Paul Løvland

Physicalism Begs the Question and Violates the 2^{nd} Law of Thermodynamics

Physicalism is critically assessed from a natural scientific viewpoint, and its basic principles are questioned. Descartes' substance dualism may seem more acceptable if it is understood as a kind of *energy dualism* where mental and cerebral processes are supposed to be analogous. A strict law connecting (mental) information and cerebral (electrical) potential is proposed. An agent's (mental) concentration on a task, an ordering process, causes cerebral concentration and thereby ordering, i.e., decreased entropy. A purely physical process in the brain without external influence will lead to increased entropy according to the 2^{nd} law of thermodynamics. Since the opposite is true in action there must either be a mental influence or the 2^{nd} law is violated. The physicalists deny mind-brain causal interaction and strict causal laws between the domains. In order to include mental entities in their basic theories they reduce them to physical ones; they may even consider them identical to the latter. This poses a new problem: Animated physical entities/neurons which seem just as "weird and phlogistic" as mind-brain interaction. Moreover, the question of mental efficacy is not properly addressed.

"The core of contemporary physicalism is the idea that all things that exist in this world are bits of matter and structures aggregated out of bits of matter, all behaving in accordance with laws of physics, and that any phenomenon of the world can be physically explained if it can be explained at all." (Kim, 2008, p. 149).

From a natural scientific basis, I will review and comment on fundamental principles of physicalism with respect to mental action and efficacy.

1 Dualism and thermodynamics

Most physicalists hold that mind and brain in dualism belong to distinctly different domains that cannot interact causally. The latter is characterised by space-time coordinates, extension, bulk, mass, energy, etc. which are absent in the former. Therefore the two domains are incommensurable. and neither substances nor properties can interact causally.

I will ask the physicalists to argue for this assertion with reference to modern physics, not only to Euclidean geometry. Could there be a possible explanation of mind-brain interaction by referring to one or more of the following phenomena, theories, and models in physics?

- *Quantum mechanics.* "Weird" phenomena are discovered and experimentally vindicated at the atomic level, like: Non-locality of particles, statistical nature of the wave function, Heisenberg's uncertainty principle, and randomness.
- *Dark matter and dark energy.* A large amount of matter and energy in the universe is unknown.
- $E = mc^2$
- *Thermodynamics.* The statistical laws of thermodynamics are not tested for cerebral reactions. A putative influence of mental entities on the 1st and 2nd laws may perhaps some time in the future be experimentally vindicated or at least indicated.
- *Information theory.* Mental information in bits can be converted to physical energy by applying the concepts of both statistical and calorimetric entropy according to L. Boltzmann. A quantitative causal connection is suggested (Løvland, 2009).

Descartes suggests that mental and physical substances interact. This dualism is much criticized, sometimes scornfully, by many philosophers on the grounds mentioned above. That there should exist mental substances is often ridiculed. However, Descartes had solely knowledge of the 17th century's science and not of to-day's chemistry and physics. Thus his use of the term "substance" was probably quite plausible at his time but to-day we would prefer to use other terms. Chemical and physical substances consist of a certain amount of internal energy that is determined by their molecular or microscopic structure. In a chemical process the substances are transformed from one structure to another whereby the amount of internal energy changes. In spontaneous processes this energy will normally diminish and the difference between the final and the initial amounts is part of the driving force of the process, in chemistry called the *free energy;* we may also call it potential energy. According to the 1st law of thermodynamics this amount of energy cannot disappear, it leaves the system as heat or as outside mechanical work. In chemical processes the free energy causes changes in the molecular structures on its way to lower energy, a change we may call chemical work. In mental processes motivation, be it desire, libido, wish, will or the like, could be considered as the analogue of free energy, while cognitive work is the analogue of chemical work. Løvland (2006) has elaborated these relationships in his psycho-energetic model which also includes emotions. Relevant parts of the model are explained below.

Prominent psychologists and philosophers have suggested that mental processes are similar or analogous to chemical and physical ones applying a vocabulary that refers to energy or force, e.g., libido and cathexis (Freud, 1915/1991), psychic energy (Jung, 1928/1973), discourse of force (Ricoeur, 1970), and law of pure wishful thinking (Hart, 1988). If Descartes had used energy terms relating to substances he would have introduced another kind of dualism which would have been more acceptable to contemporary philosophers. An appropriate term would be *energy dualism* that is a possible basis to explain mind-brain interaction. I will revert to this problem below.

Above I said that the change of internal energy is part of the driving force, the free energy. So there are more parts, at least one more. Which one?

If $\mathrm{d}U$ is the difference in internal energy between the final and initial substances the free energy of the infinitesimal process is

$$\mathrm{d}F = \mathrm{d}U - T\mathrm{d}S$$ (e.g., Prigogine, 1954) Eq. 1

where $\mathrm{d}S$ is the change of entropy between the substances, and T is the absolute temperature. The very important term entropy, S, is now introduced; in this context it means a small quota of heat per degree. This calorimetric entropy can be converted to statistical entropy by using Boltzmann's constant and his definition of entropy. The latter is grounded of the number of possible microstates and is a measure of order in the substances. It is expressed in the following equation for statistical entropy:

$$S = k \ln m$$ (e.g., Prigogine, 1954) Eq. 2

which is the Boltzmann-Planck formula where k is Boltzmann's constant and m is the number of possible microstates, i.e., the possible configurations of atoms or molecules. The fewer microstates, the higher is the order, and the lower is S.

Does this physical entropy have a mental analogue? To find out we must turn to information theory that defines the amount of information, which is a mental entity, in the following way:

$$H = \log_2 m$$ (e.g., Attneave, 1959) Eq. 3

This is a special case of Shannon-Wiener's general equation. *m* is the number of equally probable alternatives in a choice situation where one alternative is chosen. The fewer alternatives, the higher is the order, and the lower is *H,* which I prefer to call “mental entropy”. We see easily the similarity between equation 2 and 3 indicating an analogous relationship between mental entropy and the physical one. Briefly, when the order becomes higher the lower are both the mental and the physical entropy (and vice versa). Equation 1 relates entropy to energy indicating an analogy between mental and physical energy, i.e., between motivation and physical free energy.

However, here is a contradiction that could make trouble for our mind-brain analogy. *H* in equation 3 can be interpreted in two different ways: i) Thermodynamicists may call it mental entropy. ii) Information theorists call it information which is the opposite of entropy, i.e., they have different signs. - When the order becomes higher and the mental entropy lower the information increases in a choice situation due to removal of alternatives.

If the first interpretation is applied physical and mental entropy are analogous, but with the second they are not. Which one is relevant?

The contradiction can be explained by the different use of probability in thermodynamics and information theory. Probability underlies statistical entropy and increases in spontaneous physical processes because the number of microstates goes up according to the 2nd law. In mental processes the probability diminishes as the number of alternatives goes up, e.g., when playing dice. I contend that the thermodynamic definition of probability must be applied in order to compare physical entropy and *H* on equal terms with the same premises. Thus, interpretation i) is preferred, and there is a quantitative analogy between physical and mental entropy. Since this analogy can be extended to energy by equation 1 we have a strong case for dualism which corroborates the theories of mental energy put forward by Freud and others. I deal with this matter in my next paper.

2 Physicalism begs the question

Physicalists have stated two main principles that are crucial and necessary for their philosophy, i.e., for their rejection of causal mind-brain interaction (Kim, 2008):

1) *The causal closure of the physical domain.* This means that if a physical event has a cause, this cause must be physical.

2) *Causal exclusion.* If an event has a *sufficient* cause c, no event distinct from c can be a cause of this event.

These principles or axioms seem to be very peculiar to non-physicalists. They are used as premises for a whole philosophy, while others consider them as conclusions that need to be explained, the explanandum so to speak. Just to state that entities in distinct different domains cannot interact does not suffice as an explanation even though one is mental and the other is physical. Batthyany (2005) has succinctly expressed the logical problem of physicalism: `Physicalism has to presuppose itself in order to confirm itself ' (author's translation). King (2006) holds that the principles are not derived empirically but are adopted for methodological reasons.

There is also a real electrochemical ground to reject the two principles above: Without any mental influence energy from the body floods into the brain filling up groups of neurons in a fairly random, disordered, and meaningless way ending up at a certain ground level potential that can be measured with an electroencephalographic method. Neuroscientists (e.g., Libet, 1985; Trevena & Miller, 2002) have measured the potential during an intentional action involving conscious will/desire to move a finger. They found that the potential went up significantly about 10 μV from the ground level, and about 3 μV could be referred to the conscious will. The whole rise is called the cerebral readiness potential. Jung (1985) has demonstrated similar effects that were due to more complex actions such as calculating and writing. When the subjects decided to halt the action in Libet's experiment the potential dropped to the ground level. The experiments show that a conscious and unconscious mental entity caused a change in the electrical potential that can be quantitatively measured. I have suggested an explanation grounded on information theory and thermodynamics for this phenomenon (Løvland, 2009): The mental entity has an amount of information that can be calculated quantitatively in bits, ref. equation 3 above. Both the amount of information and the amount of potential/energy go up when the structural order in respectively the mind and the brain increases. And the mind's order goes up when the subject concentrates on the task. Due to the known correlation between mental and physical entities the brain's order also increases since the mental processes activate relevant groups of neurons while others remain passive, irrelevant, and fairly random. In this way a relatively ordered and meaningful brain pattern is formed. Such ordering is dependent on physical energy being supplied to the brain, and this energy can merely come from the body itself. Thus mental activity causes ordering in the brain *without* transferring energy. The increased cerebral energy is transformed to electrical potential according to electrochemical laws. I held that 1 bit of information causes a change of 3 μV in the readiness potential in Libet's tests (Løvland, 2009). The interaction between the domains is presumably possible due to "bridge-laws" linking meaningful information to physical energy; we can talk about information-energy interaction.

Now we can conclude that solely "pure" physical laws are never *sufficient* to explain meaningful mental action and efficacy. The mental is needed for intelligent and meaningful ordering in the brain, an ordering that is accompanied by a change in energy/potential. If the ordering in the brain was not caused by mental entities the 2^{nd} law of thermodynamics would have been violated since this law expresses a tendency to lower order. Briefly spoken: The basic principles of physicalism exclude mental causes thereby violating the 2^{nd} law.

The paradox is now that physicalists deny causal mental influence on the physical, yet endorsing mental efficacy. How do they resolve this contradiction? Reduction, identity, and supervenience?

3 Reduction and identity

The main idea behind reductionism is to rewrite a mental law, theory, property, or function in a neurophysiological vocabulary. The mental law must be logically derivable or provable from the physical one (Kim, 1998). It is a requirement that the latter does not refer to the mental law to be reduced if a real "reduction" shall be achieved (Kim, 2008). Certain "bridge" principles grounded on e.g., suitable definitions or empirical correlation laws can then possibly convert the mental entities to physical ones. This conversion (reduction) allows physicalists to explain mental efficacy as a complete physical causal process.

Another theory, combined with or supplementary to reduction, is psychoneural identity. "Strict identity" is governed by the following law: "If X is identical to Y, X and Y share all their properties in common" (Leibniz's law) (Kim, 1998) (type identity) as in the following examples of Kripkean identities (Kim, 2008):

Water *is* H_2O; heat *is* molecular motion; light *is* electromagnetic radiation.

On my view these are poor examples: We have here *one* phenomenon, not two (X and Y), and water *is* not H_2O, water *consists* of H_2O. Moreover, water, heat, and light do not cause resp. H_2O, molecular motion, and radiation; thus the examples do not illustrate mental efficacy. Another example is more relevant: Pain *is* C-fiber activation. Here we have two phenomena but still pain cannot cause C-fiber activation. A more appropriate example would be: Will *is* cerebral potential. These two phenomena may possibly cause each other, but do they share all their properties in common? And what is wrong with the more accurate articulation: Will is correlated with cerebral potential.

The reductive physicalists must answer the following questions: How can properties, events, etc. belonging to incommensurable and distinctly different domains, such as the mental and the physical be identical or converted into each other at the "microlevel" when they cannot on the "macrolevel"? Are mental properties "fused" into neurons? If so, who is deciding what to do, who has the upper hand – the mental or the physical? Is there a kind of microcausality inside the neurons? Or are mental and physical properties acting simultaneously?

Kim (2008) advocates a special kind of reduction: Functional reduction. It is supposed to remedy some problems in e.g., Nagel's bridge law reduction. It is performed in three steps:

1) The mental property to be reduced is given a *functional* (causal) definition.
2) The properties (or mechanisms) in the reduction (neurophysiological) base, which performs the causal task, must be found.
3) A theory that explains how this mechanism performs the causal task must be constructed.

It is easily seen that step 2 and possibly step 3 are tasks for experimental neuroscience. Functional reduction is therefore similar to the plan or research strategy of a scientist who intends to find the cause and effect of a phenomenon. This is exactly what neuroscientists have done. For example, Libet (1985) and Trevena & Miller (2002) have conducted famous experiments, some of which show that the conscious will is the cause of finger movements or lack of movements. We merely(!) have to find the mechnism or law connecting the two entities because "where there is causality, there must be a law: events related as cause and effect fall under strict deterministic laws" (Davidson, 2001; Bechtel, 1988).

4 Deterministic laws

However, Davidson (2001) insists that there "are no strict deterministic laws on the basis of which mental events can be predicted and explained". I suppose that this assertion can be turned around as a natural consequence which is more relevant to our context: That there are no strict deterministic laws connecting a (purely) mental cause with a (purely) physical effect, a statement that seems inconsistent with the will-finger movement-causality which is experimentally vindicated over and over again. Davidson resolves the inconsistency with his "anomalous monism" theory that invokes mind-brain identity. He holds that the same event is both mental and physical (token identity). Because all mental events are physical events “they can interact causally with other physical events” according to deterministic physical laws (Bechtel, 1988). Davidson’s definition of identity differs from the type identity presented above: He states that *one and the same* event has different properties, both mental and physical, and that the event belongs to the same domain; thus we have monism, not dualism, and it becomes easier to connect mental and physical events by laws.

But even Davidson has to answer the following questions: At the dualistic “macro-level” the main principles of physicalism exclude mind-brain causal interaction. Why is this possible at the “microlevel” even if the two domains are reduced to one? How can properties from such incommensurable domains be parts of the same event at this level? Do they interact inside the event and not outside? Or do they fuse inside an event? If so, does this mean that physical entities are animated? Do we then have a kind of animism? On my view this seems to be quite “phlogistic” and not more probable than causal interaction at the macrolevel. If the mental and the physical are separate entities within the same event, the latter entity will comply with deterministic laws. But are we certain that also the mental ones do likewise? Do the mental entities get a “free ride” with the physical ones? Moreover, not even Davidson has clearly explained who has the upper hand. Who decides, the mental or the physical? If we are not going to end up with epiphenomenalism the mental must take the command in action. Does it, and how?

Davidson’s logic is fascinating but he forgoes a fundamental question: What is really an event? It is described and observed by its properties, but properties alone have no driving force; there must be “something” underlying the properties. In the physical domain it is substance/energy. What is it in the mental? I revert to my idea presented above: The function of energy and force and the inferred idea of energy dualism. Mental events (processes) behave as if they were driven by energy, which we may call psychic energy (Løvland, 2006). To explain the latter we have two options: 1) Either it is real mental/psychic energy that we unfortunately cannot measure directly with our physical instruments. 2) Or the underlying energy is physical/physiological that is (strictly) correlated with mental entities. – Both these options are based on mental-physical dualism and need bridge laws in order to explain interaction. Option 2, however, could comply with Davidson’s monism based on (token) identity in that the same event consists of both mental properties and physical energy within the same domain. But this does not explain mental efficacy. Davidson merely moves the problem of bridge laws from two domains to one, actually to the event itself, and we still need an explanation of the mental as a cause.

5 Conclusions

Mind and brain as separate domains are related due to the concepts of energy, entropy, and information. Processes in the mind are considered to be analogous to physical ones such as these are formulated in chemical thermodynamics. A crucial point is that motivation is the driving force in the former, and free energy in the latter, i.e., mental energy versus physical connected by entropy and information.

In mental action will can enhance electrical potential in the brain, and a strict law based on information and entropy is proposed.

The 2nd law of thermodynamics is violated by the physicalists since their purely physical model should lead to more disorder while increased cerebral order is the observed fact.

The physicalists reduce mental processes to physical ones and consider them identical whereby they contend that mind is matter. Since they agree that mental properties exist these must then be included in matter, e.g., neurons. Then we have "animated" matter that seems quite weird, and does not make it easier to resolve the mind-brain problem.

I conclude this paper by presenting a metaphor for the mental's supremacy over the physical in intentional action: The conductor of an orchestra determines the performance of the players without touching them physically, just as the will determines the behaviour of neurons.

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Paul Løvland

Notes on Information, Entropy, Energy, and Mind

Mental energy – does it exist? Was Freud right?

The notion of mental or psychic energy has been employed in psychology since the last part of the 19^{th} century. It is an integral part of Freud's metapsychology, but has been heavily criticised for not being scientifically proven. In the present paper I argue for an analogy between part of this mental energy and physical energy. My method is to compare *uncertainty,* as defined in information theory, with *physical entropy.* It turns out that the former is quantitatively analogous to the latter, and can be named «mental entropy». When this entropy is employed in an energy equation used in chemical thermodynamics we attain mental energy that is part of the total mental energy similar to motivation and Freud's energy.

1 Introduction

Many psychologists, psychoanalysts, and even philosophers, have been criticised for using the notion of mental or psychic energy which often has been named just a metaphor of the «phlogistic» sort. The purpose of the present paper is to find a scientific way to explain the existence of this kind of energy. My method is to combine information theory with thermodynamics, presupposing that information is a mental entity.

The notion of mental energy is not explicitly and thoroughly treated by philosophers in the past. But fortunately, there are some philosophies where energy is described as will or force, e.g.: Leibnitz with his constant force, Schopenhauer with his will and representation, Nietsche with his will to power, Spencer with his fundamental force. Ranheimsæter (1962, p. 254) holds that Schopenhauer's will is unconscious and in agreement with Freud's theories of the Id, and thus became a forerunner of psychoanalysis, although Freud probably would not accept this connection.

In contemporary philosophy, Hart's thorough analysis of psychic energy, belief, desire, quantity, action, and causation is a milestone (Hart 1988). He even discusses the conversion of pure wishful thinking to belief, and he presents an imaginary quantitative law for it (p.129). Hart summarises: The crux of an economic (energetic) model, in the present state of the art, is whether or not we can make sense of the possibility of psychic energy and,

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what is necessary for that in the light of our discussion of causation, its conservation at least through wholly intrapsychic processes.

Later in the present paper I try to respond to his crux at least with respect to the quantity of mental energy. Moreover I have suggested a model for mental processes that was based on irreversible chemical thermodynamics and statistical mechanics. Motivation, thoughts, and emotions were considered to be analogous to energy and entropy (Løvland 2006).

During the 2nd half of the 20th century an extreme philosophy of the opposite kind has had, and has, a surprising influence: Physicalism (or materialism). It is well described by Kim (2008) and asserts that the mind *is* matter, and that it behaves in accordance with laws of physics. This hard monism is metaphysically grounded and difficult to explain logically, but its widespread popularity has made Freud's metapsychology harder to defend.

2 Mental energy in Freud's metapsychology

In the first part of the last century quite a few psychologists and physicians were occupied with the physical sciences, and e.g. the school of the famous physicist von Helmholtz was often consulted. Freud (1915/1991) held that unconscious «forces» such as instincts, needs, wishes, libido, and cathexes work as a source of potential energy for both primary and secondary mental processes. (See especially his paper on vicissitudes of instincts.)

The Penguin Dictionary of Psychology (Drever, 1952/1964) defines cathexis as the accumulation of mental energy on some particular idea, memory, or line of thought or action.

In his paper on repression Freud assumes that an idea (Vorstellung) or a group of ideas is «cathected with a definite quota of psychical energy (libido or interest) coming from an instinct». He says that, with the repression of an instinctual representative, clinical observation obliges us to divide what we hitherto have regarded as a single entity, though there are two parts in it: The idea and the instinctual energy linked to it. This is what Ricoeur (1970, p. 92), in his brilliant interpretation of Freud, has in mind when combining two universes of discourse: One relating to meaning and ideas subject to interpretation, and one to force or energy subject to explanation.

In addition to Freud, even Jung (1928/1973) and Harding (1948/1973) have given valuable contributions to the understanding of mental energy.

Even though the existence of mental energy has been found to be quite probable by many scholars, no proof has been presented. It is mostly regarded as an intuitive entity, and this has of course tempted several scientific researchers to phrase devastating criticisms of the concept. Ricoeur (1970, p. 344) has summarised some of the criticisms that focuses on the following major points:

- Epistemologists, logicians, semanticists, philosophers of language have generally come to the conclusion that psychoanalysis does not satisfy the most elementary requirements of a scientific theory, e.g. it lacks empirical verification.
- Psychoanalysis is not a science of observation: it is an interpretation, more compatible to history than to psychology.
- The energy notions of Freudian theory are so vague and metaphorical that it seems impossible to deduce from them any determinate conclusions.

Rycroft (1968, p. 43), in his critical dictionary of psychoanalysis, says that Freud's theory of energy has little to do with the concept of energy as used by «the other natural sciences», but is really a theory of meaning in disguise.

In the following, physical entropy is applied to find a quantitative analogy between this entity and a mental entity.

3 Quantity of mental energy

3.1 *Amount of information*

Attneave (1959) has presented an excellent explanation of the information theory for use in mental processes, and the reader is referred to him for a fundamental understanding of the subject.

Information can solely be gained if one is to a certain extent ignorant or uncertain. It may therefore be defined as «that which removes or reduces uncertainty» (Attneave 1959, p.1). In order to quantify uncertainty we can consider a subject in a choice situation, where he can choose between several alternatives. His job is to reduce the number of alternatives one by one. In this way we get a numerical measure of the reduction. Information theorists apply the old parlor game of «Twenty Questions» to carry out the job which for our purpose can be described as follows:

The alternative to be found is known by a subject who answers questions from a panel of players in the game. But he can merely answer with one of two words, either Yes or No. Gradually the players can eliminate the alternatives to finally arrive at the relevant one. If we designate the two words with digits, 1 means Yes and 0 means No, we get two possible digits for each question, that is a binary digit or bit, as it is usually called. Each question is thus associated with two possible alternatives and one bit. If we need e.g. six questions to select the wanted alternative we have $2^6 = 64$ possible alternatives which are the uncertainty that must be removed to gain the needed information in bits. Generally then (Attneave 1959, p. 4):

$m = 2^H$ which gives

$$H = \log_2 m \qquad (1)$$

where m is the number of equally likely alternatives, and H is the amount of uncertainty expressed in bits. When uncertainty is eliminated and information is maximum H expresses the amount of information gained (see §3.4).

Eq. 1 is most important and well established in information theory.

In some cases it is helpful to express information in terms of probability instead of alternatives. Probability is best described with an example: Throwing a die gives you 6 possible sides or alternatives to obtain one particular side, thus the chance or probability of getting this side is

$p = 1/6$, or, generally $p = 1/m$, thus $m = 1/p$

where m, as above, is the number of possible alternatives. When $1/p$ is substituted for m in
eq. 1 we get

$$H = \log_2 (1/p) = -\log_2 p \qquad (2)$$

The negative sign means that the uncertainty H is being reduced and that the information goes up (see §3.4), as the probability p goes up.

3.2 *Amount of statistical entropy*

Eq. 1 is compared with the statistical entropy amount of a physical system which is

$$S = k \ln m_{phys}$$ (Boltzmann-Planck formula; e.g. Brillouin 1971, p.120; Fast 1962, p. 61; Prigogine 1954, p. 45) (3)

where m_{phys}, called P by Brillouin and Ω by Prigogine, is the number of «elementary complexions», as Planck called it. m_{phys} can also be explained as the number of *possible* microstates or configurations of atoms or molecules. Fast (1962, p. 3) explains it as «the possibilities of realisation or microstates of the thermodynamic state». m_{phys} increases with more structural disorder. The k is Boltzmann's constant that links the number of microstates m_{phys} with thermodynamic or calorimetric entropy expressed in energy units (k~$1.4\text{x}10^{-23}$ J/K).

In a normal physical process m_{phys} represents an enormous number of molecules or possible microstates, which have to be treated statistically. A tiny portion of energy is attributed to each molecule, Boltzmann's k, and the sum becomes the statistical entropy.

How is this statistical entropy related to probability? Imagine an isolated box with two kinds of perfect gases, say neon and helium, where there are no forces between the molecules. A spontaneous process from state 1 to state 2 in this box is described below:

State 1: All of the neon molecules are gathered at one end and all of the helium molecules at the other end of the box. This is a highly improbable and highly ordered microstate where the two kinds of molecules have very few chances of mixing with each other. Thus there is a very low number of possible microstates, i.e. m_{phys} is extremely low, and the statistical entropy consequently is low too, ref. eq. 3.

By time the freely moving molecules are gradually mixed and the possibility for the molecules to join the other type is increasing. This means that the number of possible microstates goes up so that m_{phys} and S also go up.

State 2: At a certain moment the mixing process comes to an end and all the molecules can freely join the other type so that the number of possible microstates m_{phys} is at the maximum. This is also the equilibrium state which is the most probable one where the entropy is highest, ref. eq. 3. This is a simple statistical description of the 2nd law of thermodynamics, viz. that the entropy of an isolated system with no interacting parts tends to a maximum and to the highest possible probability. If this spontaneous process in some way or other is reversed the value of m_{phys} , p, and S are all reduced.

3.3 *Comparison of information and entropy.*

The 2nd law describes a process that is the opposite of gaining information. In the latter the probability increases when the number of alternatives is reduced, §3.1. If the number of microstates in the physical process is reduced the probability decreases, §3.2. Thus we see qualitatively that the two processes are not analogous. This is shown in table 1 where the processes are compared on equal terms, i.e. both m_{phys} and m are decreasing. We see that increasing information corresponds to decreasing entropy.

Table 1

Information gaining	Corresponding physical process
Decreasing m Eq. 1	Decreasing m_{phys} Eq. 3
Increasing p Eq. 2	Decreasing p §3.2 (Reversed 2nd law)
Decreasing uncertainty H_{th} Eq. 1,2, §3.4	
	Decreasing entropy S Eq. 3
Increasing information H Eq. 1, §3.4	

3.4 *Mental entropy*

In order to interprete eq. 1 we must consider the whole process of gaining information, see §3.1. It starts with a number of alternatives, an amount of uncertainty, and ends with the selected alternative, the infomation. Thus we must divide the interpretation in two parts.

i) Before the process starts:
Eq. 1, $H = \log_2 m$, expresses the amount of uncertainty. It corresponds to the physical $S = k \ln m_{phys}$, eq. 3, which is the physical entropy. H (uncertainty) is then analogous to S in this equation and can be named «mental entropy» and designated H_{th} (*th* refers to the thermodynamically construed H). The relations are clarified in table 1. Hence:

$$H_{th} = \log_2 m \qquad (4)$$

ii) After the alternatives are removed:
Eq. 1 expresses the amount of information. It has the same number of alternatives and the same value as has H_{th} , but is interpreted conversely to the lattter, i.e. information is opposite to uncertainty: The more information, the less uncertainty, and vice versa. See also §3.1. If m is increased by one alternative before the process starts, uncertainty H_{th} goes up accordingly. But this extra alternative has to be eliminated, subtracted, when information is to be gained so that H gets a negative sign in relation to H_{th} , table 1:

$$H_{th} = -H \qquad (5)$$

This is a quantitative relation where increased information H means less uncertainty and less mental entropy H_{th} . The two interpretations of eq. 1 are also explained in another context (Løvland 2017).

The significence of the whole process is illustrated with the example in table 2 where m as before is the number of alternatives. The process starts with 6 possible cases, alternatives m and microstates m_{phys} (6 microstates are merely symbolic since physical matter consists of an extremely high number of these states.) The process ends with 1 selected alternative and 1 microstate, i.e. maximum information and no uncertainty and entropy. The amounts of mental and physical entropies are calculated according to eq. 4 and eq. 3, resp.

Table 2

No. of cases		Mental entropy H_{th}	Phys. entropy
Initial	6	$H_{th} = \log_2 6$	$S = k \ln 6$
Final	1	$H_{th} = \log_2 1$	$S = k \ln 1$

This shows what I explained above in the present subsection: Reducing possible cases causes diminishing mental and physical entropy contrary to gaining information. The mental entity H_{th} in bits is quantitatively analogous to the physical entity S in energy units.

3.5 *Entropy and energy*

My initial question was: Does «mental energy» exist? If that is the case I contend that there must be «mental entropy» to satisfy the energy equations in chemical thermodynamics, e.g. for systems at constant temperature where only energy and entropy can be exchanged with the surroundings as in the following infinitesimal equation:

$$\mathrm{d}F = \mathrm{d}U - T\,\mathrm{d}S \qquad \text{(Prigogine 1954, p. 36; Fast 1962, p. 90)} \qquad (6)$$

where F is the free energy (Helmholtz), U is the internal energy, T is the absolute temperature, and S is the thermodynamic calorimetric entropy, which is equal to the statistical entropy when applying Boltzmann's constant. F is the driving or potential energy of the process that may perform work on or eject heat to the surroundings; it can be increased if energy is supplied to the system from outside.

In an ordering process where the number of possible microstates m_{phys}, and therefore S, diminish, dS becomes negative, dF positive and F higher. If there are no forces between the constituents, and no energy is exchanged with the surroundings, U will be constant and dU zero. Thus we can simplify our analysis by applying the shorter equation:

$$\mathrm{d}F = -T\,\mathrm{d}S \qquad (7)$$

In some processes energy may be exchanged with the surroundings making dU different from zero thus affecting dF. However, this will disguise the effect of dS that will remain the same unaffected by dU. And dS is the major point of our analysis.

We see that the energy F is equal to the negative of the entropy S, both in joules, multiplied with a constant T. Thus energy is conversely proportional to entropy in similar units.

Since mental entropy is analogous to physical entropy and the latter is related to energy it is reasonable to presuppose that mental entropy relates to mental energy in a similar way; generally, all sorts of energy require relevant entropy in our context.

In mental processes the constant T is not applicable since it relates only to physical units, but there may be a factor in the mental domain similar to T that we may have to apply in order to obtain complete analogy. Let us call it M, which then is a positive constant analogously called «mental temperature». The mental entropy H_{th} is directly determined by the number of alternatives and is measured in bits. We can then present our «mental» equation by substituting H_{th} for S in eq. 7 as follows

$$\mathrm{d}F_{\mathrm{ana}} = -M\,\mathrm{d}H_{th} \qquad (8)$$

where F_{ana} is the «mental free energy» likened with motivation, and this energy in bits is *analogous,* but not identical or equivalent, to the physical free energy in joules, i.e. equation 7 and 8 are analogous. We see that lower amounts of mental entropy result in higher amounts of mental free energy just as in physical processes. In other words: Higher amounts of information, which means lower uncertainty, give more intensive motivation. A preliminary experiment described in §5 indicates that this is the case. Could this favour Freud's understanding of mental energy?

Worth noticing is that H_{th} is equal to $-H$, eq. 5, which gives

$$\mathrm{d}F_{ana} = M\,\mathrm{d}H \qquad (9)$$

Calling the mental free energy just mental energy I suggest a definiton of the latter:

The amount of mental energy in bits is analogous to physical energy and is proportional to the amount of corresponding information in bits.

4 Remarks

The mental free energy F_{ana}, which is described in this paper, is the *objectively* created part of the *total* mental free energy that is likened with *total* motivation and Freud's mental energy. The objective part relates to numbers of possibilites and to order-disorder changes in the mental structure. Psychologists speak solely about *subjectively* emotional forces, but I contend that Freud's energy and thus the total mental free energy consist both of a subjective and an objective part (Løvland 2006). In any case my calculations suggest that mental energy *exists,* whatever one wants to compare it with in psychology, and is a mental entity separate from but analogous to the physical one.

Having contended that mental energy exists and can be quantified, an interesting question follows: Can this energy influence brain functions, or be transmitted to the brain? This vast topic lies outside the present scope, but I will mention that will may affect electrical potentials in the brain without transmitting any form of energy from the mind (Løvland 2009). The needed energy comes from the body or brain itself due to diminution of physical entropy in the brain.

5 Experimental

The present hypothesis can be tested experimentally with a psychological method that can measure «mental free energy». The latter is driving a mental process and is characterised as the intensity of motivation and aroused emotions. Such arousal can be measured with a special version of Osgood's «semantic differential» (Osgood, Suci, and Tannenbaum 1957/1978) that primarily is a psycholinguistic method:

A subject is shown a picture of concepts (words) that is associated with a set of bipolar adjectives such as weak-strong, soft-hard, and white-black. Each bipolar adjective is evaluated and given a ranking number related to the emotional intensity that it creates. An average ranking number is calculated for the whole picture, a number that represents the motivation or the mental free energy created by that picture.

Løvland (unpublished) carried out a preliminary experiment where a subject was shown two pictures, first one with 6 equal words randomly distributed, quickly afterwards another with only one of the same words. The number of words is thus reduced from 6 to1. I carefully minimised the influence of affective factors such as the meaning of the words, and evaluated the effect of several such changes of pictures on the average ranking numbers. I found that this number increased some 30% due to reduction of the number of words. This preliminary result corroborates the present hypothesis that lowering the mental entropy raises the mental free energy/motivation. The result is the objective part of total motivation and of the total mental (free) energy.

In a future experiment it would be interesting to study the relation between mental entropy and cerebral electrical activity.

6 Conclusions

The amount of information as calculated by information theory is not analogous to physical entropy; if the former is reduced the latter is increased.

On the other hand, when uncertainty is calculated according to information theory, it turns out to be quantitatively analogous to statistical physical entropy and can be named «mental entropy».

Substituting this «mental entropy» in an equation for free energy according to chemical thermodynamics we attain the analogous «mental free energy» in bits, which is proportional to the amount of information.

This mental energy is the objective part of the total mental free energy that is likened with total motivation similar to Freud's mental energy.

The comparison of mental entropy and energy with the corresponding physical entities indicates that the former behave like the physical ones, but are not identical to them. Can we then say that mental energy exists?

It is possible to test the hypothesis experimentally employing a psychological method based on a work by Osgood *et al*.

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