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### **Source and channel in the informational theory of mental content**

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With the aim of giving a naturalistic foundation to the notion of mental representation, Fred Dretske (1981;1988) has put forward and developed the idea that the relation between a representation and its intentional content is grounded on an informational relation. In this explanatory model, mental representations are conceived of as states of organisms which a learning process has selected to play a functional role: a necessary condition for fulfilling this role is that the organism or some proper part of it (presumably situated in the brain) is a natural indicator of the occurrence of a determinate type of event in the environment of the organism (or in the organism but outside of the proper part serving as the indicator). A state of the organism is a natural indicator of a type of event if and only if it carries information about the occurrence of that type of event. Jerry Fodor (1987) has devised and followed another strategy which consists in considering the relation between a mental representation and its intentional object as a relation of lawful, or nomic, dependence. A representational state of an organism has an objective content in virtue of the existence of a relation of nomic dependence between this state - presumably a property of the brain of the organism - and some objective property in the world. This dependence also creates a regular correlation between the occurrences of representational states of a certain type and the states of affairs whose type is their representational content. Both approaches encounter indeterminacy problems: for each, there exist situations in which the explanatory model chosen - information flow or nomic dependence - does not succeed in selecting, purely on the basis of the constraints characteristic of that model, one out of several potential contents for a given representational state. In such cases, that state is related to more than one type of events in accordance with the informational or nomic constraints imposed by those theories.

In what follows, I examine an attempt by Pierre Jacob (1997) to solve two problems of indeterminacy threatening the informational theory of mental representation. According to Jacob, one of these problems can be solved with the help of the distinction between the source which is the target of the information and the channel over which the information is transmitted, whereas the solution to the other problem requires the introduction of the concept of function. I shall begin with a consideration of the distinction, with respect to a situation of information transmission, between the source and the channel. I argue that both the source and the channel, and thus the information transmitted, depend not only on the external situation which characterises the source, the channel and the receiving organism, but also on the previous knowledge and the informational needs of the receiver. I then try to show that this relativity of information undermines the solution Jacob proposes to one of the problems

of indeterminacy of representational content. Finally, I examine the possibility considered by Dretske and Jacob to solve this "problem of the reference class" due to the mentioned relativity of information, by grounding the flow of information on lawful dependence instead of statistical dependence. I shall propose two arguments showing first that these two groundings are not equivalent and second that nomic dependence is inappropriate as a grounding for information flow. I conclude by suggesting that the problem of the reference class can be solved within the framework of the informational approach, on the condition of enriching it with functional considerations.

### 1. The distinction between the source of information and the channel of transmission

In the theory of information as it has originally been conceived by Shannon and Weaver (1949) in the context of the analysis of signal exchange in telecommunication, information is considered as the result of the reduction of uncertainty. The occurrence of an event informs us insofar as its occurrence was uncertain. Moreover, the quantity of information depends on how much the prior uncertainty is diminished. The uncertainties obtaining respectively before and after the occurrence of an event  $s$  can be measured most simply if  $s$  is situated in the framework of a space of possibilities whose existence is independent of the actual occurrence of the event  $s$ . To give a very simple example, throwing a dice reduces the uncertainty as to the side on which it would fall from six to one. In this case, the uncertainty has been absolutely reduced, or reduced to zero. If we come to know that the event  $t$  has occurred: that the dice has fallen on an odd number, the uncertainty is only partially reduced.  $t$  reduces it only from six to two possibilities. As simple as they are, these examples already show how both the uncertainty and its reduction, i.e. information, depend for their quantity on a background of possible events. In general, there is still another factor which intervenes in determining both the uncertainty and the uncertainty reduced by an event, i.e. the information it carries: this is the *a priori* chance of occurring of each of the possible events in the background. If the dice is biased, the different faces may not have equal chances of appearing. Let us assume that the chance that such a biased dice falls on "6" is 95%. Then it is more informative, the reduction of uncertainty is larger, to be told that the dice has fallen on "1" than to be told that it has fallen on the more probable "6".

We can express this fact by saying that the information carried by an event varies with the "reference class" associated with this event: the class of all possible events together with the *a priori* chance of occurrence of each, which constitutes the framework within which the information carried by an event is evaluated. A particular event  $s$ , considered as a signal, may provide a different information for each choice of the reference class.

Dretske (1981, pp. 78ff.) illustrates this relativity of information with the help of the following example. Two persons try to find out which out of four shells hides a peanut.

(There is only one peanut.) One of them (A) has already looked under two peanuts and found them empty. When she then looks under one of the remaining two and finds it empty too, this provides her the information *that* the peanut lies under the 4th shell. For A, the probability that the peanut is under shell 4, given that it is not under shell 3, equals 1 ( $\text{Prob}(4|-3)=1$ ). A can evaluate the signal "-3" - that the peanut is not under shell 3 - within a framework of information already acquired, with the effect that this signal reduces his uncertainty to 0. For A, at the moment of receiving the signal "3", the reference class only contains the two events "3" - the peanut lies under shell 3 - and "4" - the peanut lies under shell 4. B however who has not yet turned around any shells, receives a lesser information from the same signal "-3": that the peanut is under one of the shells 1, 2 or 4. B's reference class still contains four possible events: "1", "2", "3", "4". For her, the probability that the peanut is under shell 4, given that it is not under shell 3, equals only 0.33 ( $\text{Prob}(4|-3)=0.33$ ). The information carried by a given signal to a particular receiver at a particular moment depends on the reference class with respect to which the receiver evaluates the signal. The information may vary both with the number of members of this class and with their respective *a priori* chances of occurring<sup>1</sup>.

The fact that a given signal can in principle be evaluated with respect to more than just one set of relevant alternatives poses a serious problem to those who attempt to rely on the conceptual framework of the theory of information in order to give a naturalistic account of the content of mental representations, by first of all giving an account of the indication relation between an internal state of the organism and the type of state to which it is informationally linked. Representation itself arises then, according to Dretske (1988), from the fact that the indicator is selected to fulfil the function of indicating that type of state. We shall return to this later.

So far we have only considered the information which is produced by the occurrence of an event. Let us now make the next step. It is not in the first place the information produced by an external event *s* which it is important for us to analyse but rather the information contained in the state *r* internal to a cognitive system receiving the signal *about* the external event *s*, in virtue of the fact that this information has been transmitted from the occurring of *s* - the source - to *r* - the receiver - through a channel. The information which is relevant for the project of the informational analysis of the content of mental representations is not the information contained in the occurring of the external event *s* itself, but rather the information transmitted, e.g. by perception of *s*, to a cognitive system, more precisely to an indicator *r* internal to this cognitive system. To take into account the transmission between source and receiver, we must look more closely to the concept of a transmission channel.

Dretske proposes to conceive of the channel as the set of conditions which can be considered as *stable* within a given situation of information transmission, in the sense that the

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<sup>1</sup>The example allows to abstract from the latter source of variation of the informational content, because it is stipulated that before any observation of the shells, the probability of the presence of the peanut is the same for all four shells.

receiver does not have any uncertainty with respect to them<sup>2</sup>. This means that what counts as part of the channel, in opposition to what counts as part of the source, depends on factors which are specific for the particular receiver, his knowledge of the situation and the aim of his search of information. The channel conditions are those remaining constant within the framework of the thus constrained situation of information search. The antecedent knowledge of the receiver determines both the source - the set of alternative events and their *a priori* probability - and the channel. To go back once more to our example, from the moment when receiver A has looked under shells 1 and 2, the fact that the peanut does not lie under these two shells becomes part of the channel of information linking A to the location of the peanut. This is because these facts - that it is not under 1 nor 2 - do not change any more and thus cannot create any information for A; as to these two facts, A does not have any uncertainty which could be reduced. B's case is different in this respect. Whether or not the peanut lies under shell 1 or 2 is still uncertain; these facts can create information by reducing this uncertainty and count therefore, for B, as part of the source. In the terminology of information theory, the difference can be expressed by saying that the equivocation of the signal "-3" is 0 for A, but not for B<sup>3</sup>. This is not to say that the channels linking A and B to the place where the peanut lies are completely different. Such facts as that shells are solid and opaque objects which persist through time belong to the channel for both: None of them has any uncertainty with respect to these facts and thus no observation could carry any information about them.

That the constitution of source and channel also depends on the aim of a given process of information search, can be made clear with the following example<sup>4</sup>. When an electrician uses a voltmeter to measure the tension over a piece of wire, the tension is for him the source of information and the set of conditions determining the instrument constitutes the channel. But if his task is not to measure a tension but rather to check the well functioning of the instrument, source and channel would be switched. He would then have to take the tension for granted - having established it by other means - and the way of functioning of the instrument would then no more be considered as stable but on the contrary as uncertain and so as source of information.

### 3. The problem of imperfect correlation and the problem of transitivity

Jacob (1997) uses the distinction between the source of information and the channel of transmission to solve a problem posed to an informational account of the content of mental representation. The "problem of imperfect correlation" (Jacob 1997, p. 95) - which Fodor

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<sup>2</sup>Cf. Dretske (1981, p. 115, also pp. 123, 129, 133).

<sup>3</sup>According to an equivalent characterisation of the channel of transmission in purely statistical terms (due to Shannon and Weaver 1949), the channel is determined by the conditional probabilities of the different events occurring at the source, given the occurrence of certain events at the receiver. As the example of the shells shows, these probabilities depend on the epistemic situation of the observer.

<sup>4</sup>Cf. Dretske (1981, p. 117).

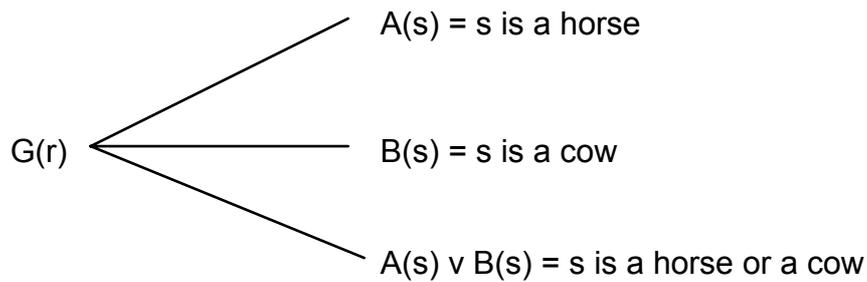
(1987) calls the "disjunction problem"<sup>5</sup> - is a problem of indetermination: on the basis of the hypothesis that the content of a mental representation is determined by the information it carries about a state in the environment, there are cases where the account predicts that the content remains indeterminate whereas it is intuitively perfectly determinate. Jacob argues that the conceptual resources of the theory of information itself, and in particular the distinction between source and channel suffice to overcome the indeterminacy allegedly arising in cases of imperfect correlation. He contrasts these cases with cases of an apparently similar indetermination which the informational account is bound to predict and which arises from the fact that the transmission of information is transitive. According to Jacob, this "transitivity problem" can be solved only by enriching the purely informational account by relying on teleological concepts: it is necessary to draw on the analysis of the biological function which natural selection confers on internal indicators in organisms with representational capacities. I shall argue on the contrary that, in the light of the above mentioned relativity of the source and the channel, the conceptual resources of the theory of information alone do not even suffice to overcome the first of the two problems.

Let us first consider a case of "imperfect correlation" between an indicator and the state of affairs which it indicates, in other words its content. The informational correlation between  $G(r)$  - the indicator  $r$  internal to an organism is in state  $G$  - and a disjunctive condition  $A(s) \vee B(s)$  - the object  $s$  at the source is either in state  $A$  or  $B$  - is in general better than the correlation between  $G(r)$  and the simple condition  $A(s)$ . Jacob gives the example of an organism which can in principle distinguish horses from cows and react differently to their perception. Now, due to occasional perceptual error,  $G(r)$  which is intuitively the internal state indicating the presence of a horse, is not only activated when the organism is looking to a horse, but also sometimes when it is looking to a cow. The problem for the informational account is that it seems to lack a justification for attributing to  $G(r)$  the intuitively correct content, namely that  $s$  is a horse, because the informational correlation is optimal on the hypothesis that  $G(r)$  indicates that  $s$  is either a horse or a cow. Moreover, it seems arbitrary, and objectively indeterminate how large a disjunction to choose, given that there may be many other, more or less improbable, causes of the activation of  $G(r)$ .

In figure 1, the different correlations are represented by lines linking the indicator  $r$  to the object  $s$  at the source.

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<sup>5</sup>The importance of this problem lies in the fact that the explanation of the possibility of misrepresentation presupposes its solution. A misrepresentation is a representation of a perceived object as something different from what it is, e.g. a representation of a horse as a cow.



(Fig. 1) The "problem of disjunction" (Fodor) or "problem of imperfect correlation" (Jacob)

The problem is that a purely informational theory of the content of  $G(r)$  seems incapable of excluding anything which might possibly cause the activation of  $G(r)$  as part of its content. In other words, it cannot account for the fact that an organism can have an indicator with a determinate condition as its content but whose correlation with the real occurrence of this condition is less than perfect. It cannot account for the fact that perceptual error leaves the content of the falsely activated indicator unchanged.

The controversial thesis defended by Jacob (1997) is that this problem can be solved within the framework of the informational account by carefully exploiting the distinction between source and channel.

"The problem of misrepresentation (or disjunction problem) may have an informational solution. [...] I am tempted to follow Dretske's (1981; 1993) lead into thinking that the solution to what I call the problem of imperfect correlation lies in a deeper understanding of what [...] I called the problem of channel conditions. [...] In other words, I think that the way to a solution to the problem of imperfect correlation which would minimize the threat of presupposing intentionality is to remind ourselves that the information carried by a signal does not nomically depend<sup>6</sup> merely upon some environmental condition. Nor does the tokening of a concept merely depend upon the instantiation of a given property. It also depends on channel conditions  $C$ . [...] The way to a solution to Fodor's version of the disjunction problem is to make plain why distinct pairings of source and channel conditions can all bring about tokens of the same mental type while explaining at the same time why not all such tokens carry the same information." (Jacob 1997, pp. 95, 99f.).

It is indeed true that the determination of the channel allows, in a purely formal way, to determine the informational content of a signal. But the question to which Jacob gives no answer is on which naturalistic basis it is possible to determine the properties of the channel. In the example used by Jacob, it is necessary and sufficient to attribute the fact that  $s$  is not  $B$  to the channel, in order to exclude the undesired disjunctive content  $A(s)$  **Erreur ! Signet non défini**.  $B(s)$  so as to obtain the intended result that the content is  $A(s)$ . If it is stipulated that the epistemic alternatives for a given cognitive subject are  $A$  or not- $A$ , no signal can possible bring him the information that something is  $A$  or  $B$ . What is controversial about Jacob's claim

<sup>6</sup>We shall come back later (§ 4) to the thesis presupposed in this passage, that the relation of information transmission presupposes, or is even equivalent, to the relation of nomic dependence.

is the thesis that the problem of imperfect correlation has a *purely* informational solution. It is clear from the context of Jacob's analysis, that in calling this solution "informational", he intends to defend the claim that it does not require any recourse to the concept of biological function.

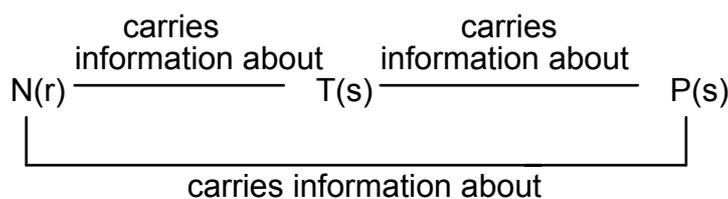
The context is the comparison of the problem of imperfect correlation with the problem of transitivity. According to Jacob, these problems differ precisely in that the first but not the second can be overcome with the help of the conceptual resources of the theory of information alone, above all by relying on the source/channel distinction, whereas the second requires the additional usage of the concept of biological function. This is how he puts the contrast: "Unlike the transitivity problem, the problem of misrepresentation (or disjunction problem) may have an informational solution. If I am right, the problem of transitivity of correlations does require a teleological solution [i.e. a solution in terms of biological function; M.K.]" (Jacob 1997, p. 95). In fact, according to Jacob (*op.cit.*, pp. 103/4) imperfect correlation (the source of the disjunction problem) does not, within the framework of the informational theory with its source/channel distinction, really lead to an indeterminate content at all. But he is wrong with this: given his naturalistic aim, he cannot use the source/channel distinction in order to attribute a determinate content to a signal, without indicating which naturalistic conditions determine the channel. As we have seen above, it is equivalent to determine the source and the channel for these sets of conditions are complementary. Without a hint as to what, in naturalistic terms, determines the source and/or the channel, the proposed solution of the problem of imperfect correlation remains purely verbal. And it is difficult to see what if not a reflection on the *function* which the reception of the type of signals in question has for a given type of organism, could lead to a naturalistic determination of the source of a given process of information search, and thus indirectly to a determination of what counts as the set of conditions whose stability is assumed for the purposes of that search: the channel.

Let us compare the case with "the problem of transitivity" which Jacob holds to be an authentic source of indetermination which can be overcome only by completing the informational analysis by considerations of biological function. There are in fact two sources of the transitivity of information transmission, the first having a logical, the second a nomological origin<sup>7</sup>. Let me give an example of the first type: if the signal that *r* is *G* carries the information that *s* is *A and B* then it necessarily also carries the information that *s* is *A* because this latter piece of information is logically implied by the conjunctive information. This has the consequence that the content of the signal *G(r)* is undetermined between  $A(s) \wedge B(s)$  and  $A(s)$ . The second source of transitivity exists for those who, like Dretske and Jacob, hold that *carrying information about* some condition presupposes *being nomically dependent*

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<sup>7</sup>In Dretske's (1981, p. 71) terms, the first origin lies in the fact that a signal carries also all the information "analytically nested" in the information it carries, the second in the fact that a signal carries all the information "nominally nested" in its information.

on that condition. Indeed, Dretske (1981, pp. 73ff.) explains that nomic dependence is *necessary* for the transmission of information whereas perfect correlation is not enough. But his own theory of laws of nature (Dretske 1977) makes it clear that nomic dependence is also *sufficient* for information flow, for a law of nature produces a perfect correlation between its antecedent and its consequent. In the end nomic and informational dependence come out as equivalent<sup>8</sup>. Then, on the hypotheses that the relation of nomic dependence is transitive and that it is equivalent with the relation of information transmission, information transmission comes out to be transitive in a second way.



(Fig. 2) The transitivity of the informational relation

Jacob illustrates the problem of the indetermination of the content of an indicator which is due to the transitivity of the informational relation with an example where this transitivity is grounded on nomic dependence. The fact that the level of quicksilver in a thermometer  $r$  is at  $N$  cm (the fact designated by " $N(r)$ " in figure 2) is nomically linked to the fact that the temperature of the enviroing air is  $T$  (the fact designated by " $T(s)$ ")<sup>9</sup>. But the fact that the temperature of the air is  $T$  is in its turn nomically dependent on the fact that the air pressure is  $P$  (fact designated by " $P(s)$ ") - where these nomic relations result in sufficiently normal situations in the existence of a *de facto* correlation between  $N$  and  $T$  and between  $T$  and  $P$ <sup>10</sup>. By virtue of the transitivity of nomic dependence, it follows that there is a nomic dependence also between  $N$  and  $P$  which manifests itself in sufficiently normal situations by the existence of a correlation between  $N$  and  $P$ . If one holds (with Dretske and others) that the informational relation is equivalent to the relation of nomic dependence, it follows that the fact that the level of quicksilver is at  $N$  carries both the information that the temperature is  $T$  *and* that the pressure is  $P$  for the information that fact carries directly - that the temperature is  $T$  - contains in turn the information that the air pressure is  $P$ . In this way, the informational content of the indicator state  $N(r)$  is not unique.

This case shows that the transitivity of the nomic dependence makes the representational content attributed to an indicator on an informational base indeterminate *if*

<sup>8</sup>We shall examine this identification below (§ 4).

<sup>9</sup> $N$  and  $T$  are linked by an equation which also features the parameters of the instrument and the exactitude of which varies with the temperature itself - it is approximately exact within a certain range of temperatures characteristic of the instrument.

<sup>10</sup>We come back below (§ 4) to the distinction between nomic dependence and the correlation in general less than perfect that this dependence creates at the level of the instantiations of the law in particular circumstances. This issue is the object of closer scrutiny in Kistler (forthcoming).

onomic dependence is considered as sufficient for information. Through the multitude of nomic dependencies in which the immediate source of information (in our example, air temperature) is implicated, the signal gets loaded with other contents (in our example, air pressure). If it is correct to generalise the result obtained by the analysis of this case, every signal carries more than just one content: it cannot carry one content without also carrying all the contents that it implies either logically or nomologically.

What I shall now try to show is that the framework of the theory of information permits to solve the problem of transitivity to the same extent as it permits to solve the problem of imperfect correlation. In both cases, such a solution requires an independent determination of what counts as the source and of what counts as the channel. Information theory in itself cannot provide this determination which must rather be found on the basis of epistemic and biological criteria taking into account the particular situation of the receiving organism with respect to its antecedent state of knowledge and its informational needs.

Once one has succeeded in determining the source and the channel for a given transmission of information, the indetermination due to transitivity can be overcome in the following way. If the correlation grounded on a nomic dependence between the first and the last link in the chain of transitivity is perfect, then the signal (the first link; in our example: the fact that the quicksilver is at level N) can both carry the information contained in an intermediary link (in our example: the fact that the temperature is T) and the information contained in the last link (in our example: the fact that the air pressure is P). But the determination of the source (and indirectly, of the channel) for a given receiver allows to determine which of these possible pieces of information the signal really delivers to that receiver. The constitution of the source can be determined in its turn on the basis of a teleological analysis of the function that signals of that type have for receiver. Let me take Dretske's (1986)<sup>11</sup> famous example of the marine bacteria.

"Some marine bacteria have internal magnets (called magnetosomes) that function like compass needles, aligning themselves (and, as a result, the bacteria) parallel to the earth's magnetic field. Since these magnetic lines incline downwards (towards geomagnetic north) in the northern hemisphere (upwards in the southern hemisphere), bacteria in the northern hemisphere, oriented by their internal magnetosomes, propel themselves towards geomagnetic north. The survival value of magnetotaxis (as this sensory mechanism is called) is not obvious, but it is reasonable to suppose that it functions so as to enable the bacteria to avoid surface water. Since these organisms are capable of living only in the absence of oxygen, movement towards geomagnetic north will take the bacteria away from oxygen-rich surface water and towards the comparatively oxygen-free sediment at the bottom. Southern-hemispheric bacteria have their magnetosomes reversed, allowing them to swim towards geomagnetic south with the same beneficial results. Transplant a southern bacterium in the North Atlantic and it will destroy itself - swimming upwards (towards magnetic south) into the toxic, oxygen-rich surface water." (Dretske 1986, p. 26).

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<sup>11</sup>Dretske cites Blakemore and Frankel (1981) as the scientific source of this example.

In this example of information flow, what is the source and what the channel of transmission ? The mere analysis of the case of the marine bacteria in purely informational terms, or in purely nomological terms, cannot deliver a unique answer to these questions. The indetermination arises from the fact that the state of the magnetosome indicates (carries information about) the direction of oxygen-free water *by indicating* the direction of geomagnetic north. By virtue of the transitivity of the indication relation, it indicates *both* conditions. An analysis in terms of nomic dependencies leads to the same result. The state of the magnetosome nomically depends on the direction of oxygen-free water indirectly, *by way of* depending directly on the direction of geomagnetic north. How can we nevertheless attribute a unique content to the state of the magnetosome although it cannot carry information about one of two different conditions in the environment without also carrying it about the other, and although it is equally nomically dependent on these two different conditions?

New light can be thrown on this issue by turning to a teleological analysis of the *function* natural selection has bestowed on the magnetosome within the overall goal of survival and reproduction of the bacteria. However, rather than permitting to solve the question immediately, the way in which such an analysis has to be carried through is itself highly controversial. Without going into the matter here, let me just note two crucial theoretical choices which have to be made in this context. First, one can interpret the question as to the function a given feature which is present in an organism, in two ways. Either etiologically: Why has this feature been selected in the course of the phylogenetic prehistory of the species ?, or analytically: How does the feature permit the organisms *actually alive* to accomplish the overall task of survival and reproduction ? Second, independently of the answer given to the first question, one will reach a different conclusion as to the function of the feature in question, according to whether one opts for the "point of view of benefit" (Cf. Millikan 1989) or for the "point of view of the stimulus" (Cf. Neander 1995). According to the former, what counts in the identification of the function of the indicator is the benefit which its correct functioning procures to the organism. In the case of the marine bacteria, one gets the result that the function of the magnetosomes is to represent to the bacteria the direction of oxygen-free water. Accordingly, one can identify the set of possible directions of the gradient leading to oxygen-free water with the source; on this hypothesis, the informational content of the state of the magnetosome is the direction of oxygen-free water. According to the latter, what counts in identifying the function of the indicator is what it is actually on itself capable of detecting, independently of favourable circumstances in the environment. For the magnetosomes, this means that it is rather their function to indicate the direction of geomagnetic north. By way of consequence, one can identify the set of possible directions of geomagnetic north with the source; on this hypothesis, the informational content of the state of magnetosome is the direction of geomagnetic north.

We do not need to enter this debate in order to draw two lessons for our issue. First, the decision to turn to a functional analysis of the indicator in order to complete its informational analysis does not yet in itself guarantee the success of identifying a unique function the indicator serves. But it seems at least possible that the different hypotheses have different biological consequences so as to allow an empirical decision between them. Second, *if* the functional analysis of the indicator provides a unique result, the function can fill a gap in the informational analysis which is to specify the content of the source and/or the channel of information transmission. The source of the indicator consists of the set of conditions between which it is the function of the indicator to discriminate in order to allow discriminative reaction.

This gap in the informational analysis exists not only, *pace* Jacob, for cases of indetermination of informational content due to the transitivity of information flow - as in the case of the magnetosomes of Dretske's marine bacteria - but also in cases of indetermination due to imperfect correlation. In both cases, the informational analysis fails to provide by itself a clue as to what constitutes, for a given indicator, the source and the channel, and in both cases, although the search for the biological function of the indicator in question is difficult and the way it is to be undertaken controversial, *if* a function can be identified, the source, and indirectly the channel, can be determined. We have seen how this determination would follow from the identification of the function in the case of the magnetosomes. To see how the identification of the function would do the same work in the case of an indetermination due to imperfect correlation, let us turn to the example of the perceptual indicator whose content was left indeterminate between the fact that some object in the visual field *s* is a horse and the fact that *s* is a horse or a cow. Imagine an organism for whom this indicator serves a clear function: a foal, e.g., needs a representational state which is activated upon the recognition of a horse, in order to lead its behaviour towards adult horses providing food and shelter. Once again, far from suggesting that such a functional analysis is in fact as simple as that, my aim is only to show that if such a function can be identified, then one can identify as the source of the indicator the set of the condition between which it has the function to discriminate, in this case that the object *s* is a horse and that *s* is not a horse. The functional consideration will then overrule the purely informational consideration of an optimal correlation between source and receiver: we shall classify the case where the indicator is activated by the perception of a cow as a case of error, and recognise that the equivocation of the received signal is greater than zero, or in other words that the channel is not perfect.

#### 4. Flow of information and nomic dependence

Before the perspective of a functional completion of the informational analysis of the content of mental representations began to be thoroughly investigated, Dretske proposed a

different solution to the problem of the indetermination of the reference class, at the origin of the indetermination of the content attributed to indicator states on the mere basis of the informational analysis. The proposal was to abandon the statistical foundation of the concept of information, as it has been quantitatively worked out in the theory of Shannon and Weaver (1949). This can be done, according to Dretske (1983) if we make the hypothesis that there is flow of information between two particular events if and only if there exists a relation of nomic dependence between certain properties of these events. If this hypothesis is correct, then one could reason, with Dretske, that "the simplest [way to reply to the criticisms addressed to his *Précis* (Dretske 1983); M.K.] is to embrace Loewer's [1983] suggestion: to drop the notion of probability altogether and emphasise that my account of informational content only requires a particular kind of lawful dependency between signal and source (given channel conditions and k)." (1983, p. 83)<sup>12</sup>.

But Dretske's justification for the hypothesis that nomic dependence is equivalent to a flow of information is insufficient<sup>13</sup>. In fact I shall try to show that the proposal to ground the concept of information not on conditional probabilities and Shannon's measure of uncertainty but directly on the concept of a law of nature comes to an important change in perspective. On the nomic construal of the flow of information, the events at the source are not conceived to be linked to the events at the receiver by conditional probabilities but by nomic dependence. First, what are Dretske's grounds for holding that nomic dependence is *necessary* for the flow of information ?

"Truth alone, even when the truth in question is a perfectly general truth expressing an exceptionless uniformity, is not sufficient for the purposes of transmitting information. Even if the properties F and G are perfectly correlated [...] this does not mean that there is information in s's being F about s's being G (or vice versa). [...] For the correlation between F and G may be the sheerest coincidence, a correlation whose persistence is not assured by any law of nature or principle of logic. All Fs can be G without the probability of s's being G, given that it is F, being 1." (Dretske 1981, pp. 73/4).

The latter claim is wrong, at least on a frequency interpretation of probability. Its plausibility stems perhaps from an ambiguity in the scope of the "all" operator in "All Fs are G": if it is restricted to the past, that universal sentence carries no information about the future, and there is indeed no reason why the probability that there will still be a universal correlation between Fs and Gs in the future, should be 1. If on the other hand, one understands the scope of "all" to be universal without any temporal restriction, as it is usually understood when one speaks of a universal correlation, then it is simply false to say that the probability of s's being G, given that it is F can be lower than 1. Let us consider Dretske's own example where the "universal" correlation is that "all Herman's children have the measles" (Dretske 1981, p. 74).

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<sup>12</sup>"k" represents the background knowledge of the receiver of the information. Another formulation is this : "One needs only to stipulate that the content of the signal, the information it carries, be expressed by a sentence describing the condition (at the source) on which the signal depends in some regular, lawful way." (Dretske 1983, p. 57).

<sup>13</sup>Jacob (1997) takes this equivalence for granted.

This can indeed be plausible only on the condition of restricting the scope of the universal operator to a quite limited time-span  $t$ . Within the period  $t$  the correlation is perfect and, *during that interval*, the probability for someone to have the measles, given that she is one of Herman's children, is 1. But of course this does not mean that before and after that period, there is any correlation whatsoever nor even that the probability of the former given the latter, is substantially higher than 0. Dretske's discussion of the case seems plausible only thanks to the ambiguity between a temporally restricted and a temporally universal sense of "all".

"Recognizing Alice as one of Herman's children is not good enough for a medical diagnosis no matter what *happens* to be true of Herman's children. It is diagnostically significant only if the correlation is a manifestation of a *nomtic* (e.g., genetic) regularity between being one of Herman's children and having the measles" (*ibid.*).

A medical diagnosis could indeed not be grounded on a correlation concerning only Herman's children, and still less on a correlation valid only for a few days or weeks. This is why it is plausible to say that correlations so weak as these cannot justify a medical diagnosis. But they nevertheless are sufficient to justify that, within that limited range of facts consisting of being one of Herman's children during period  $t$  and having the measles during  $t$ , the probability of the former given the latter, is 1.

It becomes clear in the sequel of Dretske's (1981) work that he has an important motivation for requiring nomic dependence for the flow of information: both statements reporting propositional attitudes and statements expressing nomic dependencies are intensional, in the sense that they do not allow the substitution of coextensional predicate expressions *salva veritate*. So, if information flow is grounded on nomic dependence, an explanation of mental content in terms of informational content might be capable of reducing the intensionality of mental attitudes to the intensionality of nomic dependence.

The condition of a nomic dependence between source and receiver is absent from the statistical account of the flow of information. What this means is that Dretske, by imposing it - with an eye on its subsequent use in the explanation of the properties of mental content - as an additional condition on the flow of information, has switched to a new and different concept of information. So far, I have only tried to show that nomic dependence is not necessary for the flow of information, in the sense of the original statistical theory. But it is in fact even more important that nomic dependence is not *sufficient* for the flow of information in the statistical sense, for the reason that it is not sufficient for perfect correlation<sup>14</sup>. I shall argue for this claim in the rest of this paper. If it is correct, then nomic dependence and perfect statistical correlation are not two equivalent foundations of the very same concept of information<sup>15</sup>.

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<sup>14</sup>I argue for this point at length in Kistler (forthcoming).

<sup>15</sup>We would already have reason to be suspicious of this equivalence on the basis of the very fact that Dretske moves from the statistical to the nomological interpretation in order to escape from difficulties encountered only by the first.

The concepts of information growing out respectively of the statistical and the nomological foundation differ in two important respects. First the nomological but not the statistical approach leads to the existence of "misinformation"<sup>16</sup>, and second the transmission of information is transitive as it should be in the statistical but not in the nomological approach. If these contentions are justified, it follows that the identification of the flow of information with nomic dependency has two unacceptable consequences: that there is misinformation and that the flow of information is not transitive. But there is still another reason not to take this line: the proposed identification would not allow by itself to overcome the problems encountered by the statistical approach in function of the indetermination of the reference class, which was Dretske's (1983) original motivation for this proposal.

#### 4.1. Misinformation

The nomological conception of the flow of information between two series of events destroys a fundamental property of the information relation. This property is that there cannot be "misinformation", in other words that information is by its essence veridical. If the signal that  $r$  is G carries the information that  $s$  is F and if  $r$  is G, then necessarily  $s$  is F. If a signal carries the information that  $s$  is F, then  $s$  is F. However, this is not necessarily the case according to the nomological conception of information for the fact that the property G of the signal is nomically dependent of the instantiation of a property F, does not necessarily imply that if  $r$  is G then there is an  $s$  which is F. Let me explain.

According to the nomological conception of information, an indicator  $r$  carries the information that there is an  $s$  which is F because the property G of the signal  $r$  depends nomically - by virtue of a law of nature - on the property F. But this dependency does not exclude the exceptional possibility that no F whatever is at the origin of the signal, notwithstanding the existence of the lawful dependency. The reason for this is that the laws of the special sciences are not strict, in the sense that their validity does not guarantee that there are no exceptions<sup>17</sup>.

In such an exceptional situation, the nomological conception predicts that the indicator "misinforms". Let us take a compass to illustrate this. The compass needle indicates - and thus carries information about - the direction of geomagnetic north for its orientation nomically

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<sup>16</sup>Although Dretske recognizes the possibility of "misinformation" (Dretske 1981, p. 122), this is really a contradiction in terms: by definition, every piece of information is veridical, in the same way in which knowledge is by definition veridical. As he makes clear himself, "*false* information and *mis*-information are not kinds of information - any more than decoy ducks and rubber ducks are kinds of ducks. [...] Information is what is capable of yielding knowledge, and since knowledge requires truth, information requires it also." (Dretske 1981, p. 45, italics Dretske's). As we shall see in § 4.1. below, the fact that a theory predicts that there are situations in which a signal "misinforms" constitutes a *reductio* of that theory.

<sup>17</sup>It is generally admitted that the laws of the special sciences can have exceptions. On this point, see, e.g., Fodor (1974). Given that the laws which are relevant for the theory of mental representation are at this level, we do not need to examine the stronger thesis that even most of the laws of physics can have exceptions. Cf. Hempel (1988); Kistler (forthcoming).

depends on the direction of geomagnetic north. An exceptional situation might arise from the fact that another force, e.g. mechanical, interferes with the force exerted on the needle by the magnetic field of the earth. If the additional force is sufficiently powerful, the direction indicated by the needle is not the direction of geomagnetic north. However, it does not in those circumstances stop indicating and carrying information about the direction of geomagnetic north for according to the nomological theory of information, it suffices for this to be the case that there be nomic dependency. This dependency does not disappear when there is an additional force present. The state of the compass carries information about  $x$  because this state depends nomically on  $x$ , but nevertheless  $x$  is not the case. The information that  $x$ , carried by the compass is not veridical; it is a case of misinformation. The existence of the relation of nomic dependency between the direction of the needle and the direction of geomagnetic north does not suffice to insure that, in all circumstances, the needle is oriented towards north. This directly contradicts Jacob (1997):

"If a signal's informational content arises out of the nomic dependency of property  $G$  of the signal upon property  $F$  of the source, then the signal cannot *misinform* about its source. If the dilatation of a metal bar  $r$  carries information about variations in temperature in virtue of the nomic dependency of the former upon the latter, then the length of the metal bar cannot misinform about temperature." (Jacob 1997, p. 93).

Reasoning about exceptional situations leads to challenge this affirmation. According to the nomological account of information, the dilatation of the metal bar can "misinform" about a change of temperature in spite of the nomic dependence of its length on its temperature. This can happen in a situation where its dilatation is due a different nomic dependence that interferes with the dependence on temperature. A strong electrical tension, e.g., applied on the bar may cause its dilatation at a constant temperature<sup>18</sup>. The nomological theory of information leads to the result that in such a situation, the length of the bar misinforms about the temperature. The fact that the bar has been expanded carries the information that the temperature has raised, in virtue of the nomic dependence between these two properties. But in point of fact, the expansion has here occurred without a raise of temperature. Nevertheless, the informational relation is unchanged: it depends only on the nomic dependencies which are independent of any particular situations. The expansion therefore carries the information that the temperature has raised but this information is not veridical.

One could try to counter this argument by saying: what the direction of the compass needle indicates is a disjunctive property whose terms are the members of the set of all properties on which the direction of the needle depends. This allows indeed to avoid the problem of misinformation. But it has another unacceptable consequence. Now we conceive of nomic dependency as of a global dependency, not of one determinate property, but of the disjunction of all the properties on which the signal depends in virtue of some law or other. But this move makes the theory lose the advantage of simplification that was the benefit of

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<sup>18</sup>This is the phenomenon of electrostriction - the inverse of the piezo-electric effect.

substituting the determination of information by nomic dependency for the determination of information in statistical terms. For if the nomic dependency proposed is a dependency on a disjunctive property, then one faces an indetermination problem which is the exact analogue of what we have called, with Jacob "the problem of imperfect correlation", which Fodor has called precisely "the disjunction problem" and which we have analysed above. The fact that the compass needle points at direction D does not any more carry the information that D is the north, but only the disjunctive information that either D is the north or that D is the direction forced upon the needle by the net force acting upon it.

The nomological theory seems to face a dilemma: either it insists on the veridicality of the informational relation. Then, as we have just seen, it is necessary to conceive the nomic dependence as a dependence on an open disjunction of all conditions on which the signal as a concrete entity nomically depends. This means that the theory leads to the same result as the statistical theory with its requirement to attribute the content to the indicator which it is best correlated with. But the difference is that the statistical account with its source/channel distinction promises to cut down the number of disjuncts so as to make the content of the indicator more determinate, on condition of finding a foundation of the determination of the source. This perspective is absent within the nomological approach for it does not seem possible to attach a meaning to the concepts of source and channel within that framework. The other alternative is to tie the informational content of the indicator to just one nomic dependence. But then, as we have seen, the so defined information it carries is not always veridical.

#### 4.2. Transitivity

Jacob (1997) presents the problem of transitivity in purely nomological terms, thus reducing the transitivity of the flow of information to the transitivity of nomic dependence. I do not challenge the fact that nomic dependence is transitive, and I consider that Dretske was right in imposing the transitivity of the flow of information as a condition *sine qua non* for any acceptable theory of information<sup>19</sup>. But this requirement leads directly to the statistical condition that the probability of the indicated state of affairs, given the state of the indicator, be one.

However, the nomological account of information, at least in its simplest variant, does not allow to preserve the transitivity of the informational relation. This is because nomic dependence creates, at the level of its instantiations, only an imperfect although very often reliable<sup>20</sup> correlation. It would be perfect between pure instantiations of the nomically linked

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<sup>19</sup>Cf. the "Xerox principle" (Dretske 1981, pp. 57/8).

<sup>20</sup>The "reliability" of a piece of information is determined by the narrowness of the channel through which it has been transmitted, in other words by the number of events whose occurrence is excluded independently of the transmission of the signal. The narrower the channel, the smaller is the number of *a priori* possible events between which the signal reduces uncertainty. This means that a given signal carries more information (or, in the

properties, but in a set of concrete situations in which, to take up an example already considered (in § 3) one measures T (air temperature) by N (level of quicksilver in a thermometer), there are deviant cases, due to interfering factors which act, e.g., on N without acting on T. It is true - this is the transitivity of nomic dependence - if N nomically depends on T and T nomically depends on P, then N nomically depends on P. But the existence of situations which are exceptional with respect to these lawful regularities, leads to the result that the correlation created by the law at the level of the instantiations of the nomically linked properties is in general inferior to 1, in other words it is imperfect. In situations which are exceptional with respect to the dependence between N and T, the properties N and T can vary independently of one another, as a function of the interference of nomic dependencies to which N and T are subject independently of each other, with respect to still other properties. In such situations, N can vary without T varying or T can vary independently of N, which means that the correlation  $c_1$  between N and T is smaller than 1. Now if  $c_1 < 1$ , and if the correlation between T and P is  $c_2$  where  $c_2$  is also  $< 1$ , then the correlation between N and P is  $c_1 \cdot c_2$ , which is smaller than  $\min\{c_1, c_2\}$ . In other words, states of affairs which are indirectly nomically linked in virtue of the transitivity of nomic dependence, are in general correlated the more weakly the larger the number of intermediate links in the chain of dependence. But it seems plausible to require a threshold of reliability  $c_0$  below which a given correlation is too weak to be able to transmit information. If one creates a sufficiently long chain of nomic dependence and if the correlations between two adjacent links are always  $< 1$  (while being  $> c_0$ ), there will be a point at which the correlation between the first and the last link in the chain falls below the threshold  $c_0$  although all the correlations between adjacent links are  $> c_0$ . This means that the transmission of information is not transitive on this account.

This result might appear paradoxical in the light of a regularist analysis of lawful dependence where a law - or a nomic dependence - linking two properties is *identified* with the correlation between the instances of these properties. The preceding analysis presupposes a different conception of the nature of laws. It requires to distinguish sharply between the law itself which is a relation between properties themselves, and the regularity it creates at the level of the instantiations of these properties<sup>21</sup>. The latter correlation is in general imperfect. This distinction allows to explain why nomic dependence at the level of the properties themselves is transitive, whereas the correlation between the *instances* of the lawfully correlated properties diminishes with increasing length of the chain of dependence. The result

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terminology here used by Jacob, a more reliable information) if it has been transmitted through a narrow channel than if it has been transmitted through a large. Our simple case of the shells and the peanut illustrates just this: the channel linking A to the location of the peanut is narrower than that linking B to it and this is why the same signal "-3" carries more information to A than to B.

<sup>21</sup>Dretske (1977) and Armstrong (1983), conceive of laws as of relations of dependence between universals. However, according to their analysis, a law entails an exceptionless universal correlation between the instances of the antecedent and the consequent of the law. Kistler (forthcoming) proposes a realist account of laws which is compatible with the possibility of exceptions to valid laws.

is that a correlation with a coefficient  $> c_0 > 0$  between instantiations of properties is not transitive although the relation of dependency between the properties themselves is transitive.

If this argument is sound, it corroborates the well-foundedness of Dretske's (1981) original choice to require an absolute condition on the possibility of the transmission of information. This means, in our example, that in order to justify the idea that the height  $N$  of the quicksilver contains the information that the air pressure is  $P$ , it is necessary to interpret information on a statistical basis, and to require that the conditional probability that  $P$ , given  $N$ , be 1. The fact that the nomological approach is incapable of preserving the transitivity of the flow information, pleads for a return to the statistical approach.

#### 4. Conclusion

That version of an informational account of mental representation which reduces the relation of the transmission of information to the relation of nomic dependence, is faced with two important problems: it leads to the possibility of misinformation and it makes the transmission of information lose its transitivity. These problems can be overcome within the framework of the statistical approach to information, provided that one can find an independent basis on which the set of conditions constituting the source - and indirectly those constituting the channel - of information can be determined naturalistically and non-arbitrarily. Such a solution is not open to the defenders of the identification of the informational relation with a relation of nomic dependence for in that framework, the notions of source and channel have no clear content, whereas they can be clearly defined in terms of conditional probabilities.

I think we should conclude that it is ill-advised to react, as Dretske once recommended, to the problem of the indetermination of informational content which is due to the indeterminacy of the reference class by abandoning the statistical approach and trying to ground the concept of information on the relation of nomic dependence. We have seen emerging an alternative strategy to overcome the indetermination problem which has not yet been sufficiently explored: to return to the original statistical account of information which allows to avoid "misinformation" and to preserve the transitivity of the flow of information. We have also seen that it is only at a first approach that the reference class for a given process of information flow has remained indeterminate. The biological analysis of the function an indicator plays for the overall aims of the organism, may eventually allow to determine the class of biologically relevant alternatives, and their respective *a priori* probability, between which it is the function of the indicator to discriminate. In this perspective, informational semantics is even more "impure" than it is in the form defended by Jacob (1997). Not only the

transitivity problem but also the problem of imperfect correlation can only be overcome by appealing to the concept of biological function.<sup>22</sup>

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