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The Synesthetic Experience of Color and the Grain Argument

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The grain argument has been offered by Bechtel and Mundale (1999) against the multiple realizability thesis. According to this argument, if we adopt the same grain of analysis with respect to mental and neural states, we can map correspondences between such states. The objective of this paper is to evaluate this argument by examining research on the synesthetic experience of color. It is argued that although such research has managed to obtain rather detailed descriptions of the phenomenal properties of this type of experience, the descriptions of the corresponding neural states are rather coarse grained. A variety of issues are raised which undermine the epistemic plausibility of the grain argument.

Keywords: synesthesia/synaesthesia, grain of analysis, phenomenal color

According to the grains of analysis argument (the grain argument for short) proposed by Bechtel and Mundale (1999) and Bechtel (2008), we need to reevaluate the multiple realizability thesis since the skepticism it expresses against neuroscience is misguided. Neuroscience is the leading player in understanding the mental since it relates brain states to mental states and by doing so, it makes possible the decomposition of psychological function. Differences between brains can be ignored in the formation of generalizations since these abstract away from differences among brains of one or many species. This is accomplished because a coarse-grain of analysis is used when identifying brain states. Philosophers, on the other hand, use a coarse-grain of analysis to identify mental states and a fine-grained one to identify brain states; this way, multiple realizability is made possible. If one were to use a coarse-grain of analysis for brain states, then a one-to-one correspondence could be achieved. Similarly, if one adopts a fine-grain to differentiate mental states between individuals or the same individual over time and a fine-grain for analyzing the brain then one will be able to map mental state

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differences onto brain differences. If one adopts the same grain, fine or coarse, with respect to the mind and the brain, then mapping correspondences between mental and brain states will be systematic and as a result the multiple realization thesis will not look very plausible. Thusly, it depends on the context whether states are similar or different, e.g., hunger may be the same in humans and octopi with respect to the general behavioral features of these organisms and different with respect to their more specific behaviors. Hence the suggestion that our taxonomies in psychology and neuroscience must be developed having a frame of reference in mind (Bechtel and Mundale, 1999).

The objective of this paper is to assess the viability of some of the claims made by the grain argument by examining research on the synesthetic experience of color. Since the grain argument is offered as an attack on the multiple realizability thesis, which is considered by Bechtel and Mundale to be false and detrimental to psychology, neuroscientific research gives us the opportunity to evaluate it. It is not uncommon for philosophers of science to propose that a discussion of issues, such as that of realization, needs to be carried out without the aid of outlandish examples (Boyd, 1999) and that by paying attention to actual cases of interaction between psychology and neuroscience we can avoid practicing something that looks like "philosophy of science fiction" (Hatfield, 1994). These proposals are similar to a more recent assessment according to which philosophy discussions about reduction and emergence have been rather misleading due to their failure to engage with actual scientific practice (Gillett, 2016).

One reason for choosing the synesthetic experience of color is that it has come under increased scientific scrutiny during the past decades, thusly providing enough evidence for carrying out such an assessment. Another reason is that it provides a concrete frame of reference for understanding what the grain of analysis for mental and neural states may look like so that we choose the appropriate frame of reference for comparing them. This is important because the grain argument does not provide an indication of what constitutes a fine or a coarse-grain of analysis with respect to mental and neural states or a taxonomy of the relevant units of analysis that can be used for comparison. If we do not know what these are, then it is difficult to know whether we have chosen the appropriate frame of reference for comparing them and finding correspondences for ultimately establishing identities. The example given above about hunger in humans and octopi is not that helpful since it refers to general behavioral characteristics whereas the grain argument is primarily addressing the relationship between mental and neural states which, as it will be shown, is central to the research to be discussed. In addition, an ontology of states gives us the opportunity to talk about the properties of such states which in turn gives us a better way to understand the notion of grain and its different manifestations. After all, the relations of realization and multiple realization, which are the targets of the grain argument, are understood in terms of the way the realized (mental) and the realizing (neural) properties are related (Shoemaker, 2007).[1]

In the second section, an examination of the literature will provide a description of some of the phenomenal properties constituting the synesthetic experience of color. Some of the obstacles that have been faced in the attempt to provide a fine-grain of description of these properties will also be identified. In the third section, a discussion will be provided on research concerned with the description of the neural states supporting such experiences; similarly, the various obstacles encountered by such research will be identified. It will be argued that the grain argument underestimates our ability to obtain rather fine-grained descriptions of the phenomenal properties presented from the point of view of the experiencing subject, while it overestimates our ability to obtain similar descriptions of the neural states with which such properties are correlated; in this respect the grain argument expresses a general tendency that seems to characterize the study of the mind, that of privileging psychophysical and neurophysiological analyses over that of phenomenology (Albertazzi, 2013; Jack and Roepstorff, 2003; Marcel, 2003). If this assessment is correct then we have some reasons to doubt the accuracy of the grain argument's claim regarding the practices of the "philosophers" and the prospects for attaining something that looks like the same grain of analysis for both mental and neural states. If this is the case then we have some reasons to doubt the viability of the grain argument against the multiple realizability thesis.

The Phenomenal Properties of the Synesthetic Experience of Color

Research on synesthesia relies partly on reports provided by synesthetic subjects on the phenomenal features of their synesthetic experience (the concurrent) upon perceiving a certain stimulus (the inducer). Subsequently these experiences are related to other behavioral and psychological data (Harrison and Baron–Cohen, 1995). Because synesthetes often have difficulties describing their experiences and their reports exemplify great variability, e.g., two subjects respond to the same inducer without reporting identical, or similar, synesthetic responses, it became necessary to devise behavioral tests through which any doubts about the reality of the phenomenon could be abated (Cytowic, 1997). The consistency

[1] A mental state is realized by a neurophysiological state when the activation of the latter is sufficient for the activation of the former. According to the thesis of multiple realization, a mental property type may be realized by some neural property type C in humans, a neural property type D in bees, and so on; the same issue may be raised with respect to a mental state type as this is realized across humans or even in a single person at different times. As a result, a mental state type cannot be identified with a neural state type as proposed by the type identity theory (Kim, 2011).

test has been used to support the view that synesthesia is indeed a genuine perceptual experience by showing that synesthetic subjects are significantly more consistent in their responses to inducers than controls and that their performance is not explained by memory strategies (Baron–Cohen, Burt, Smith–Laittan, Harrison, and Bolton, 1996; Baron–Cohen, Harrison, Goldstein, and Wyke, 1993; Baron–Cohen, Wyke, and Binnie, 1987; Eagleman, Kagan, Nelson, Sagaram, and Sarma, 2007). The Stroop test has been used to support the view that synesthesia is involuntary and for supporting the distinction between projectors (synesthetes who see synesthetic colors in the world) and associators (synesthetes who see synesthetic colors in the mind's eye) [Banissy and Ward, 2007; Nikolić, Jürgens, Rothen, Meier, and Mroczko, 2011]. The perceptual character of synesthesia has been demonstrated by a variety of psychophysical tasks (e.g., Hubbard, Arman, Ramachandran, and Boynton, 2005; Nikolić, Lichti, and Singer, 2007) and neuroimaging techniques (e.g., Nunn, Gregory, Brammer, Williams, Parslow, Morgan, Morris, Bullmore, Baron–Cohen, and Gray, 2002). However, in order to appreciate the detail and complexity of the phenomenal character of such experiences we need to examine the various descriptions that can be found in the neuroscientific literature of the phenomenal properties that typically constitute the synesthetic experience of color.

Hue–Saturation–Lightness. The visual experience of color is the more common type of synesthetic concurrent (Day, 2005; Simner, Ward, Lanz, Jansari, Noonan, Glover, and Oakley, 2005). A synesthete has visual experiences with a certain phenomenal character that is similar to the phenomenal character of experiences that one has when looking at colored objects. This is the case with grapheme–color synesthesia which is one of the most prevalent types of synesthesia; these experiences of color are typically produced when the synesthetic subject sees a grapheme. It is clear from these studies (Barnett, Finucane, Asher, Bargary, Corvin, Newell, and Mitchell, 2008; Baron–Cohen et al., 1996; Blake, Palmeri, Marois, and Kim, 2005; Day, 2005; Gray, Chopping, Nunn, Parslow, Gregory, Williams, Brammer, and Baron–Cohen, 2002; Grossenbacher, 1997; Hubbard et al., 2005; Marks, 1978; Niccolai, Jennes, Stoerig, and Van Leeuwen, 2012; Nunn et al., 2002; Ramachandran and Hubbard, 2001a; Rich, Bradshaw, and Mattingley, 2005; Rich and Mattingley, 2002, 2005; Smilek, Dixon, and Merikle, 2005; Ward, Simner, and Auyeung, 2005), that the central feature of the synesthetic experience of color that is under investigation is one particular dimension of the color space, its determinable hue. Although different individuals can experience the same form of synesthesia and can even share the same inducer set, synesthetic concurrents may vary greatly across people. For example, it is highly unlikely to find two people for whom every alphabetical letter induces the same determinate hue (Grossenbacher and Lovelace, 2001). This is seen by the fact that synesthetes often describe their concurrents with meticulous care and attempt to convey specific hues by combining color terms in phrases like "bluish gray." We should also bear in mind that at times synesthetes have synesthetic experiences of colors not seen in the real world, e.g., the experience of seeing a voice as being red and green at the same time (Ramachandran and Hubbard, 2005).

There are also indications that synesthetes exemplify a variety of differences in the saturation of synesthetic colors. It has been found that upper and lower-case letters typically evoke the same color (although there are exceptions) while lower-case letters are usually less saturated compared to upper case letter; one particular subject reports that different fonts produce the same color but slightly different hue values (Hubbard and Ramachandran, 2005; Ramachandran and Hubbard, 2001a).

Intensity. According to Cytowic (2002, p. 69), the memorability of synesthetic experience has to do with the fact that synesthetic percepts are remembered easily and vividly; at times, they are remembered better than the original stimulus. This raises a question concerning a difference among synesthetic experiences, and a difference between synesthetic and ordinary experiences, in terms of their intensity. We cannot assume that the intensity remains constant throughout the duration of a particular synesthetic experience, across different experiences a synesthete undergoes during her lifetime, or across synesthetes who have experiences of the same type (Luria, 1968; Mills, Boteler, and Oliver, 1999; Motluk, 1997; Myles, Dixon, Smilek, and Merikle, 2003).

The intensity factor has been utilized for making a distinction between weak and strong synesthesia (Marks, 2000; Martino and Marks, 2001), and between synesthesia and other types of perceptual states. According to this view, weak synesthesia differs from strong synesthesia in that it lacks the "phenomenal vividness" that characterizes strong synesthesia (Marks, 2000, p. 122).[2] Tracking variations in the property of intensity may also be important for understanding the underlying neurophysiology. For example, according to Hubbard et al. (2005) the conflicting results concerning the activation of region V4 of grapheme–color synesthetes may be due to differences in the strength of the colors experienced by the different subjects. It is proposed that it is the degree of activation of area hV4 "that leads to the synesthetic colors and that the strength of this activation directly influences the strength of the synesthetic colors" (Hubbard et al., 2005, p. 981; see also Ramachandran and Hubbard, 2001a, 2001b). Hence their suggestion that we need to collect behavioral and neuroimaging data in the same subjects so that we obtain independent measures of the strength of synesthetic colors. If we do ignore this particular feature of synesthetic experience, we are bound to be led methodologically astray as it has happened in the past where strong synesthetes were disproportionately represented in early studies of synesthesia. The reason seems to be that strong synesthetes, due to the strength of their experiences, were

[2] The distinction between weak and strong synesthesia has been questioned (Deroy and Spence, 2013). For a response and a defense of the distinction see Marks and Mulvenna (2013).

far more aware of their synesthetic colors and hence more likely to approach researchers (Hubbard and Ramachandran, 2005).[3]

Shape–Orientation–Depth–Size–Texture–Motion. Grossenbacher (1997, p. 154) has claimed that "the concurrent color experienced by many synesthetes often has some shape to it and can appear more substantial than shapeless flecks of color." However, this seems to be partially correct in that it describes some of those colors seen in the "mind's eye." Synesthetic colors projected in space may be uniform surfaces of a single hue, but they can also be presented as complex patterns of colored shapes such as swirls (Cytowic, 2002, p. 15). This description suggests that synesthetic experiences of color can contain other than uniform surfaces of a single hue. They can be made up of surfaces that vary in terms of size, shape, orientation, motion, depth, and texture (Cytowic, 2002; Harrison and Baron–Cohen, 1995; Motluk, 1997). In addition, these properties may alter as the properties of the inducer change. For example, the size and shape of a synesthetic color may vary with changes in the sound's pitch; high-pitched sounds produce synesthetic colors that are small and angular while low-pitched sounds produce synesthetic colors that are large and rounder (Marks, 1997; Martino and Marks, 2001).

Temporality. Most descriptions of synesthetic experiences of color presented in the literature seem to suggest that when the inducer and the concurrent are present, they are tightly synchronized so that they present themselves to the subject as a single unit. It is common for synesthetes, due to the synchronization of the two experiences, to believe that the synesthetic experience reveals properties of the inducer. However, there are exceptions. According to one subject, the synesthetic images, which appear a bit later than the inducing stimulus, are projected onto an inner screen that is accessed by closing the eyes (Tyler, 2005); when this happens, the subject may be less inclined to feel that the synesthetic experience presents one with features of the inducing stimulus. Under these conditions, one is more likely to interpret the synesthetic experience as a byproduct of the original stimulus.

Dixon and Smilek (2005) point out that grapheme–color synesthetes who experience the synesthetic colors in their mind's eye seem to have their synesthetic colors activated only after graphemes have been attended. Projector synesthetes, on the other hand, who see the synesthetic color on the grapheme itself, claim to experience the two colors together, which is taken to support the hypothesis that graphemes and synesthetic colors are bound together before the synesthete attends to the graphemes. This suggests that there are cases of grapheme–color synesthesia which at first glance seem similar but actually differ on how rapidly

[3] Other types of synesthetic experience seem to exhibit an emotional component (Cytowic, 2002). Since it is not clear the extent to which grapheme–color synesthesia exhibits emotions (Sinke, Halpern, Zedler, Neufeld, Emrich, and Passie, 2012), its emotional properties will not be discussed. For a discussion on the hedonic and emotional tone of synesthesia and its relationship to aesthetic experience see Nikolinakos (2012).

the synesthetic experience arises once the subject comes into perceptual contact with the inducer.

Complexity. It has been claimed that synesthetic colors are simple, since they consist of a single color or shape (Cytowic, 2002; Martino and Marks, 2001). However, this description does not seem to fit the phenomenology of a great number of synesthetic experiences. When a subject describes a single unbounded hue pervading the whole visual field or a bounded hue with some geometric shape, we can perhaps consider this as a simple structure. However, many other experiences described in the literature seem to be more complex than this, since they are presented as conglomerates of colored bounded surfaces standing in a variety of relationships among themselves and the viewer. Because synesthetic experiences of color can be made up of a variety of shapes, sizes, hues, depths, intensities, etc., they present rather complex dynamic patterns.

This is clearly seen in the case of grapheme–color synesthesia. Although words may be characterized by synesthetes as having an overall hue, this is often constituted by the synesthetic colors produced by each of the letters of the word. For example, the synesthetic colors of a word may clash and cancel one another if the graphemes are too close, they may enhance one another if they are similar, the color of the first letter may affect the rest of the letters so that the whole word gets tinged by this color, etc. Such patterns of synesthetic colors can become so complex that they may get too difficult to paint even for someone who has been trained to paint such colors, e.g., the case of the painter Stewart–Jones (Harrison and Baron–Cohen, 1995; Motluk, 1997). There are also cases where the synesthetic colors can fill the entire visual field as music changes, while several colors may appear simultaneously "each color reflecting a particular aspect of the music" (Marks, 1997, p. 70). The following remark seems to capture more accurately the overall complexity of the synesthetic experiences of color described by many subjects: "visual concurrents … can range in intensity and specificity from a 'sense' of a particular color to a kaleidoscopic montage of shifting forms, colors, and textures" (Marks and Odgaard, 2005, p. 217). This is similar to non-figurative abstract paintings, e.g., Kandinsky, which exhibit a rather complex composition despite the simplicity of each of their constituent parts.

The spatiality of synesthetic colors. An important feature of the synesthetic experiences with color as the concurrent is that such colors are often characterized as having spatial qualities such as spatial extension and localization (Cytowic, 2002; Simner, 2012.). Since the spatiality of synesthetic colors seems to be a feature that differentiates them more radically than their hue does from ordinary experiences of colored surfaces, it is no wonder that spatiality can be used as a taxonomic criterion for determining the various types and sub-types of synesthetic experience. However, according to Rich and Mattingley (2002), although synesthetes typically do not confuse synesthetic colors with the color of surfaces in the world and there are no cases of synesthetic colors interfering with color vision, it has been difficult to determine precisely the location of synesthetic colors. For example, one synesthete claims that "Tuesday is yellow. I don't 'see' it anywhere in particular; rather, I have a general awareness of yellowness in relation to the word" (Rich and Mattingley, 2002, p. 44). Given the spatial indeterminacy of synesthetic colors, then, it is not surprising that, according to these authors, such experiences are ineffable. Similarly, Harrison (2001, p. 104) maintains, "every synesthete I have met assures me that their experience is not 'out there.' By this they mean that the experience of color perceived on hearing sound does not color the outside world." He also claims that synesthetic colors are not seen in the mind's eye, which is interpreted to mean that these experiences are not similar to the experience that one has when one is asked to imagine an object. The spatiality of synesthetic colors and their location in particular, seem to be rather elusive properties.

However, according to more recent studies the location of synesthetic colors is not that elusive. According to Dixon, Smilek, and Merikle (2004) and Smilek, Dixon, and Merikle (2005), a distinction can be made between two types of grapheme–color synesthetes, associators and projectors. Those who see their colors in space are called projectors while those who see colors in internal space or the mind's eye are called associators. When synesthetic colors are projected onto external objects, they may be similar to ordinary colors and as a result the synesthete may have difficulty in differentiating them. This does not occur with synesthetic colors that appear in the mind's eye; such colors are said to be in some mental space.

Nevertheless, these claims cannot be generalized. A close inspection of synesthetic reports reveals that synesthetes present different accounts of the location of their synesthetic colors. According to these studies (Anderson and Ward, 2015; Blake et al., 2005; Cytowic, 2002; Grossenbacher and Lovelace, 2001; Harrison and Baron–Cohen, 1995; Hubbard and Ramachandran, 2005; Mills, Boteler, and Oliver, 1999; Rich and Mattingley, 2002; Sagiv and Robertson, 2005; Smilek and Dixon, 2002; Ward, 2003; Ward and Simner, 2003; Ward, Li, Salih, and Sagiv, 2007) synesthetic colors can be placed in the following locations: they can surround the inducing grapheme or a person like a halo; they can cover the surface of the inducing grapheme without spilling over the grapheme's boundaries and without blocking its original color from view; they can surround the shape of the inducing grapheme like an outline; they can hover above the inducing stimulus; they can be projected on a screen which is located at some variable distance from and above the subject's line of vision or waist;[4] they can be located in some specific area inside the subject's head, e.g., the mouth, brain, or in the mind's eye; they can float; they can have a dual locus, etc. In some cases, there is no fact of the matter about their location, since synesthetic colors cannot be determinedly located

[4] For some of these, synesthetes claim that the screen may have sharp boundaries capturing only a portion of the visual space since colored lines and shapes may fall off (Cytowic, 2002).

either inside or outside the subject's body, e.g., when a synesthete claims that she "knows" that a grapheme has another color even if she does not see it. These descriptions of synesthetic experiences of color reveal that such colors are often spatially located, that such localization may not be vague and that the distinction between projectors and associators does not capture the subtleties of these experiences with respect to their spatial location.

An attempt to deal with the limitations of the distinction is the following. The category of projectors can be subdivided to surface-projectors, because they experience synesthetic colors on the surface of the inducing object and near space-projectors, who experience them in surrounding space. Similarly, associators can be subdivided into see-associators, because they see synesthetic colors in their mind's eye and know-associators, who claim that they know, rather than see, the color associated with the inducer; in the case of know-associators there is no experience of synesthetic colors and as a result there is no sense of their spatiality (Ward et al., 2007). However, there are those grapheme–color synesthetes (Edquist, Rich, Brinkman, and Mattingley, 2006) who claim that their synesthetic colors are extended but are not located anywhere in particular which suggests that they are neither projectors nor associators (Anderson and Ward, 2015). In addition, even these more refined categories still fail to capture fully the variegated nature of synesthetic colors described by subjects, since a synesthetic color may be located anywhere between the subject and the inducer, occupying various portions of phenomenal space. For example, in the case of surface-projectors, a synesthetic color hovering over a grapheme is phenomenally distinct from a color that surrounds the grapheme's outline, while in the case of near space-projectors there is a phenomenal difference among the colors projected on to an external screen that may be located at any portion of phenomenal space.

There is still another issue that relates to the spatiality of synesthetic colors that is rather elusive. It concerns the intelligibility of the claim that is often made in the literature, according to which, the subject perceives two colors as covering a grapheme simultaneously. We can make sense of the co-presence of two colors if these are located at different portions of phenomenal space, e.g., one color is located on the grapheme, which is seen as being straight ahead, and the other on a screen located in some portion of space slightly above the line of vision. Such cases do not present a problem since these colors appear to have some distance between them due to the differences in the phenomenal space that they occupy. However, we cannot make sense of those cases where the synesthetic color covers the grapheme or lies somewhere in between the grapheme and the subject's line of vision.

According to Sagiv and Robertson (2005, p. 100), there has been no attempt to "quantify the report that two colors can coexist at the same location at the same time… " nor has there been an attempt to answer whether the one color is more dominant than the other. They advance a variety of hypotheses to account for such omission. One hypothesis is that there are two different perceptions one for each color that alternate so quickly that they give the impression that the two colors co-exist in the same place at the same time. The second hypothesis is that each color dominates under certain conditions and not others.

However, the first hypothesis does not seem to answer the question since the phenomenology of the experience typically presents the two colors as coexisting at the same location and as being attended at the same time. In addition, if both colors appear to be along the same line of vision, we cannot make sense how one can have a different perception for each color. The second hypothesis does not answer the question either, since the fact that the synesthetic color may dominate under weaker lighting conditions does not explain why the synesthete is able to detect both as being located at the same place and time. Additionally, synesthetes often claim that the synesthetic color is perceived as being very vivid which suggests that its vivacity has nothing to do with the surrounding lighting conditions.

There is another more parsimonious hypothesis that may explain the facts. The synesthete may perceive two colors located at the same place and time because the synesthetic color, which normally covers or fills in the color of the grapheme, is transparent. Although this feature of synesthetic colors is hardly ever mentioned in the literature, it is nevertheless suggested by some reports: "the synesthetic sense is definitely not 'in my mind.' It is just sort of there. It is sort of translucent overlay with depth that I can see through" (subject RP quoted in Cytowic, 2002, p. 34) and "the colored shape is seen as if I were looking through a plastic transparency which is in front of my eyes" (subject MM quoted in Cytowic, 2002, p. 19). If the superimposed synesthetic color were not transparent, it would occlude the color of the inducer. Since no occlusion takes place, the synesthetic color must be more or less transparent. This seems to be the most obvious way to make sense of descriptions where a grapheme is said to be black and red all over at the same time. If the transparency of the superimposed color is diminished then we will have a case of replacement of one color by another and not coexistence. This interpretation is also supported by reports suggesting that the degree of transparency exhibited by a synesthetic color may differ from person to person. Contra Rich and Mattingley (2002), who claim that there are no cases of synesthetic colors interfering with color vision, there is the case of subject DS whose synesthetic percept is made up of moving lines which may block her vision (Cytowic, 2002). Additionally, the degree of transparency of a synesthetic color may at times be indeterminate, i.e., the person may have difficulty in determining exactly the degree of transparency exhibited by the synesthetic colors she is experiencing. All these issues suggest that transparency, to some degree or other, is another property exemplified by synesthetic colors and it needs to be taken into account. It is a salient property of synesthetic colors but may not be easily captured by the categories that we use when attempting to understand their spatiality.

The example concerning the transparency of synesthetic colors suggests that our probing activities regarding the phenomenal character of synesthetic experiences need to be more systematic so that more detailed descriptions of such experiences are obtained. The questionnaire can be a method which can give synesthetic subjects the ability to provide more detailed descriptions of their experiences which are often characterized as being ineffable. Sometimes the validity of this method has been debated. For example, the validity and reliability of the projector–associator (PA) questionnaire has been contested since consistency was not found to be very high (Edquist et al., 2006; Skelton, Ludwig, and Mohr, 2009). In addition, some individuals changed their description of the location of their synesthetic colors even if the hue had remained constant, while some individuals claimed that the color was located both in the mind's eye and in space (Edquist et al., 2006). The conclusion these authors draw is that the distinction between the two subtypes of synesthesia is questionable. However, a more recent version of this test has exhibited consistency between test and retest over a period of years which is taken to suggest the viability of the distinction between projectors and associators (Cohen, Weidacker, Tankink, Scholte, and Rouw, 2015). When we encounter paradoxical claims, such as the claim that the synesthetic color is both inside the mind and out in space, we must probe the subject with more questions so that we get a better understanding of the experience. This does not mean that the probing will help us to reach a verdict on the phenomenal character of an experience that may be accommodated easily by our preexisting categories. It does not mean either that subjective reports are unreliable when they do not fit our theoretical expectations or when they conflict with previous studies carried with the same subjects. There are no reasons why synesthetic experiences should exhibit exactly the same phenomenal features over time, or that questionnaires should prompt the same responses from subjects every time, or that subjects should provide the same answers to questions that have been altered slightly (Edquist et al., 2006). There is already evidence indicating the following changes may take place over time: change in intensity, change in the inducer, change in the sensory modality of the synesthetic experience, change in the number of inducers, and change of some aspect of the synesthetic experience via the control of attention, medication, or substances such as caffeine and tiredness (Niccolai et al., 2012). This is taken to suggest that even if some synesthetes appear not to be consistent according to the consistency test, it does not mean that their experiences are not genuine. As a result, these are facts that we must take into consideration when collecting reports from synesthetes since the inconsistencies that appear may not reflect a weakness of the questionnaire but a change in the experience measured. Because it is difficult to capture individual variability with psychophysical tests (Hupé, Bordier, and Dojat, 2012; Hupé and Dojat, 2015), our best hope is the expansion of our concepts so that we may improve our ways of capturing the phenomenal character of synesthesia.[5]

Therefore, when it is argued that our phenomenal concepts such as "this is red," are rather vague and it is therefore highly unlikely that we will manage to discover some neural kind corresponding to them (Papineau, 2003), this purported vagueness seems to be, at least as far as the case of the synesthetic experience of color is concerned, the artificial result of our poor phenomenological practices. Phenomenal properties picked out by statements like "seeing red" or "I am in pain" are too crude. Our vocabulary can be enriched so that we can identify the variety of phenomenal properties that constitute these experiences just as we did in the case of synesthetic colors. Statements containing more precise phenomenal predicates need to, and can, be produced, if we are to describe more accurately the experience undergone by a person who sees a color or experiences pain. By removing such vagueness, to the degree permitted by our language and other practices, we can remove at least one obstacle toward the discovery of cognitive and neural mechanisms.

Descriptions of the Neural States Underlying the Synesthetic Experience of Color

In the previous section a description of some of the determinable properties that typically characterize the synesthetic experience of color was given. Now it is time to turn to the neurophysiological descriptions of synesthetic experiences of color so that we may assess more fully the grain argument. The general tenor of the studies to be examined agrees with the mechanistic model of explanation, where the phenomenon to be explained, i.e., the synesthetic experience of color, can be explained by appealing to underlying mechanisms (Craver, 2007). Various studies and proposals attempting to delineate such mechanisms will be examined. It will be argued that the complexity of the phenomenal character of synesthetic experience as described by synesthetes is not captured by the descriptions provided by these mechanistic explanations. In other words, these descriptions are, contra the grain argument, coarse-grained. The following claim will be used as a guideline toward the conclusion: "One way to tell that a description of a mechanism is sketchy and incomplete is that it explains only some aspects of the phenomenon and not others. If a hypothesized schema

[5] This effort is part of a larger project that seeks to improve first-person methodologies, e.g., Schmidt and Walach (2014); Varela and Shear (1999).

fails to explain all aspects of the phenomenon in which the investigator is interested, or if it makes predictions that do not accord tolerably well with aspects of the phenomenon as it is observed in the wild (or, more generally, under the conditions in which one is interested in explaining the phenomenon), then it is not an adequate description of a mechanism for the purposes at hand. A mechanism includes all and only the entities, activities, and organizational features relevant to the phenomenon to be explained. Anything less is, in some sense, incomplete; anything more includes something irrelevant" (Craver and Darden, 2013, 171.8 kindle).

Discovering the "seat of synesthesia" (Cytowic, 1993, p. 152) is a central aim of contemporary research on synesthesia. It is often assumed that synesthesia is a unitary kind and that by studying the most common types of synesthesia we will be able to reveal their cognitive and neurophysiological underpinnings (Rich and Mattingley, 2002). By discovering such mechanisms, it is hoped that we will be able to construct "a general theory that is consistent across all types of synesthesia…" (Cytowic, 2002, p. 156). It is recognized, however, that the methodological tendency to group together data from multiple synesthetes and treat them as if they all come from a homogenous population, may backfire, since the results obtained from one synesthete may not be easily generalizable to other synesthetes (Hubbard et al., 2005). We may end up with generalizations by collapsing together data from different synesthetes, even if the phenomenology of their synesthetic experience exhibits a complexity that does not warrant such generalizations (Cytowic, 2002, p. 157; Marks and Odgaard, 2005; Smilek and Dixon, 2002). This suggests the possibility that the term "synesthesia" may refer to a variety of different types and, because these types are phenomenologically very diverse, there may be different patterns of brain activation manifested by each one of them (Grossenbacher and Lovelace, 2001). It is suggested that it is rather unlikely that we will discover such a common basis even if we do manage to discover some common abnormal process, e.g., unusual cross wiring among brain regions. The worry expressed by some is that if a single underlying mechanism is not found, we may not be able to possess a single general explanation and theory (Harrison and Baron–Cohen, 1997; Rich and Mattingley, 2002; Smilek and Dixon, 2002). The term "synesthesia" may refer to a multiplicity of entities that have phenomenological and behavioral similarities but are produced by distinct neurophysiological mechanisms (Marks, 2000). These considerations have led to an attempt to determine the neurophysiological profile of a single type of synesthesia, such as grapheme–color synesthesia, which makes possible the unraveling of the neural states underlying the synesthetic experience of color. If this can be done, then the challenge presented by the grain hypothesis may be vindicated.

It will be shown that there is hardly any support for the grain hypothesis with respect to the description of the properties that have been presented in the previous section. Some issues will be raised with respect to the neural support of the experience of color and its location in space followed by a discussion of the general mechanistic models that have been proposed to explain grapheme-color synesthesia.

Although color is the most salient property of these experiences, it seems to be rather difficult to track at the neural level. A central problem encountered in synesthesia research is the inconsistent results concerning area V4 which is typically activated with color perception. An early study by Paulesu, Harrison, Baron–Cohen, Watson, Goldstein, Heather, Frackowial, and Frith (1995) revealed activation of language areas and visual associative areas and no activation of the primary visual cortex, suggesting that this type of synesthesia involves only high-level cortical mechanisms due to the involvement of higher-level cognitive activity. However, a later study by Nunn et al. (2002) of spoken words–color synesthesia found activation of area V4 which suggests that the synesthetic experience is perceptual and that it arises at an earlier stage of visual processing. Such evidence, along with other findings pertaining to neural structures (Cohen et al., 2015; Hubbard et al., 2005; Rouw and Scholte, 2007, 2010; van Leeuwen, den Ouden, and Hagoort, 2011), has been used to defend the distinction between projectors and associators. The activation of early visual areas explains why projectors have experiences that are similar to visual perception proper and why the associators, who exhibit a stronger involvement of the hippocampus, have experiences that are more memory like.

Hupé, Bordier, and Dojat (2012) found that color areas are not activated when subjects are experiencing synesthetic colors. It is suggested that either synesthetic colors are localized outside the visual cortex or there is distributed processing within cortical networks of the visual system. Hupé et al. favor the distributed and non-modular processing hypothesis with respect to synesthetic colors, which they consider to be rather undeveloped at this stage (Hupé et al., 2012; Hupé and Dojat, 2015).[6] Another proposal offered for explaining the absence of structural and functional anomaly in synesthetes is that synesthetic colors are the contents of a special kind of memory states that are rather difficult to track at a neural level (Hupé and Dojat, 2015). Similarly, Chiou and Rich (2014) argue that the behavioral evidence suggests that synesthetic colors have properties that are different from actual colors, e.g., lack of precision, which is due to the fact that conceptual representations of inducers are implicated. According to the conceptual mediation model they propose, the synesthetes use the same semantic knowledge that we all share instead of using different neural connections; this is taken to suggest

[6] For a defense of the distributed model of brain functioning see Uttal (2013, Ch. 4).

that synesthetic colors do not share the same neural basis with the perception of actual colors since their instantiation involves higher level cortical areas implicated in memory.[7, 8]

It should be clear from the above that these studies do not support the grain argument since the neural descriptions do not capture any of the phenomenal properties identified in the previous section. The research is primarily concerned with the gross architectural structures that may be activated during the synesthetic experience of color, and the evidence, as it has been shown, is conflicting with respect to area V4.[9] If synesthetic colors are memory dependent then the prospects of identifying neural structures even at this gross level of analysis are even harder to attain. The grain argument could be vindicated if we were in the position to identify a specific pattern of neural firings corresponding to the phenomenal character of the experience that a subject has when she is perceiving, for example, a determinate shade of red. But as things stand right now, neuroscience does not seem to have the ability to identify fully neural patterns that respond selectively to such features of our experience; we do not even understand the perception of simple objects such as "a circle, a triangle, or the letter A" (Hubel quoted in Gold and Stoljar, 1999, p. 813). This indicates that neuroscience does not appear to have the ability to obtain the appropriate grain level of analysis in relation to the phenomenal character of our experience.

Mechanistic Models of Synesthesia

In this section it will be shown how similar issues arise with respect to more general explanatory concerns that pertain to the "architectural models" (Hubbard, 2007, 2013) that have been proposed in relation to the synesthetic experience of color. A brief description will be provided of these mechanistic models, so that

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[7] Chiou and Rich (2014) also maintain that the area ATL seems to be central to the mechanism supporting the conceptual processing of synesthesia. However, current research typically ignores its role because, due to the limitations of MRI, researchers try to confine analysis to perceptual areas where they can obtain a better signal. These observations provide more support for the claim that the grain argument underestimates the difficulties encountered in the attempt to identify even grossly the areas supporting a certain type of mental states.

[8] If these observations are correct then the distinction between lower and higher synesthetes may be disputed. Such a distinction is based on differences in cognitive penetrability, i.e., the synesthetic experience of lower synesthetes is not cognitive penetrable while that of higher synesthetes is (Hubbard et al., 2005; Hubbard and Ramachandran, 2005; Ramachandran and Hubbard, 2001a).

[9] An explanation offered for the conflicting results with respect to the activation of V4 is that synesthetes are a heterogeneous group and that the results are influenced by the subjects chosen (Rouw, Scholte, and Colizoli, 2011). These authors suggest that better results with respect to the detection of the areas supporting color may be obtained by choosing subjects with intense synesthetic experience. One implication of this proposal, with respect to the grain argument, is that we do not have adequate tools for detecting and describing the neural correlates of some of the properties exhibited by the synesthetic experiences of color and that the grain argument needs such a procrustean maneuver for its vindication.

some of the issues that are relevant to the assessment of the grain argument are identified. But first some remarks need to be made about the type of mechanistic explanation that is being deployed in these studies.

One type of mechanistic explanation used in neuroscience is constitutive or componential. It explains a phenomenon by describing the mechanism that underlies it. The activity of the mechanism is explained by the activity of the component parts: "a component is relevant to the behavior of a mechanism as a whole when one can wiggle the behavior of the whole by wiggling the behavior of the component *and* one can wiggle the behavior of the component by wiggling the behavior as a whole. The two are related as part to whole and they are *mutually manipulable*" (Craver, 2007, p. 153). Due to this bidirectional dependency, constitutive relations are not causal. Causal explanations require relata that do not take place at the same time, that are distinct from each other and that there is mediation of force (Aizawa, 2016; Gillett, 2010). An additional requirement for constitutive explanation is that such parts should be constitutionally relevant, detectable, physiologically possible, and amenable to intervention (Craver, 2007). It is constitutive explanation that is used in the studies on synesthesia even if the term "production" is often used to refer to the relationship between neural and synesthetic states. The reason is that mechanistic models provide descriptions of the neural processes that underlie, and occur at the same time as, mental states.

The first mechanistic model that has been proposed with respect to synesthesia is the cross-activation model which emphasizes structural differences. According to this model the senses are innately cross-wired and, as a result, we are all synesthetes (Baron–Cohen et al., 1993, 1996; Maurer, 1997). There are many objections to this hypothesis, e.g., there is a lot of evidence suggesting that synesthetic experience is the result of a learning process (Shriki, Sadeh, and Ward, 2016). Another version of this model attempts to explain grapheme–color synesthesia by proposing that there is failure of pruning during childhood development which gives rise to excessive connections between adjacent areas, such as the grapheme area and area V4 (Hubbard and Ramachandran, 2005; Ramachandran and Hubbard, 2001a). More recent versions of this model include the parietal cortex which is responsible for the attention mechanism required for the binding of the grapheme and the synesthetic color that is generated during the first stage of the process. This additional processing has been proposed as an explanation for other types of synesthesia (Hubbard, Brang, and Ramachandran, 2011; Hubbard, 2013; Jäncke and Langer, 2011; Shriki, Sadeh and Ward, 2016). According to the disinhibited feedback model there is disinhibited feedback from higher level multi-modal cortical areas to uni-modal visual areas. That is, there is a neural circuit that connects different areas and which is inhibited in non-synesthetes but disinhibited in synesthetes. Because this model stresses functional brain differences, it can explain synesthesia induced by hallucinogens (Cohen Kadosh and Henik, 2007; Grossenbacher and Lovelace, 2001; Mulvenna and Walsh, 2006). According to the re-entrant processing model, which is a synthesis of the cross-activation model and the disinhibited feedback model, there is cross talk between form and color supporting areas while there is also neural activity between higher level areas that support concepts and visual areas such as V4 (Chiou and Rich, 2014; Smilek, Dixon, Cudahy, and Merikle, 2001). This model emphasizes the role of concepts in the formation of synesthesia. According to the hyper binding model, synesthetic experience arises as a result of overactivation of parietal binding mechanisms which are normally used to bind together various types of information in order to form representations of the world (Alvarez and Robertson, 2013; Esterman, Verstynen, Ivry, and Robertson, 2006; Robertson, 2003). This model must also work together with some other model that will explain the way the basic elements of synesthetic content are bound together (Hubbard, 2013).

One characteristic of these models is that they highlight the central role played by the parietal cortex. This area is found to be activated during the synesthetic experience and its disruption by transcranial magnetic stimulation (TMS) leads to the disruption of synesthetic experiences (Esterman et al., 2006; Grossenbacher and Lovelace, 2001; Jäncke, Rogenmoser, Meyer, and Elmer, 2012; Muggleton, Tsakanikos, Walsh, and Ward, 2007; Paulesu et al., 1995; Steven, Hansen, and Blakemore, 2006). Other methods have also shown that the parietal region is strongly functionally interconnected in synesthetes (Dovern, Fink, Fromme, Wohlschlager, Weiss, and Riedl, 2012; Jäncke and Langer, 2011; Neufeld, Sinke, Zedler, Dillo, Emrich, Bleich, and Szycik, 2012; Tomson, Narayan, Allen, and Eagleman, 2013; van Leeuwen, Hagoort, and Händela, 2013; Volberg, Karmann, Birkner, and Greenlee, 2013).

According to a review of studies that have attempted to determine the areas that are involved in linguistic–color synesthesia (Gould van Praag, Garfinkel, Ward, Bor, and Seth, 2016; Rouw, Scholte, and Colizoli, 2011), the following areas have been identified: bilateral activation in occipito-temporal cortex for synesthesia involving color, the posterior parietal cortex, the bilateral insula, the left precentral gyrus, and the frontal cortex. Rouw, Scholte and Colizoli (2011) maintain that some of these areas are likely to be involved in other types of synesthesia;[10] they also claim that the cross-activation model is likely to be the correct one and they support this view by identifying anatomical brain differences between synesthetes and non-synesthetes, such as increased white and grey matter found throughout the brain and not just in areas that are directly involved in a particular type of synesthesia.

One problem with this proposal is that, as the authors indicate, it is tentative since it is based on a few studies; their proposal is offered more as a heuristic

[10] In a similar vein it is proposed that that "the presence of different distinct forms (e.g., grapheme–color, or taste–hearing) of synesthesia within the same family suggests that common mechanisms may be shared across synesthetes, but developed or expressed into different forms" (Rouw and Scholte, 2010, p. 6212), while according to Hubbard (2013) it is hypothesized that the neural mechanisms of various types of synesthesia may have parts that are common to all of them and other parts that lead to differences among them.

hypothesis that needs to be explored further. The second problem is that with respect to the frontal cortex, only "some location" (Rouw, Scholte, and Colizoli, 2011, p. 227) was found to be activated. The third problem is that the anatomical differences are spread throughout the brain which is indicative of the presence of a disposition to have some type of synesthesia in general. Finally, the authors make it clear that according to their analysis the areas that they have identified as correlates of synesthetic experience are used in sensing, motor, and higher cognitive processes.

All these issues suggest that, as far as a functional analysis is concerned, the grain of description is rather coarse-grained and the structural descriptions are even coarser. Even if we assume that these functional areas are implicated in grapheme-color synesthesia and that the cross-activation model is correct, we are still operating with a very gross grain of analysis since the areas that are implicated are widely used in other cognitive activities. That is, although brain imaging is supposed to identify the "where" of a psychological activity, the answer seems to be, as Uttal (2013, p. 142) has argued, "almost everywhere." In this respect, even this proposal does not really provide an explanation of the synesthetic experience of color since it does not tell us what the mechanism is or how it works for producing the experience. Although the components of the mechanism are specified by describing the brain areas that underlie the phenomenon, this is done through a very general description that does not tell us how the mechanism, using these component areas, works. We just have a very general description of the areas that seem to be responsible for supporting some of the phenomenal properties that constitute the content of the synesthetic experience of color. Due to the many gaps presented by this model, it may be characterized as, following Craver and Darden (2013), an incomplete model.

The incompleteness of the model is also manifested by the conflicting views that have been expressed about the role of the parietal cortex. TMS studies have found effects on synesthesia when TMS was used on the right parieto-occipital region while neuroimaging studies have found left inferior parietal activation during the synesthetic experience. Studies by Neufeld et al. (2012) and Sinke et al. (2012) did not detect the same areas, while the Tomson et al. (2013) study found no role for the parietal cortex. Rouw, Scholte, and Colizoli (2011) acknowledge that there are conflicting results with respect to the particular parietal lobe areas that are activated. The same conclusion has been reached more recently by a review of various studies by Hupé and Dojat (2015).

In addition, Hupé and Dojat (2015) argue that there is another difficulty with the interpretation of findings concerning the activation of the parietal cortex. This area is implicated in the presence of attention which is required for the unification of the properties that constitute the content of the synesthetic experience of color. However, attention is also required for the processing of the inducer that is responsible for the production of the synesthetic experience. Consequently, the activation of the parietal cortex may as well be a prerequisite since it may be correlated with the attention directed at the inducer. If this is the case then such activation is not a real substrate of the synesthetic experience. As a result, if a neural description of parietal cortex activation cannot adequately distinguish between the two modes of attention and this distinction is essential for identifying the neural substrate of the synesthetic experience of color, then it is coarse-grained. This difficulty is important because it is an expression of a more general problem that plagues any attempt to identify the neural correlates of a conscious state. That is, it is not clear whether a neural activation is a general neural correlate which functions as a prerequisite, as a consequence, or as a real substrate of the mental state in question (de Graaf and Sack, 2015; Hohwy and Bayne, 2015; Miller, 2015).

Given such problems it is not surprising that there is the following verdict about the mechanistic models that have been discussed in the literature: "Up to now, morphological and functional neurophysiological data cannot be taken as hard evidence for one theory or the other" (Sinke et al., 2012, p. 1427) and "while many differences are observed in the brains of synesthetes compared to non-synesthetes, the current data is [sic] not able to falsify one of these models" (p. 1428). Similarly, Hubbard, who is a supporter of the cross-activation model, claims that we may be in a position to choose between the cross-activation and the re-entrant model in the future, but as things stand right now, "current neuroimaging data are *too coarse* to distinguish with certainty between these two models" (Hubbard, 2007, p. 195, my emphasis). Additionally, it should be noted that the cross-activation, re-entrant feedback, and hyper binding models are based on the study of grapheme–color synesthesia while the feedback model is based on word–color and tone–color synesthesia. Since there are at least 152 types of synesthesia (Cytowic and Eagleman, 2009), there is no reason to assume that grapheme–color synesthesia provides the best model for these other types (Hubbard, 2013). If we accept this assessment then it is very likely that there is still no single model describing the underlying mechanism of synesthesia.[11]

Additionally, a more recent review of all studies on the neural correlates of synesthesia reaches an even more skeptical conclusion. It is maintained that "we did not find any clear-cut empirical evidence so far about the neural correlates of the subjective experience of synesthesia. We did not find any structural or functional anomaly in the brain of synesthetes that could explain synesthesia. In our view, most published studies to date show, in fact, *that the brains of synesthetes are*

[11] We should also note that it is possible that all models are vindicated since different mechanisms may be found to support grapheme–color synesthesia even if the same areas are activated (see also Aizawa's [2009] argument according to which sameness of BOLD signals or positron emission does not provide evidence for univocal realization or Uttal's [2013] claim that very different networks can produce the same BOLD signal).

functionally and structurally similar to the brains of non-synesthetes" (Hupé and Dojat, 2015, pp. 13-14, my emphasis). Hence their proposal that synesthesia is a form of memory of some kind whose neural correlates may be difficult to identify "as long as detecting the signature of memory contents in the brain remains beyond the reach of current brain imaging techniques" (Hupé and Dojat, 2015, p. 2). The implication of this more skeptical scenario offered by Hupé and Dojat is that the mechanistic models that have been presented to this day are inaccurate since no neural differences can be detected between synesthetes and non-synesthetes. At best, we have phenomenal models (Craver and Darden, 2013) that can describe causal relations between inducers and concurrents but fail to reveal the internal structure of the mechanism that underlies synesthetic experience.[12]

Given this predicament, the following line of response may be a viable alternative. If macroneural descriptions, i.e., descriptions that pick out processes that are distributed over extended brain regions, do not provide enough grain to match the grain of the descriptions of phenomenal properties, then we need to adopt another strategy. A mechanism identified by a mechanistic explanation is typically thought to have parts with intrinsic behaviors. When these parts are coupled to one another they succeed in producing the behavior of the whole system. These parts in turn can be considered to be whole systems whose behavior needs to be explained by identifying their parts and the respective intrinsic behaviors that constitute them. In the case of synesthesia there are different mechanisms that have been proposed along with their respective parts, e.g., the Rouw, Scholte, and Colizoli (2011) proposal. A much finer analysis could be provided of these parts and the parts that make them up until we reach a much finer level of analysis, e.g., one that appeals to the behavior of single neurons. We may accept that a mechanistic explanation typically does not have to reach the lowest level possible and that this analysis of decomposition can stop anywhere it seems appropriate once components have been identified that are relatively fundamental or unproblematic (Machamer, Darden, and Craver, 2000). However, this response is not adequate since a finer analysis at a lower level of organization, e.g., at the level of single neurons or small networks of neurons, seems to be desirable if the grain argument is to be vindicated.

The coarse character of macro descriptions also veils another element which motivates this search for a finer analysis located at the microneural level. The fMRI

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[12] Some of the reasons given for this impasse in synesthesia studies are methodological differences among studies, differences in behavioral tasks, small number of subjects used, differences in the selection of synesthetes, differences in experiments and analyses as well as an absence of standard among such analyses, statistical inferences used with MRI analyses, individual differences between subjects, etc. (Cohen et al., 2015; Gould van Praag et al., 2016; Hupé, 2015; Hupé, Bordier, and Dojat, 2012; Hupé and Dojat, 2015; Rouw, Scholte, and Colizoli, 2011). These reasons are similar to the ones that have been identified with respect to scientific research in general and in relation to the cognitive sciences in particular (Ioannides, 2005; Ioannides et al., 2014; Uttal, 2016, 2017).

image, which is the basic tool deployed in the construction of macro descriptions, is a measure of the cumulative response of neurons. That is, the initial responses of neurons are not, and cannot be, retrieved from such an image. Because the fMRI image is neutral about microneural activity, it is possible that the "same macroneural responses can be produced by a variety of different microneuronal responses" which is considered to be "the fundamental weakness of the macroneural approach" (Uttal, 2017, p. 24). The weakness of macroneural descriptions, according to this view, is that it they are concerned with macroneural states that can be multiply realized by the activity of microneural states. It is due to the presence of multiple realizability of macroneural states that one may seek a better understanding by studying the behavior of individual neurons and their interactions directly. In other words, descriptions of the activity of networks of neurons are needed to bypass the presence of multiple realizability as this seems to be expressed between different neural levels.

This level may also be preferable because one may be in a better position to intervene and manipulate conscious states by altering the neural correlates of such states. Our ability to change a conscious state through intervention seems to be a good indicator that such a correlate is indeed the neural correlate of that particular state; if the conscious state does not change through such manipulation then it is a good sign that the neural state is not the neural correlate sought (Hohwy and Bayne, 2015). This way one can disentangle the real substrate of a mental state from states that act as prerequisites or consequences. There is no reason in principle to preclude the possibility that there are such fine-grained neural states that correspond to the properties of the synesthetic experience of color and these are to be found at the microneural level. According to the radical neuron doctrine, "a successful theory of the mind will be a theory of the brain expressed *in terms of* the basic structural and functional properties of neurons, ensembles, or structures" (Gold and Stoljar, 1999, p. 814). Since "individual neurons are the elementary signaling elements of the nervous system" (Kandel, 2000, p. 6), an adequate theory of perceptual function needs to be formulated at the level of individual neurons and the ways these interact, rather than at a lower molecular level or at a higher level of population of cells (Barlow, 1972, 1995). After all, this form of reductive explanation is used in the biological sciences where the behavior of a biological object or system is to be obtained by referring to factors that are to be found at a lower level of organization (Kaiser, 2015). Therefore, in terms of this reductive approach one could expect to find a single neuron or a network of neurons corresponding to each particular phenomenal property that constitutes such an experience and a description at this level could be considered to be the level at which the appropriate neural correspondences are located. However, this scenario does not seem to be currently a viable option. This is the level where there is an overabundance of data that needs to be obtained because one must deal with the behavior of individual neurons and their connections. Due to the complexity of this level and the lack of the appropriate technology and methods, access to it is not possible and this situation will most likely remain the same in the near future.[13]

Given this state of affairs, the evidence does not show that there is no multiple realizability of the synesthetic experience of color since, given the grain of analysis attainable by current neuroscience, it is more likely that our scientific practice is not in a position to identify its existence.[14] Furthermore, the plausibility of this scenario can be defended by taking into consideration some findings from research on the elicitation of synesthesia through the use of psychedelic substances (Grossenbacher and Lovelace, 2001). If the same synesthetic experiences can be elicited by pharmacological means, then it is likely that such states are realized by different neural mechanisms than the ones that realize genuine synesthesia. It has been objected, however, that there are important phenomenological differences between these forms of synesthesia. Due to such differences, according to Sinke et al. (2012), we should expect that such states are most likely related to different neural mechanisms. The main phenomenological difference between the two types of experience, according to this study, is intensity, i.e., drug induced synesthetic states are more intense. However, one can imagine an experiment where one can vary the quantity of the psychedelic substance so that the synesthetic experience produced matches the intensity of a genuine synesthetic experience. After all, a person can take very small quantities of LSD which enhance his cognitive activities without having a psychedelic experience (Fadiman, 2011). Small quantities have also been related to the production of simple geometric patterns during hallucinations (Sinke et al., 2012) that are phenomenologically similar to some of the synesthetic patterns described earlier.[15] If this is a feasible scenario, then one could produce synesthetic experiences via psychedelic substances whose phenomenology matches the experiences of a genuine synesthete, at least with

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[13] This is a brief list of some of the problems faced by microneural theories: the complexity and idiosyncrasy of neurons, the multiple realizability of macroneural states by diverse microneural states, the inability of macroneural states to preserve microneural information, the intractability of microneural activity and hence the difficulty with its simulation, etc. For a more detailed criticism of microneural network theories see Uttal (2016, 2017).

[14] For a similar point see Aizawa (2009).

[15] In order to defend the realistic nature of this scenario, we can point out the following with respect to the Sinke et al. (2012) study which sets out to articulate the differences between genuine, drug induced, and acquired synesthesia. The study identifies a variety of phenomenological features that are used to characterize the differences among these types of synesthesia. For example, consistency is listed as a feature exhibited by genuine synesthesia but not by drug induced synesthesia since a person is very likely to have synesthetic experiences with a different content every time he takes the same hallucinogenic substance. However, consistency is strictly speaking not a phenomenological feature since it relates to the fact that different experiences during the life of a genuine synesthete are instances of the same type of phenomenal content. Similarly, most of the other phenomenological properties listed in the study are also of a functional sort.

respect to intensity and colored patterns, that are realized by different neural mechanisms. If these considerations are correct, then the synesthetic experience of color seems to be multiply realizable. If we also take into consideration that it is very likely that macro neural states are multiply realized by micro neural states, then multiply realizability seems to go all the way down.

Conclusion

It has been argued that research on the synesthetic experience of color shows that such experiences are constituted by a variety of phenomenal properties and that an accurate description of them requires that we impove our practices and concepts. By doing so we are in a better position to discover the mechanisms that explain such phenomena. The grain argument, however, seems to underestimate the magnitude of the obstacles that must be faced in the attempt to provide descriptions of neural states that are of the same grain as the descriptions of the phenomenal states. Since these obstacles are manifested in the study of mentality in general (Uttal, 2016, 2017),[16] then we have enough reasons to conclude that the grain argument is not vindicated and that, as a result, it cannot offer a viable objection to the multiple realizability thesis which is its prime target.

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[16] We should also take into consideration that as studies on multisensory perception grow, our theoretical understanding of perception and perceptual experience also changes. For example, the notion of modularity, which has been rather central in our understanding of the architecture of the mind, has been challenged due to studies which show that perceptual experiences in one modality may be affected by experiences in other modalities at many levels of processing, e.g., Sathian and Ramachandran (2020).

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