Alfredo Vernazzani

Psychoneural Isomorphisms and Content-NCCs

1. Introduction

In 1994, Gaetano Kanizsa accused the Gestalt psychologists of 'inaccuracy of some definitions, the scarcely scrupulous use of some terms, or the ambiguity of some fundamental concepts' (Kanizsa 1994, 149). The Gestalt concept of "psychoneural isomorphism" is a paradigmatic example in this sense. Roughly, the idea is that there should be a relation of structural identity – i.e. an isomorphism – between the "psychological" dimension and something "neural" underlying it. What this exactly means is far from clear, and Gestaltists such as Rudolf Arnheim (1949), Kurt Koffka (1935), or Wolfgang Köhler (1929) provided very different definitions of psychoneural isomorphism, adding to the general confusion.

Framing the concept within the current philosophical landscape, the problem of psychoneural isomorphism is but one aspect of the quest for the neural correlates of the contents of consciousness or "content-NCCs" for short (Metzinger 2000, Hohwy 2007). What is at stake is our understanding of the relation between *what* we consciously experience and the underlying neural system that engenders it. Hence, it will not surprise that psychoneural isomorphism still plays a role in debates about the heuristic role of phenomenological methods in guiding brain research (Petitot, Varela et al. 1999). A philosophical clarification of psychoneural isomorphism bears on two currently debated issues:

- Our understanding of the problem of content-NCCs.
- The heuristic role of phenomenology in guiding brain research.

Few attempts have been made to provide a systematic exploration of our concept (Lehar 2003, Petitot 2008). However, much work is still needed to link it with the current philosophical debates. In this study, we will pursue two goals. Firstly, we will broadly locate psychoneural isomorphism within the current debates about content-NCCs. Secondly, we will tackle one specific issue: whether psychoneural isomorphism is a relation between phenomenological and neural contents or rather a relation between phenomenological contents and neural vehicles. Following the general trend in the studies, we will narrow down the phenomenological contents to conscious *visual* contents. Accordingly, these considerations will

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only apply to the case of conscious visual perception. We will first clarify what is meant with 'isomorphism' and its relevance for the current debates (§2). In §3, we will clarify the concepts of consciousness, visual contents, and content-NCCs. In §§4-5, it will be argued that psychoneural isomorphism is better understood as a content-vehicle relation.

2. Psychoneural Isomorphism: Filling-In and Phenomenology

An isomorphism is a bijective morphism, a map that preserves sets and relations among elements (Dunn & Hardegree 2001, 17). A "morphism" or "homomorphism" in mathematics is a map between two objects or domains that partially preserve their structures. Whereas a homomorphic relation requires mere similarity of structure, a map is isomorphic if and only if the two objects or domains have an identical structure under some level of description. For example, the sequence of natural numbers and the sequence of years after 0 according to the Gregorian calendar are isomorphic. Two ordinary dice with six faces are also said to be isomorphic. These examples help us to distinguish isomorphism from identity. Two dice can be isomorphic, and yet not only be two different objects, but also possess different properties (like, say, their colors). Recognizing that two objects are isomorphic can be heuristically useful. Consider the following case: let there be two objects, the first one A is accessible for observation, whereas the other one, call it B, is somehow unobservable. If A and B are isomorphic, we can infer the structure of B from the structure of A.

This brief analysis of the concept of isomorphism suggests that any philosophical clarification of psychoneural isomorphism must specify the following:

a. What are the two isomorphic domains;
b. That these two domains contain elements in some relation to each other, i.e. how the domains are structured.
c. That the two domains have the same structure under some level of description.

The choice of the domains is somewhat arbitrary. Virtually everything can be isomorphic to something else, provided that the level of description is general enough. In the literature, *psychoneural* isomorphism is commonly understood as the relation between the phenomenologically perceived and the underlying neural system (Luccio 2010, Madden 1957, 179). Framing psychoneural isomorphism in this way means locating it within the research for the neural correlates of consciousness (or NCCs). On this reading, assuming that A is the domain of conscious vision, and B the neural system underlying it, we can exploit the isomorphism A-B to gain insights into the structure of B. The obvious assumption here is that the phenomenological domain has a neural correlate.

In recent years, philosophical discussions about a family of visual phenomena known as "filling-in" or "perceptual completion" has forced researchers to reconsider the concept of psychoneural isomorphism (Dennett 1991, Pessoa & De Weerd 2003). "Filling-in" is an umbrella term for a family of visual phenomena (Pessoa, Thompson et al. 1998, Weil & Rees 2011) that consist of the perception of visual features – such as for example color and shape – in a part of the visual field, although such features are not physically present (Komatsu 2006, 220). Two paradigmatic examples of perceptual completion are the filling-in at the blind spot and filling-in due to stimulus configuration. The blind spot is an area of the retina where the optic nerve leaves the eye. This area lies 15º medial to the fovea, above the horizontal meridian, and is devoid of photoreceptors. In normal binocular vision, the eyes compensate the reciprocal lack of visual information. Interestingly, however, filling-in of the absent information also occurs in monocular vision, clearly suggesting the presence of an active mechanism (Ramachandran 1992).

The most popular cases of filling-in triggered by stimulus configuration are the Kanizsa figures. In fig.1, the observers can see an illusory triangle generated by a specific configuration of high contrast figures: in this case, three incomplete black circles and angles (Weil & Rees 2011, 42, Kanizsa 1979).

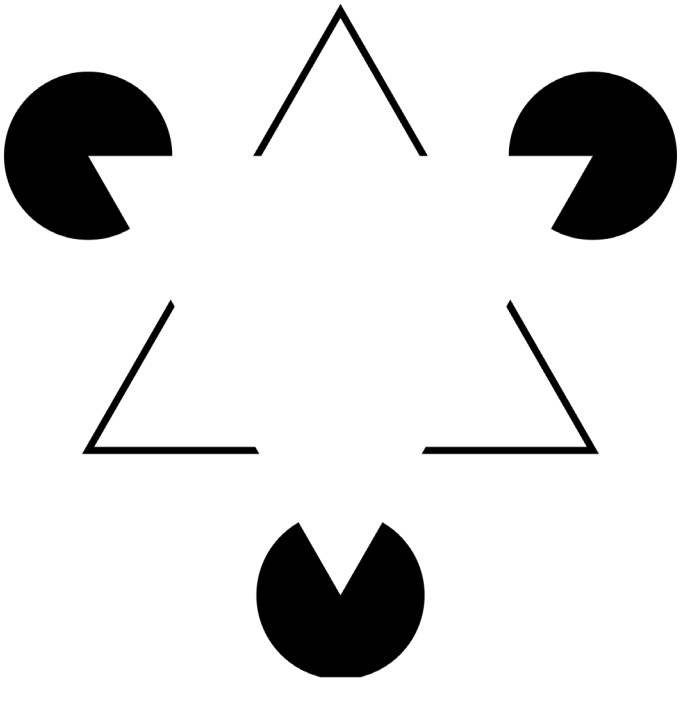

Fig. 1 A Kanizsa triangle.

Phenomena like filling-in suggest that our vision is not a passive registration of features instantiated in the environment. It is instead a process involving the active role of brain mechanisms. It is at this juncture that the role of psychoneural isomorphism is revealed: since there is no complete correspondence between our visual perception and the environment, it is suggested that our visual states are instead isomorphic with something at the underlying neural system. One obvious implication of the foregoing discussion is that accurate phenomenological descriptions of the contents of our visual conscious experience can be used to guide the search for the underlying neural correlates. Yet, what is meant with "conscious experience" and "contents"?

3. The Visual Contents and their Neural Correlates

Scientists and philosophers interested in NCCs usually focus on a specific concept of consciousness: phenomenal consciousness. In this concept, consciousness is characterized "by the way it feels" (Chalmers 1996, 11). A technical expression often associated with it is that of 'what-is-it-like-to-be' (Nagel 1974). An experiencing subject would thus be feeling an arbitrary conscious mental state in a way that is qualitatively different from an unconscious mental state. What exactly explains this qualitative character is a matter of controversy among philosophers of mind. In this paper, we will use the following expressions interchangeably, without making any particular metaphysical assumption: phenomenal consciousness, consciousness, phenomenal experience, phenomenality, and cognate formulations.

Visual perceptual experiences are a specific kind of conscious mental states. They are the kinds of states that a subject typically enjoys when she perceives the environment. We will understand visual perceptual experiences as "intentional" or "representational states". We will call the thesis according to which visual states have representational character "intentionalism" or "representationalism". On this interpretation, a perceptual experience carries information about an object *o* via a receptor system – in this case, the visual system – and this state *represents* what it carries information about. I favor this understanding of perceptual states mainly because this is how most contemporary vision scientists understand perceptual experience. One straightforward reason that explains the wide acceptance of representationalism lies in its explanatory power, in contrast with forms of naïve realism that assume a non-representationally mediated perceptual contact with the environment (Pautz 2010).

The information represented by a visual state will be called "content". The notion of 'content' is a piece of philosophical jargon. Tim Crane (2011) put forward three reasons for talking about contents: aspect, absence, and accuracy. The notion of aspect captures the perspectival nature of our visual experience. The ob-

jects of our intentional states can be represented in different ways (Crane 2001, 6ff). For instance, two visual states might both have the cat on the mat as object, and yet represent it in different ways when seeing the object from different angles. "Absence" suggests that an intentional state can carry information about absent objects (Crane 2001, 22). According to representationalist philosophers of perception, visual hallucinations are a typical case of inexistent intentional objects. Finally, intentional states carry information about objects that can be more or less accurate. An observer might see a red book on the table, although the book is actually white. Intentional states that represent absent objects, like visual hallucinations, and less accurate experiences – like properties different from the ones really instantiated in the environment – are both examples of misrepresentations. Intentional conscious visual states can thus be said to set the conditions of accuracy of the subject's visual experience (Siegel 2010).

There are different theories about the nature of the perceptual content. In general, most philosophers agree that in perceiving the environment things look a certain way. Perceiving things to be a certain way is just another way of expressing the idea that we see visual properties or features, like being red or white, having a specific shape, etc. That we see such properties is not controversial among vision scientists, who discuss what are the basic visual features (Wolfe 1998). What is controversial is what these properties are – universals or tropes – and what kind of properties are represented in visual experience (Siegel 2010). We will focus here on *types* of properties, like color-properties, or shape properties, rather than token properties.

As we have seen, intentional states are about something else, an object or "target" that might or might not be present, as in the case of visual hallucinations. This is the represented object. Representation itself is the content that stands in some relation to the represented object, pending on the form of representation. For example, a portrait can be a pictorial representation of its target. Finally, a *vehicle* supports such a representation, which, in the case of a portrait can be the canvas it is painted on. The search for the neural correlates of conscious contents is thus an attempt to localize the brain areas that correlate with types of contents.

Much more could be added about the problem of the contents of consciousness. However, this sketchy survey should help the reader to localize the problem of psychoneural isomorphism within the current philosophical debates. As we have seen in §2, one assumption required to make sense of psychoneural isomorphism is that not only must we focus on one specific domain – in our case, conscious visual perception – but, moreover, that domain must contain elements in some relation to each other. We have clarified what is meant with "contents of perceptual experience". In the remainder, we will gloss over the structure of visual experience. As declared in §1, we will rather focus on their neural correlates. There

are basically two ways to understand the isomorphic relation. According to the first way, types of conscious visual contents are correlated with types of neural contents. According to the second way, types of conscious visual contents are correlated with underlying vehicles. Let's call the first option "content-content" isomorphism, whereas the second one will be called "content-vehicle" isomorphism.

4. Content-Content Isomorphism

According to the first interpretation, psychoneural isomorphism should be understood as a relation between *contents*. We thus have two contents, the first one being the types of conscious visual contents (type properties, etc.), and the second one being the underlying content of a neural state. This view has been discussed in recent philosophical literature as the "Matching Content Doctrine" or MCD (Noë & Thompson 2004, Pessoa & Thompson, et al. 1998). The MCD is plainly suggested by the single most influential definition of content-NCC put forward by David Chalmers in a classic paper:

'An NCC (for content) is a minimal neural representational system N such that *representation of a content in N* is sufficient, under conditions C, for representation of that content in consciousness.' (Chalmers 2000, 31; emphasis added).

Chalmers states that: "We require that the content of the neural state in question match the content of consciousness" (2000, 23). The verb "to match" has different meanings. Selecting only the ones relevant in the present context, "to match" can mean something like (1) "to be similar to", (2) "to be equal to", or (3) "to form a suitable combination", "to correspond", "to fit". The second reading (2) is the one at stake in this section. Noë and Thompson (2004) explicitly interpret Chalmers' matching relation as a form of psychoneural isomorphism. But what exactly is the neural content, and what justifies the matching relation?

According to Chalmers, Francis Crick & Christof Koch (1995, 1998) argued that the neural activity of the primary visual cortex V1 cannot be the direct neural correlate of conscious visual perception in virtue of a *mismatch* between conscious perception and the alterations of a neuron's receptive field in V1. An example is provided by the Land effect, a case of partial color constancy, where the perceived color at one particular location is influenced by wavelength of the light entering from the surrounding region of the eye (Land & McCann 1971). Studies on anesthetized monkeys have shown that neurons in region V4, but not in V1, exhibit the Land effect (Schein & Desimone 1990, Zeki 1983). Another case that allegedly motivates the MCD would be described in the experiments of Gur & Snodderly (1997). Alternating two isoluminant colors at a frequency beyond 10Hz in humans causes the perception of a single fused color. Yet, in spite of the perceived color, color opponent cells in V1 of two alert macaque monkeys follow

high-frequency flicker above heterochromatic fusion frequencies (Crick & Koch 1998, 102). Let us consider one more example. The syndrome of achromatopsia – the inability to see the environment as colored – provides indirect evidence for the role of areas V4 and V4α in color perception (Sacks et al. 1988, Zeki 1990). However, indirect proof can be deceiving, since it does not bring conclusive evidence of the direct functional role of a brain area for a specific function. Direct evidence confirming the correlation of activity in V4 with color perception was later found by Semir Zeki and collaborators (1991) by means of experiments involving color and gray stimulation, detecting a significant change of activity only in the region of the lingual and fusiform gyri: the areas we call V4 (McKeefry & Zeki 1997). The matching relation would thus be an implicit assumption hidden behind much of vision science. Chalmers interprets similar cases as supporting the idea that the neural content would be a property or a functional state of the neural representational system N.

To sum up, the content-content interpretation of psychoneural isomorphism is supported by the following theses: (1) scientists assume that the conscious content has a neural correlate; (2) such a neural correlate is individuated in virtue of a correspondence relation with the conscious content; (3) the correspondence relation is an isomorphism between conscious content and neural content. The first thesis is a mere assumption that there is such a thing as a content-NCC. We will not question it. What about thesis 2? That there is a generic relation between an NCC and its content seems to be beyond dispute, once we have accepted the existence of content-NCCs. We will later return to such a correspondence (§5). We shall now examine whether a content-content isomorphism is plausible. Three reasons suggest that thesis 3 is questionable: content mismatch, dual contents, and descriptive adequacy.

Content-mismatch. To reject the content-content isomorphism, one ploy is to attack the idea that the matching relation should be understood in its second meaning, i.e. as "equal to". Assuming that the contents are structured, where the neural content is interpreted as a functional state, denying that the matching relation is a relation of structural identity we come to reject the content-content isomorphism. Notice that this clearly assumes that the correspondence relation holds between neural and conscious content. In short, what this criticism attacks is only the isomorphic relation between contents. This is the strategy adopted by Alva Noë & Evan Thompson (2004).

Accepting Chalmers' characterization of neural content as a functional state of the representational system, Noë and Thompson have drawn attention to recording spike activity of neurons, i.e. to recording the receptive fields of neurons. A "receptive field" is the area surrounding a neuron where the presence of a stimulus will alter the neuron's firing. Noë & Thompson then show that perceptual con-

tent does have properties that the underlying receptive field does not possess. In particular, they claim that perceptual content exhibits structural coherence; it is experienced; and has perceptual presence (Noë & Thompson 2004, 11ff). Structural coherence refers to the fact that perceptual experience exhibits a characteristic structure – exemplified by Gestalt principles of organization, or figure-ground segmentation. The experienced character of conscious visual states refers to their qualitative character, as described in §3. Finally, perceptual presence means that the objects of perceptual experience are often "attentional" objects that are only incompletely represented by visual perceptual states. According to Noë & Thompson, none of these features would be possessed by the neural content. For this reason, they interpret the content-content relation as an "agreement". What exactly they mean with "agreement" is, however, unclear. One suggestion would be that the "matching" relation should be interpreted not as a structural identity, but perhaps as a form of similarity, something along the lines of the first meaning of "to match". Assuming that the contents are structured, this could be taken to mean that the content-content relation would be a homomorphism. The plausibility of this interpretation seems supported by Thompson's later considerations on psychoneural isomorphism (2007). Grounding his considerations in his paper with Noë, Thompson suggests that the content-content relation could be interpreted as a "weak" isomorphism. Again, it remains mysterious what a "weak" isomorphism is, given that the concept can be rigorously defined (see §2).

A dubious assumption of Noë and Thompson's argument is that an isomorphism should obtain between contents of conscious visual states and the neurons' receptive fields. Jean Petitot (2008) has correctly observed that a content-content isomorphism could instead hold at some higher functional level, involving larger neural populations. Again, the assumption is that the relation holds between contents. We therefore turn our attention to the content-content relation.

Dual contents. Another way to resist the MCD is perhaps to cast doubt on the duality of contents. To make this point pellucid, we can graphically represent the Matching Contents Doctrine as follows:

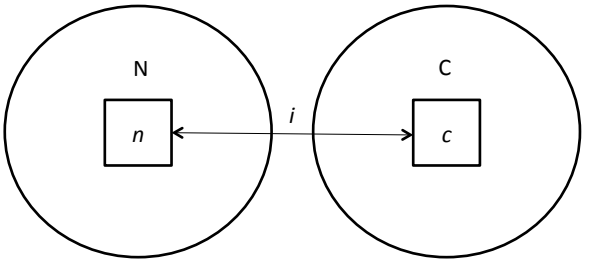

Fig. 2 The Matching Content Doctrine

Fig. 2 shows that the two contents *n* and *c* stand in an isomorphic relation *i*. An implicit assumption of Chalmers' definition seems also to be that of requiring *two vehicles* (see §3). The first vehicle is the neural representational system N that carries the neural representation *n*. Recall that Chalmers defined the content-NCC as a neural representation *in* N. The other vehicle seems to be consciousness itself, as a representation in N is alone sufficient for "representation of that content *in* consciousness". There is a representation in N *and* a representation in consciousness. If this were the case, then Chalmers would have implicitly assumed a form of dualism in defining the content-NCCs. One could therefore start wondering what is the nature of consciousness, and whether it can be a vehicle of representational content. Even assuming the plausibility of the content duality, a problem with the MCD is that it seems to postulate a parallelism between contents that falls short of capturing the explanatory undertaking of neuroscientists, as we will now see.

Descriptive adequacy. Another way to argue against content-content isomorphism is to attack Chalmers' philosophical interpretation of the "neural domain". Is it true that the experimental cases discussed above show a correspondence between neural functional states and phenomenological contents? Joseph Neisser (2012) points out that scientists are not looking for discrete neural representations. My suggestion is that scientists are looking for mechanisms functionally related to the contents of consciousness. Indeed, reference to mechanisms is ubiquitous in NCC research as well as in cognitive science and the life sciences (Craver & Darden 2013). Consider the following examples: Koch defines content-NCCs as "the smallest set of brain *mechanisms* […] sufficient for some conscious feeling" (2004, xv-xvi); Giulio Tononi & Koch (2008, 246) define the NCCs as "minimal neuronal *mechanisms* that are jointly sufficient for any one specific conscious percept" (all emphases are mine). A closer reading of the experiments mentioned in support of a correspondence relation between visual contents and underlying brain regions seems to undermine Chalmers' interpretation. Scientists are not looking for "neural contents"; they are hunting mechanisms functionally related to the visual contents. Psychoneural isomorphism should thus be described as a content-vehicle relation. But what is a mechanism, and how do mechanisms "correspond" to the visual contents?

5. Content-Vehicle Isomorphism

Recently, philosophers of science have drawn considerable attention to mechanisms and mechanistic explanation (Bechtel & Richardson 2010, Craver 2007, Craver & Darden 2013). Roughly, a mechanism is a complex entity made of operations and parts arranged together so as to be responsible for a specific function. There is an important difference between mechanisms and machines. Whilst a

machine is basically a mere structured aggregate of component parts, mechanisms are inherently active: they comprise both parts and operations.

Mechanisms are individuated in virtue of the function they carry out (Bechtel 2008, 13f, Darden 2006, 273, Glennan 1996). Consider the case of achromatopsia described in the previous section. We now know that V4 is somehow functionally responsible for color perception. The mechanism in question was individuated in virtue of its functional role for color perception, registering an altered activity when the observers are shown color stimulation. (Notice that this does not imply that V4 is the only region responsible for color perception, nor that it is alone sufficient for color perception). In the literature, the function of a mechanism is defined in terms of *phenomena*. Phenomena are repeatable patterns rather than individual events, they are stable, they result from a small number of causes, and they are the explananda of scientific inquiry (Bogen & Woodward 1988, Woodward 2011).

To provide a mechanistic explanation means to show how the joint interaction of a mechanism's parts and operations produces the explanandum phenomenon. The nature of parts and operations depends on the mechanism under scrutiny. For example, the mechanism of neurotransmitter release described by Carl Craver as an example of mechanistic explanation (2007, 22ff), is structured in different component parts, among which we find Ca2+, and operations, among which we find the intracellular reactions triggered by it. The individuation of parts and operations requires a meticulous process of mechanistic decomposition: the dissection of a mechanism into its components (Bechtel 2008, Bechtel & Richardson 2010).

How is this related to psychoneural isomorphism? Recently, philosophers interested in the problem of NCCs are increasingly paying attention to mechanistic explanations (Hohwy 2009, Neisser 2012, Opie & O'Brien 2015, Revonsuo 2015, Vernazzani 2015). The idea is that the neural correlates of consciousness – and in our case, of the contents of visual experience – should be understood as mechanisms. My contention is that the visual contents of consciousness should be construed as *phenomena* functionally related to the underlying neural mechanisms. Individuating the *types* of visual contents, likes types of properties represented in visual perception, is therefore the first step in inferring the presence of a mechanism underlying it. This stage is usually described in a mechanistic explanation as "phenomenal decomposition": the segmentation and accurate description of the explanandum phenomenon as a preliminary step towards mechanistic decomposition (Bechtel 2008). My proposal thus vindicates the idea that psychoneural isomorphism can provide a useful heuristic guide for uncovering the structure of the underlying brain's architecture. Thorough descriptions of our visual experience can help us identify the types of visual contents of which our

vision is made. Such types are then related to underlying mechanisms, thus vindicating also the idea of some sort of "correspondence" between visual phenomenology and underlying brain mechanisms.

It is not possible to fully articulate this proposal here. Substantial research is still needed to fully spell out the required details. However, the arguments I have put forward in the foregoing discussions strongly suggest that psychoneural isomorphism is better understood as a content-to-vehicle relation, rather than a relation of content matching.

6. Conclusion

In this study, I have mainly pursued two objectives. The first one was that of clarifying the relevance of the Gestalt concept of psychoneural isomorphism for current debates about the neural correlates of the contents of consciousness, and for phenomenological approaches to the study of the mind. The second one was that of clarifying the nature of the isomorphic relation between phenomenological contents and underlying neural vehicles. Many other issues remain to be addressed in future works.

Summary
The Gestalt concept of psychoneural isomorphism means that the phenomenological dimension should have the same structure as the underlying neural dimension. Understood in this way, this concept seems to be still relevant in philosophical debates concerning the quest for the neural correlates of the contents of consciousness, and the role of phenomenological descriptions in brain research. However, much work is still needed to clarify what psychoneural isomorphism means. Focusing on the visual contents of consciousness, some researchers have understood psychoneural isomorphism as a "matching" relation between visual perceptual content and underlying neural content. In this study, it will be argued that the content-content relation is not a plausible interpretation, and that psychoneural isomorphism is best understood as a content-mechanism relation, a form of content-vehicle isomorphism.
Keywords: Psychoneural isomorphism, content-NCC, consciousness, intentionality, mechanism.

Zusammenfassung
Das Gestaltkonzept des psychoneuronalen Isomorphismus besagt, dass die phänomenologische Dimension des Erlebens dieselbe Struktur wie die ihr zugrunde liegende neuronale Dimension haben sollte. So verstanden scheint dieses Konzept insbesondere für philosophische Debatten hinsichtlich der Suche nach den neuronalen Korrelaten des Bewusstseins und zur Rolle phänomenologischer Beschreibungen in der Hirnforschung immer noch relevant zu sein. Allerdings ist zur Klärung der Bedeutung des psychoneuronalen Isomorphismus noch weitere Arbeit zu leisten. Einige Forscher haben in Bezug auf visuelle Bewusstseinsinhalte den psychoneuronalen Isomorphismus als eine "matching" Beziehung zwischen visuellem Wahrnehmungsgehalt und darunterliegendem neurona-

len Gehalt angesehen. In diesem Aufsatz wird argumentiert, dass solch eine Gehalt-Gehalt-Beziehung keine plausible Interpretation darstellt, sondern dass psychoneuronaler Isomorphismus am besten als Gehalt-Mechanismus-Beziehung, als eine Art Gehalt-Träger- Isomorphismus, zu verstehen ist.
Schlüsselwörter: Psychoneuronaler Isomorphismus, content-NCC, Bewusstsein, Intentionalität, Mechanismen.

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Alfredo Vernazzani (b. Naples 1984) is currently a PhD student in philosophy at the Universität Bonn, and visiting PhD at the University of Cambridge (Michaelmas 2015 – Lent 2016). His research interests are: scientific explanation in cognitive science, neural correlates of consciousness, and the philosophy of perception. This paper was written thanks to the financial support of the Barbara-Wengeler Stiftung.
Address: Eifelstraße 23, 53119, Bonn, Deutschland.
E-Mail: av463@cam.ac.uk