They found no significant difference between the RTs for photism and colour naming. Similar results were found by Mills et al. (1999), who studied the digit-colour synaesthete GS. They also found no significant difference between the RTs associated with photism and colour naming. Taken together the available evidence from three different synaesthetes suggests that in letter- and digit-colour synaesthesia the speeds of the processes underlying synaesthetic colour experiences and normal colour perceptions do not differ.

## 2.4. Synaesthetic Photisms Influence Responses to Subsequent Stimuli

There are now a number of studies which suggest that synaesthetic photisms elicited by one stimulus can have an effect on responses to a subsequently presented stimulus (Mattingley et al., 2001; Odgaard et al., 1999). Studies investigating the effects of photisms elicited by one stimulus on responses to a subsequently presented stimulus have used a variant of the priming procedure. On each trial of this procedure, participants are first presented with an initial stimulus (prime), which is then followed by another stimulus (probe) that is either related or unrelated to the prime. The speed and accuracy with which participants respond to related and unrelated probes are recorded. Any differences between the speed or accuracy of participants' responses to related or unrelated probes are referred to as *priming effects.* The pattern of results characterised by faster or more accurate responses to related probes than unrelated probes is referred to as *positive priming* and the opposite pattern of results, characterised by faster or more accurate responses to unrelated probes than related probes, is referred to as *negative priming.* The available evidence regarding priming effects in digit- and letter-colour synaesthesia suggests that synaesthetic photisms associated with an alphanumeric prime can lead to both positive priming as well as negative priming of responses to a subsequently presented coloured probe stimulus.

Evidence supporting the notion that synaesthetic photisms elicited by alphanumeric characters can lead to positive priming comes from a large-scale study conducted by Mattingley and his colleagues (2001). In this experiment, 15 synaesthetes and 15 normal controls were presented a sequence of stimuli consisting of an alphanumeric character (prime), a mask, and a coloured patch (probe). On each trial of the experiment, the colour of the patch was either congruent or incongruent with the colour of the photism associated with the alphanumeric prime presented just prior to the presentation of the coloured patch on that trial. When the alphanumeric primes were presented for 500 ms such that observers were aware of the prime, the results showed that synaesthetes were much slower at naming the colours of the coloured patch on incongruent trials than congruent trials. In contrast to these results, the non-synaesthetes showed no difference in reaction times on congruent and incongruent trials. These results suggest that the synaesthetic photism associated with an alphanumeric character can positively prime a colour naming response to a subsequently presented colour patch.

There is also some evidence which suggests that synaesthetic experiences elicited by an alphanumeric stimulus can lead to negative priming of a response to subsequently presented colour stimulus. Support for this notion comes from a study reported by Odgaard et al. (1999). In this study a digit-colour synaesthete, L, named the colours of a sequence of incongruently coloured digits. The stimuli were presented on separate cards and the reaction time was measured upon the completion of each card. As L named the colours, her responses were recorded and accuracy was measured for each card. For present purposes there were two important conditions in this study. In one condition, the incongruently coloured digits were presented on the card in a random order. In the other condition, the digits were ordered such that the colour in which a given digit was presented was the same colour as the colour of the ignored photism associated with the preceding digit. The results showed that L's colour naming was much slower when the incongruently coloured digits were ordered than when they were randomly organised. These results suggest that when the incongruently coloured digits were ordered such that the colour in which a given digit was presented was the same as the colour of the ignored photism on the preceding trial, the ignored photism negatively primed the naming of the colour of a subsequent digit.

Although the priming effects shown by synaesthetes can be interpreted as resulting directly from synaesthetic perception of colour, the priming effects can also be interpreted as resulting solely from semantic associations between alphanumeric characters and colours. Indeed, standard priming effects obtained with non-synaesthetes are typically observed when the semantic relationships between prime and probe are varied (e.g., Tipper, 1985). Just as priming effects can result from varying semantic relationships between primes and probes in non-synaesthetes, the priming effects that have been observed with synaesthetes may also be the result of semantic relationships between alphanumeric characters and colours. According to this interpretation of synaesthetic priming effects, when digit- or letter-colour synaesthetes are presented with an alphanumeric character, the activation of the semantic representation of the character would lead to semantic and possibly lexical activation of a particular colour, which would then influence colour naming of a subsequently presented colour stimulus. Consistent with this alternative, Odgaard et al. (1999) suggest that the negative priming effects that they found provide evidence that "lexical activation may have an even more substantial role in synaesthetic processing than simple sensory processing" (Odgaard et al., 1999, pg. 656). Unfortunately, because synaesthetes' subjective descriptions of their experiences during the priming experiments were not reported in the available studies, the subjective descriptions of synaesthetes cannot help us determine whether perceptual experiences are directly involved in producing priming effects. Therefore, while the results from priming tasks may provide strong evidence that colours and digits are associated in digit- and letter-colour synaesthesia, and that these associations can have an effect on responses to other stimuli, the priming tasks may not directly assess a critical aspect of alphanumeric-colour synaesthesia, namely that the colours associated with digits and letters are experienced as conscious percepts.

## 2.5. Assessing Perceptual Aspects of Synaesthetic Photisms

The question of whether alphanumeric-colour synaesthesia involves conscious percepts of colour is a question of fundamental importance to synaesthesia. In a recent paper, Ramachandran and Hubbard (2001) addressed this question using perceptual grouping. They studied two synaesthetes (J.C. and E.R.) who reported that they "saw" synaesthetic colour "spatially in the same location as the form" (p. 979) of visually presented graphemes. In this study, the two synaesthetes and 40 non-synaesthetes were briefly presented (i.e., for one second) with matrices comprised of approximately 45 small graphemes. For example one matrix was comprised of Hs, Ps and Fs. Prior to being shown the matrix, the participants were informed that the H's would be aligned is such a way as to form the borders of either a square, a rectangle, a diamond or a triangle. Participants were asked to indicate which of these shapes was formed by the designated grapheme. The task was made difficult by the presence of distractor graphemes (in this case the Ps and Fs) that were randomly located around the shape formed by the designated grapheme. Synaesthetes and non-synaesthetes were presented with numerous matrices such as this, and accuracy for correctly detecting the shape formed by the designated grapheme was recorded. The rationale underlying the experiment was that if the synaesthetes experienced conscious percepts of colour when viewing the displays of black graphemes, then the synaesthetes might be able to perceptually group the graphemes by their synaesthetic colours and thus be more accurate at identifying the shape formed by the designated graphemes than the non-synaesthetes who could not use synaesthetic colours to group the graphemes. The results showed that the synaesthetes were indeed more accurate at identifying the shapes formed by the designated graphemes than the non-synaesthetes, leading Ramachandran and Hubbard (2001) to conclude that synaesthetes experience a conscious percept of colour when viewing black digits or letters.

In our most recent work, we have also focused on assessing the perceptual aspects of synaesthetic photisms. When C, a digit-colour synaesthete that we have studied is shown a standard black digit, she experiences a dual perception. She sees the black digit, but also experiences a red overlay that sits atop the black digit. This coloured overlay conforms to the shape of the presented digit and completely covers the digit. Importantly, C experiences this coloured overlay "out there, on the page" rather than in her mind's eye. C describes being able to attend to either the presented black digit, or to the photism that lays atop this digit. However, she reports that the photism is the more dominant of the two perceptions. We used C's subjective descriptions of her projected photisms to devise an experiment that would inform us about the perceptual characteristics of these photisms (Smilek, Dixon, Cudahy and Merikle, 2001). Our premise was a simple one: If C experiences a black digit in colour, then the digit should be harder to see when the digit is presented against a background that is the same colour as her photism for the presented digit, than when the digit is presented against a background that differs in colour from her photism for the presented digit. Concretely if a black 2 is experienced as red, then this synaesthetically perceived "red" 2 should be harder to perceive against a red background than against a green background.

In one experiment C's task was to identify black digits that were briefly presented and followed by a pattern mask. On each trial, the colour of the background was varied so that it was either congruent or incongruent with the photism associated with the presented digit. Consonant with our predictions, C was significantly poorer at identifying a black digit when the digit was presented against a background that was congruent with her photism for that digit (e.g., a synaesthetically perceived "red" 2 against a red background) than when the digit was presented against a background that was incongruent with her photism for the digit (e.g., a synaesthetically perceived "red" 2 against a green background). In contrast to C's results, a group of seven non-synaesthetes showed no difference between their performance on congruent and incongruent trials. We (Smilek et al., 2001) interpreted these results as showing that C's synaesthetic experiences influenced her perception of the black digits.

In another experiment based on the same rationale, C attempted to localize a black target digit (either a 2 or a 4) embedded among black distractor 8's. As in the previous experiment, the colour of the background was varied such that it was either congruent or incongruent with C's photism associated with the target digit on that trial. The results showed that C was significantly slower at localizing the target digits on congruent trials than incongruent trials. In contrast to C's results, a group of seven non-synaesthetes showed no difference between their performance on congruent and incongruent trials. These results are consistent with the findings of the previous experiment and further corroborate the conclusion that C's synaesthetic experiences influenced her perception of the black digits.

Based on these findings, we (Smilek et al., 2001) proposed a model stipulating how synaesthetic photisms influence perception of digits in the visual system. Two of the basic premises of our model are that 1) information flows through the visual system in cascade form rather than in discrete stages (e.g., Humphreys, Riddoch and Quinlan, 1988), and 2) information flows through the visual system along both "feedforward" and "feedbackward" connections (e.g., Enns & Di Lollo, 1997; Grossenbacher & Lovelace, 2001). Ultimately we believe that for synaesthetes like C, who experience their photisms as being projected "out there on the page", the synaesthetic photisms influence perception of digits as a result of feedback connections from anterior fusiform and posterior inferior temporal (PIT) areas back to area V4, located along the bank of the collateral sulcus of the fusiform gyrus. Like non-synaesthetes, when C views a black digit, information concerning the form of the digit likely cascades forward through striate cortex to the fusiform gyrus. Posterior areas of the fusiform gyrus processes the form of the digit and area V4 on the bank of the collateral sulcus processes the colour of the digit (in this case black). Information regarding the form and colour of the digit then cascades forward to anterior fusiform areas where the meaning of the digit is processed (see Allison, McCarthy, Nobre, Puce & Belger, 1994). We postulate that C's processing of the digit differs from non-synaesthetes in that for C, colour information based on the meaning of the digit is fed from anterior fusiform areas back to area V4 where colour is processed. Importantly, perception does not occur all at once, but rather accrues over successive cyclical iterations - low level areas contact higher areas using feedforward connections and high level areas contact lower level areas using feedbackward connections, with the forward and reentrant signals cycling over and over again until a conscious percept emerges. Figure 1 shows a concrete example of how C's perception of a black 2 could lead to a red synaesthetic experience according to our model. Concretely, we propose that when the various straight and curved line segments that comprise a 2 are computed in striate cortex and posterior fusiform areas, this information cascades forward leading to activation in anterior fusiform areas associated with the meaning of a 2. Crucially, on initial iterations this partial activation of meaning may not be enough to signal a conscious experience that a 2 was presented, but will still lead to the concept of a 2 being more activated than other concepts (e.g., 3, 5, b, d). Nevertheless, even though this partial activation of the concept of a 2 does not lead to a conscious experience of a 2, it will still activate feedback connections that ultimately synapse in areas of V4 corresponding to the colour red. Over successive iterations of this reentrant circuit, signals along feedforward connections will continue to increase the activations for the concept of 2, and these in turn will lead to signals being propagated along feedbackward connections that will increase activations for the colour red. As this information cascades along feedforward and feedbackward pathways the perception that gradually accrues over successive iterations will be that of a synaesthetically red 2.

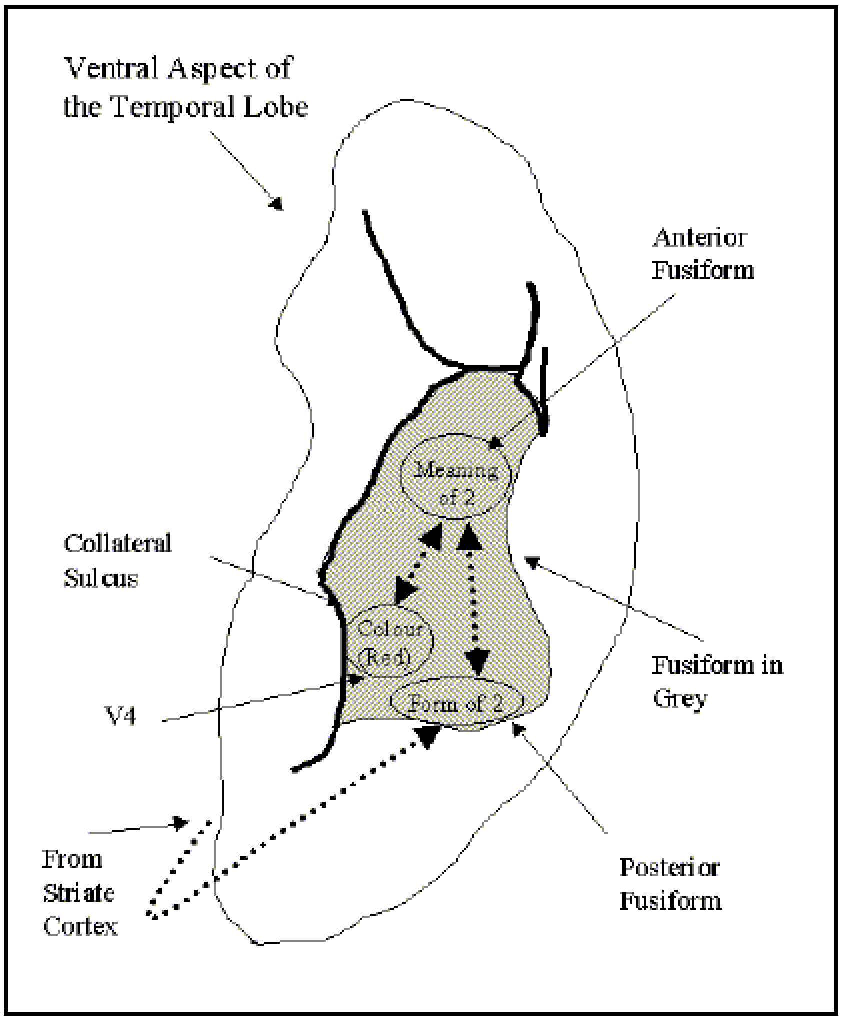


**Figure 1.**

**A schematic representation of the critical pathways that we believe are involved in the activation of the synaesthetic colour *red* when C views the digit *2.* Arrows with broken lines depict the flow of information. Double-headed arrows depict both feedforward and feedbackward connections.**

If one assumes that even partial activation of meaning can back-activate colour in V4 then one can easily understand why C would find it easier to identify masked digits when they are presented against background colours that are different than her photism colours. If a 2 is presented against a blue background, the 2 will partially activate the concept of 2, which will, in turn, activate the experience of a red photism via feedback connections from PIT to V4. As perception accrues, C will begin to perceive a red 2 against a blue background. If, however, a 2 is presented against a red background, the perception that will accrue over successive iterations is one of a red 2 against a red background. As a result, the digit will be harder to segregate from the background and hence will be harder to identify or localise than when the background colour is different from the photism colour. While at present this model is still highly speculative and more experimental data is required to confirm the premises that underlie the model, the data do conclusively show that somehow, the endogenously produced photism colour can influence C's perception of black digits.

At first, the neural model we (Smilek et al., 2001) forwarded may seem inconsistent with the findings of a brain imaging study reported by Paulesu, Harrison, Baron-Cohen, Watson, Goldstein, Heather, Frackowiak and Frith (1995). Paulesu et al. (1995) used positron-emission tomography (PET) to study the brain activation of six women who experienced colour-word synaesthesia and six women who reported no synaesthesia. The colour-word synaesthetes in this study experienced coloured photisms only to words presented auditorily and did not experience photisms to either visually presented words or auditory stimuli that were not words. When listening to words, the synaesthetes showed significantly greater activation than non-synaesthetes in the prefrontal cortex<1>, insula, superior temporal gyrus and visual association areas (i.e., posterior inferior temporal (PIT) cortex). The results also showed no differences between synaesthetes and non-synaesthetes in the activations of areas V1 and V2. Importantly, however, while there was increased activation in area V4 for the synaesthetes compared to the non-synaesthetes, this increase did not reach the predetermined criterion for significance. These results suggest that the synaesthetic experiences associated with hearing words in colour-word synaesthesia involve higher-level visual association areas (i.e., PIT) but do not involve activation of V4 or primary visual cortex. At first glance these findings do not seem to support the model that we forwarded because we postulated that activation in V4 was critical to C's synaesthetic experiences but the PET study showed that activation in V4 was not significantly greater for the synaesthetes than the non-synaesthetes.

One reason that the PET findings of Paulesu, et al., (1995) may not directly support our model (Smilek et al., 2001) is that this study was based on synaesthetes who experienced photisms only to auditory stimuli whereas our model was based on the study of a synaesthete whose photisms were elicited by visually presented alphanumeric characters and were experienced as being projected externally onto the characters. For this reason we proposed that whereas synaesthetic photisms induced by auditory stimulation may not involve V4 activation, synaesthetic photisms induced by visual stimulation, which are experienced as being projected onto and conforming to the shape of alphanumeric characters, do involve V4 activation.

It is important to remember that there is large variability in the subjective experiences of synaesthetes. Given this variability, there is likely not one single pattern of brain activation associated with all cases of synaesthesia. Rather, the variability in subjective experiences suggests that there may be different patterns of brain activation involved in different kinds of synaesthesia (see Grossenbacher and Lovelace, 2001). Therefore, any general claim about the "seat of synaesthesia" (see Cytowic, 1993, p. 152) is likely to be incorrect. Because of the large variability in synaesthetes' subjective experiences, we also suggest that group studies of synaesthesia, in which the data from individual synaesthetes are pooled together, should be interpreted with caution. Grouping data across synaesthetes may obscure individual differences between synaesthetes and may lead to data patterns that are not representative of any of the individuals studied. At this early stage in the study of synaesthesia it may be more advantageous to describe and compare individual synaesthetes. We believe that studying individual synaesthetes is a valid way to proceed in the study of synaesthesia provided that any results found when testing a synaesthete are directly or conceptually replicated through further testing of that individual.

Another interesting set of experiments designed to assess the perceptual aspects of synaesthetic photisms has been reported by Wagar, Dixon, Smilek and Cudahy (in press). In these experiments, Wagar et al. first tested eight non-synaesthetes. In the critical conditions of the experiment, participants were briefly (i.e., 16 ms) presented with a black target digit (either a 2, 4, 5 or 7) embedded in a display containing 15 distractors (black 8's). The target digit was surrounded by four dots and the participants were told to identify this digit. Critically, on half of the trials the four dots surrounding the target digit disappeared from the screen at the same time as the digits, and on the other half of the trials the digits disappeared, but the four dots remained on-screen until participants responded. Previous findings using this methodology have shown that digit-identification accuracy is poorer when the four dots remain on the screen than when the four dots disappear at the same time as the digits (Enns & Di Lollo, 1997). The accepted explanation of these results is that the trailing four dots serve to mask the perception of the target stimulus initially contained within the dots when there are multiple items in the display (Enns & Di Lollo, 1997). Consistent with this interpretation, when Wagar et al. (in press) tested non-synaesthetes in their experiment they showed that participants made significantly more errors (mean of 19 errors out of a possible 48 errors) when the four dots remained on the screen than when the four dots disappeared with the digits (mean of 6 errors out of a possible 48 errors).

The authors then tested C using the same methodology where both targets and distractors were presented in black. For C, the colour of the photism for the digit 8 is black, whereas the colours of the photisms for 2, 4, 5 and 7 are red, blue, green and yellow respectively. Wagar et al. predicted that C's endogenously generated photisms for target digits (the red, blue, green and yellow overlays appearing atop 2, 4, 5 and 7) would serve to draw attention to these targets and eliminate the masking caused by the four dots. The results showed that in the key condition (15 distractors, and a trailing mask), where controls made an average of 19 errors, C made only 5 errors. This error rate was 3 standard deviations below the mean of the non-synaesthetes, and not significantly different from her performance in the condition without the trailing mask (2 errors). From these results Wagar et al. concluded that C's endogenously generated photisms served to draw attention to the target digits and prevent the four dots from masking the target when the target was embedded among distractors.

The findings reported by Ramachandran and Hubbard (2001), Smilek et al. (2001) and Wagar et al. (in press) are interesting because they are not easily explained solely in terms of semantic associations between alphanumeric characters and colours that may account for the high consistency of synaesthetes' alphanumeric-colour pairings as well as the priming results discussed earlier. The most straightforward explanation of the findings described in this section is that they are a direct result of the perceptual aspects of synaesthetic experiences rather than the result of semantic associations between alphanumeric characters and colours.

## 2.6. The Binding of Form and Synaesthetic Colour Prior to Awareness

One issue that is currently receiving much attention in the study of synaesthesia is whether synaesthetic colour is activated before or only after a synaesthete becomes aware of the eliciting stimulus (e.g., alphanumeric character). The views on this issue are mixed. Whereas the findings reported by Smilek et al. (2001) suggest that synaesthetic colour is activated *prior* to the awareness of an alphanumeric character, Mattingley et al. (2001) conclude on the basis or their findings that synaesthetic colour is only activated *following* awareness of an alphanumeric character

Recall the studies reported by Smilek et al. (2001), where C attempted to identify masked digits that were presented against coloured backgrounds. The results of this experiment showed that C was poorer at identifying (for example) a black 2 (which she perceived as having a red overlay) against a red background, than against a blue background. One implication of this finding is that the synaesthetically perceived colour (in this example red) must have been bound to the form of the digit prior to awareness of that digit. Concretely, in order for the "red" 2 to get lost in the red background, the red overlay must have been bound to the digit prior to awareness of the digit. If she had to be aware of the digit *before* the synaesthetic colour was bound to the digit, there would have been no effect of the background colour on her ability to identify the presented digit. Smilek et al. (2001) suggested that C's synaesthetic colours influenced the figure-ground segregation of the digit shape from the background prior to her awareness, thus influencing her resulting percept of the display. A similar interpretation was invoked to explain the fact that C was much better in visual search when black target digits were presented against backgrounds that were incongruent in colour to her photisms for the targets digits than when they were presented against backgrounds that were congruent in colour to her photisms for the target digits.

A very different conclusion was reached by Mattingley et al. (2001). In this study Mattingley and his colleagues used the priming procedure to evaluate whether synaesthetic colour was bound to an unconsciously perceived alphanumeric character. Recall from our earlier discussion that when an alphanumeric prime was presented for 500 ms such that the synaesthetes were *aware* of the prime, the synaesthetes were much slower at naming the colour of a subsequent colour patch when the colour of the patch was incongruent with the photism elicited by the prime than when the colour patch was congruent with the photism elicited by the prime. In other words, when synaesthetes consciously saw the alphanumeric prime, the photism associated with the alphanumeric character positively primed the colour naming of a subsequently presented colour patch. Importantly however, in another critical condition, Mattingley et al. (2001) assessed whether colour naming would be influenced when the alphanumeric primes were presented such that the synaesthetes were unaware of the primes. In order to reduce awareness of the alphanumeric primes, the exposure duration of the primes was reduced from 500 ms to 56 ms and 28 ms. Reducing the exposure duration in such a manner reduced awareness as indicated by a drastic reduction of prime identification in the 56 ms and 28 ms conditions compared to the 500 ms condition. When awareness of the alphanumeric primes was reduced, the results showed that the alphanumeric characters no longer primed the colour naming of a subsequently presented colour patch suggesting that synaesthetic photisms were not activated by the primes under these viewing conditions. Mattingley et al. (2001) argued that although the photisms were not activated when the synaesthetes were unaware of the alphanumeric primes, the synaesthetes nevertheless perceived the primes below the level of awareness. Support for this argument was based on the results of an experiment in which participants again viewed alphanumeric primes that were briefly presented (56 and 28 ms) so that the participants were unaware of the primes. This time, however, the probes were alphanumeric characters rather than colour patches. On each trial the alphanumeric probe was either the same as (congruent with) the alphanumeric prime (e.g., "a" followed by "A") or different than (incongruent with) the prime (e.g., "a" followed by "B"). The results showed that the synaesthetes were slower at identifying the alphanumeric probe when the probe was incongruent with the prime than when the probe was congruent with the prime. Based on this combination of results, Mattingley et al. (2001) argued that "the obligatory binding of colour and form in synaesthesia can be broken when inducing stimuli are masked, rendering them unavailable for conscious report" (p. 582).

Clearly, further research is needed to reconcile the inconsistent conclusions reached by Mattingley et al. (2001) and Smilek et al. (2001). Whereas Mattingley and his colleagues conclude that synaesthetic colour is *not* activated outside of awareness, the results of our experiments suggest that synaesthetic colour *may indeed* be activated outside of awareness. One obvious way to reconcile these two views is to postulate that there are important and yet unarticulated individual differences between the synaesthetes tested by Mattingley and his colleagues and the synaesthete whom we tested. An alternative possibility is that the colour priming methodology used by Mattingley et al. (2001) was not sensitive enough to measure synaesthetic colour activated outside of awareness. At this juncture, perhaps the best course of action is to await new experimental findings that may reconcile these inconsistent views regarding the activation of synaesthetic colours outside of awareness.

## 2.7. Conceptually Driven Synaesthetic Experiences

Thus far, all of the behavioural experiments investigating synaesthetic experiences that have been mentioned involve the external presentation of the stimuli that induce the synaesthetic experiences. However, a question of interest is whether synaesthetic experiences can be elicited even in the absence of such externally presented stimuli. Although experimental investigations of synaesthesia have typically utilized externally presented stimuli, subjective reports of some synaesthetes suggest that their photisms may be elicited even in the absence of an externally presented stimulus. For example, FKD who perceives nouns, verbs and proper names as blobs of colour, claims that each of his synaesthetic experiences "comes involuntarily and cannot be altered and is most often the result of hearing the word or *thinking* of the person so named" (Cytowic, 1989, p. 41). Likewise C reports that her photisms can be triggered simply by thinking of digits. Unlike her experiences when she views visually presented digits, when C thinks of digits, her photisms are experienced as coloured blocks appearing in her "mind's eye" - blocks that morph into an image of the digit she is thinking about.

Empirical evidence supporting the idea that photisms can be activated without an externally presented inducing stimulus has recently been reported by Dixon et al. (2000). On each trial of their experiment, the digit-colour synaesthete C was presented with a simple arithmetic equation (e.g. 5 + 2) that was followed by a colour patch. The colour patch presented on each trial was either congruent or incongruent with the single digit *answer* to the arithmetic problem. C's task was to calculate the answer to the arithmetic problem and then to name the colour of the patch as quickly and as accurately as possible. Dixon et al. (2000) reasoned that if a photism was an automatic consequence of simply thinking of the answer to the arithmetic problem, then the photism should interfere with C's ability to name the colour of the patch on incongruent trials compared to congruent trials. The results of this experiment showed that C was much slower at naming the colour of the coloured patch on incongruent trials than on congruent trials. This large congruent/incongruent difference has been replicated with C on another occasion (Smilek, Dixon, Cudahy & Merikle, in press) and thus appears to be robust. These large congruent/incongruent differences (in excess of 200 ms) are particularly striking when C's results were compared to the mean results of eight non-synaesthetes who showed only small (on average 1 ms) differences. C's large congruent/incongruent difference suggested that photisms were elicited even though the answer to the arithmetic problem was never physically presented and that simply activating the concept of a digit is sufficient to induce a photism.

One interesting aspect of C's experiences that warrants further research is that her synaesthetic experiences differ depending on whether the synaesthetic experiences are elicited by an externally presented digit, or simply by thinking of the digit. When C's views externally presented black digits, she experiences the resulting photism as being projected onto the digit. She reports a dual perception comprised of a perception of the black digit, as well as a perception of the photism that conforms to the shape of the digit and completely covers the digit. In contrast to this experience, when C simply thinks of a digit, she experiences a coloured block "in her mind's eye" that changes into the shape of the digit she is thinking about. Thus, when the inducing digit is exogenously presented, C's photisms are experienced exogenously whereas when she endogenously thinks of a digit, the photism is experienced endogenously.

Although the results reported by Dixon et al. (2000) strongly suggest that C's photisms can be activated even in the absence of externally presented stimuli, the findings do not rule out the possibility that *some* synaesthetes do require externally presented stimuli to elicit their synaesthetic experiences (see Grossenbacher, 1997; Marks, 2000, Cytowic, 1995). Externally presented stimuli may be necessary for the elicitation of synaesthetic experiences particularly in cases where inducing stimuli consist of simple physical properties. One example of such a case is MW whose synaesthetic experiences involve different shapes to different gustatory sensations (Cytowic, 1993). In cases such as this an externally presented inducing stimulus may very well be necessary for the elicitation of the associated synaesthetic experiences. Whether or not an externally presented stimulus is necessary for the elicitation of synaesthetic experiences may be an important individual difference between synaesthetes and may be an important variable in distinguishing different kinds of synaesthesia.

# 3. Subjective Reports and Experimental Investigations of Synaesthesia

The primary focus of the present review has been on the experimental investigations of synaesthesia. These experimental investigations are essentially *third-person* descriptions (see Varela & Shear, 1999) because they are based on overt behavioural or neural responses that are observable by others. However, most would agree that the fundamental characteristic of synaesthetic experiences is that they are conscious. As such, there are important aspects of synaesthesia that cannot be captured by third-person methods. The lived experiences that are manifest to the self are generally referred to as *first-person* events (see Varela & Shear, 1999). In order to capture first-person aspects of synaesthesia, we must rely on the subjective reports of synaesthetes. Surprisingly, the precise relationship between first-person reports and third-person experimental investigations of synaesthesia has received little attention in the synaesthesia literature. What do first-person reports add to third-person experimental investigations of synaesthesia? Conversely, what do third-person investigations add to first-person subjective reports of synaesthetes?

## 3.1. The Role of First-Person Subjective Reports

A common use of first-person subjective reports in third-person experimental investigations of synaesthesia has been to use subjective reports to generate experimentally testable hypotheses. Good examples of this use of subjective reports are the studies investigating the automaticity of synaesthetic experiences (e.g., Dixon et al., 2000; Mills et al., 1999; Odgaard et al., 1999). These studies were largely motivated by synaesthetes' subjective reports that their photisms occurred independent of their intentions. Subjective reports of the synaesthetes tested by Ramachandran and Hubbard (2001) lead the authors to devise clever experiments designed to demonstrate that photisms were a perceptual phenomenon as opposed to merely a memorial associations. Similarly, subjective reports of the synaesthete C have also led to the experiments that we reported (Smilek et al., 2001) investigating whether C's photisms influence her perception of digits. These experiments were motivated by C's subjective report that her photisms are projected externally onto the presented digits and conform to the shapes of the digits. As these examples suggest, first-person subjective reports of synaesthetes have proven to be a powerful tool for generating experimentally testable hypotheses.

First-person reports can also be used to validate the conclusions drawn from experimental studies of synaesthesia. This use of subjective reports is implied when the experimental results obtained from synaesthetes are compared to the experimental results obtained from matched non-synaesthetes. The assumption underlying the categorization of participants into synaesthetes and non-synaesthetes is that any empirical difference between the two groups is the result of processes associated with synaesthesia. Importantly, because the categorization of participants into synaesthetes and non-synaesthetes is based on subjective reports, it is fundamentally the subjective reports that validate the conclusion that the differences between the groups are the result of synaesthesia. This use of first-person reports is, therefore, integral to any experimental investigation of synaesthesia. Without using subjective reports to validate that a given set of experimental findings are in fact a result of synaesthesia, the experimental findings would be uninterpretable.

Subjective reports can also be used to verify that participants are actually experiencing synaesthesia during the experiment. A good example of this use of first-person reports is a study in which brain activation associated with synaesthesia was measured using event-related potentials (ERPs) (Schiltz et al., 1999). In this study, participants were asked to report their subjective experiences during the experimental session itself. From the 17 synaesthetes who participated in the study, "14 subjects reported definite synaesthesia throughout the experiment, 2 were not sure, and 1 subject denied synaesthesia during the experiment" (Schiltz et al., 1999, p. 60). Reports such as these are important because they suggest that ERP data from the one subject who, although a synaesthete, denied having synaesthetic experiences during the experiment, likely does not reflect brain activation associated with photisms. Removing the ERP data associated with this participant from the overall data analysis would lead to a better indication of the differences in brain activation between synaesthetes and non-synaesthetes. Unfortunately many recent experimental studies of synaesthesia fail to report whether participants were experiencing synaesthesia during the studies.

Finally, first-person reports may be used to aid in the interpretation of third-person experimental data. For example, consider the Stroop experiments conducted on synaesthetes (e.g., Dixon et al., 2000) and on non-synaesthetes trained to associate colour with forms (MacLeod & Dunbar, 1988). Although both synaesthetes and trained non-synaesthetes yielded colour-naming Stroop effects, the first-person reports of synaesthetes led us to conclude that different processes were responsible for the Stroop effects shown by synaesthetes compared to trained non-synaesthetes. Whereas we interpret the Stroop effects shown by synaesthetes to be the result of their synaesthetic photisms, the Stroop effects shown by trained non-synaesthetes are most likely the result of trained associations between form and colour. The use of first-person reports in aiding the interpretation of third-person experimental findings will likely become more important as more experimental data is collected. It is foreseeable that as more experimental data is collected, apparent inconsistencies in experimental findings will emerge. Inconsistencies in the experimental findings may be resolved and explained by considering individual differences between synaesthetes' subjective descriptions of their experiences. We foresee that subjective reports will comprise important data for the overall interpretation of third-person experimental findings because the subjective reports will be necessary for elucidating the individual differences between synaesthetes that may explain the apparent inconsistencies in the third-person experimental findings.

## 3.2. The Role of Thrid-Person Experimental Investigations

In the preceding section we outlined the possible contribution of first-person reports to third-person experimental findings. In this section we discuss what third-person experimental findings add to first-person reports. Because synaesthetic experiences are fundamentally conscious, one extreme view may be that third-person experimental investigations of synaesthesia do not really add anything to first-person reports and at best are completely redundant with first-person reports. A proponent of this extreme view may suggest, for example, that experimental demonstrations of the automaticity of synaesthesia based on Stroop tasks add nothing to the subjective reports offered by synaesthetes that their synaesthetic experiences occur independent of their intentions. In contrast to this extreme position, we believe that third-person experimental investigations of synaesthesia do contribute to the study of synaesthesia over and above subjective reports and that third-person studies address issues that cannot be addressed by first-person reports of synaesthetes alone. Outlined below are three important ways in which third-person experimental studies contribute to the study of synaesthesia over and above first-person reports.

Initial experimental investigations of synaesthesia were used to confirm the subjective reports of synaesthetes. Although currently many investigators accept subjective reports as a valid source of information regarding synaesthesia, initial confirmation of synaesthetes' subjective reports was necessary because historically many were sceptical of these reports. One factor that contributed to the scepticism was a widespread belief that the technique of introspection in general was not a reliable tool for studying psychological phenomena. Another important contributor to the scepticism was the disillusioning discovery that many individuals considered by late nineteenth-century artists and intellectuals to be synaesthetes did not in fact have any abnormal conscious experiences and only used synaesthetic language as part of their artistic expression (Dann, 1998). Because of the general scepticism caused by such factors, initial experimental investigations of synaesthesia played an important role in confirming that synaesthetes experienced the world in a way that was consistent with their subjective reports.

Experimental investigations of synaesthesia further contribute to the first-person descriptions of synaesthesia by providing a more detailed and refined description of synaesthetic qualia. Although the subjective reports of synaesthetes are useful and important for studying synaesthesia, subjective reports do have certain limitations. Synaesthetes often find it difficult to precisely describe the characteristics of their synaesthesia. One such example is our investigation concerning the relative automaticity of the processes underlying C's synaesthetic photisms and the processes underlying her normal colour perception (Dixon et al., submitted). When addressing this particular issue, the first-person insights were not fine grained enough to allow C to make such comparisons. Synaesthetes also find it difficult to specify how their experiences compare to the subjective experiences of other synaesthetes. For example, it comes as no surprise to find that synaesthetes are unable to specify the relative degree or strength of their synaesthetic experiences relative to other synaesthetes. Third-person data, however, such as Stroop effect sizes, may be quite capable of gauging relative strengths of synaesthetic experiences. Thus, experimental investigations of synaesthesia can be useful for both increasing the precision of the descriptions of cases of synaesthesia, as well as providing objective ways to compare individual synaesthetes. Experimental investigations are able to contribute in these ways because these investigations are based on a scientifically agreed upon common language which is grounded in experimental findings.

Finally, third-person experimental investigations lead to a better understanding of the cognitive and neural processes underlying synaesthetic experiences. While synaesthetes have access to the phenomenology associated with synaesthesia, they do not have access to the neural and cognitive processes underlying this phenomenology. Whereas subjective experiences cannot reveal the processes that lead to those experiences, behavioural experiments and neuroimaging techniques can be used to investigate the cognitive process underlying synaesthetic experiences as well as the brain areas involved in these cognitive processes.

## 3.3. Combining First-Person and Third-Person Perspectives

As described above, first-person and third-person approaches each provide important contributions to the study of synaesthesia. We suggest that future experimental investigations of synaesthesia should 1) include more detailed descriptions of the first-person experiences of the synaesthetes participating in the experiments, and 2) clearly articulate the specific contribution of the subjective reports in the context of the experimental studies. The position taken here is that a complete understanding of synaesthesia will require a clearly articulated combination of both first- and third-person approaches to the study of this fascinating phenomenon.

# Note

<1>. Frontal regions have also been implicated in synaesthesia by Schiltz, Trocha, Wieringa, Emrich, Johannes, and Munte (1999), who used event-related potentials to measure cortical brain activity in 17 synaesthetes and 17 non-synaesthetes. While these results are interesting, the interpretation of these results is unclear.


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