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Mathematical Models of Desire, Need and Attention

Alexander J Ovsich

Abstract. Desire plays an important role in the explanation of behavior in general, for example, in the contemporary Belief-Desire theories. These theories (for example, Bratman's Belief-Desire-Intention theory) are widely used in the AI applications. However, there is neither much literature, nor even consensus about the meaning and definition of desire. There is not much clarity about the concepts and mechanisms of need and attention either.

The author presents here simple, closely linked mathematical models of desire, need, and attention. They are based upon the hedonistic principle proclaiming that animals and humans alike are driven by striving to maximize pleasantness of their internal state (Pleasantness of the State of this Subject("PSS"). What directly follows from this principle is that for such a subject (S), the most important characteristic of any phenomenon (X) should be how much X influences the process of maximization, how much X increases or decreases PSS, that is measured by the magnitude and direction of its change (Δ PSS).

I propose that terms such as 'desire,' 'want,' and their cognates describe PSS change associated with (caused by) a phenomenon: DESIRE_{S x}= Δ PSS_{S x};

if $\Delta PSS_{S,X} > 0$, then X is called desirable;

if $\Delta PSS_{s,x} < 0$, then X is called undesirable.

The magnitude of the PSS change is what is called "strength of desire":

STRENGTH of the DESIRE_{S,X}=|DESIRE_{S,X}|=| Δ PSS_{S,X}|.

Need is defined here as a term describing a periodic or cyclical desire.

There is another direct inference from the hedonistic principle: the more a phenomenon affects the process of PSS maximization, i.e. the larger a PSS change it creates or the stronger a desire is associated with it, the more attention should a subject pay to it:

$$\begin{split} \text{ATTENTION}_{\text{S},\text{X}} &\sim \mid \Delta \text{ PSS}_{\text{S},\text{X}} \mid \sim \mid \text{DESIRE}_{\text{S},\text{X}} \mid; \\ \text{ATTENTION}_{\text{S},\text{X}} &= \text{k} \mid \text{DESIRE}_{\text{S},\text{X}} \mid. \end{split}$$

Considering that an overall attention of a subject S at any given moment t $(ATTtotal_t)$ is distributed between a number of objects (1 to n) and that it has an upper limit $(ATTmax_{s,t})$:

 $\begin{aligned} & \text{ATTmax}_{s,t} >= \text{ATTtotal}_{s,t} = \\ & \text{k}|\text{DESIRE}_{s,t,1}| + \text{k}|\text{DESIRE}_{s,t,2}| + \ldots + \text{k}|\text{DESIRE}_{s,t,n}|. \end{aligned}$

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1 LACK OF CLARITY AND CONSENSUS

There are many 'ways' [1] and 'faces' [2] of desire, but there is one fundamental question about the meaning and definition of desire that is the focus of this paper. There is neither much literature nor consensus about the notion of desire. Schueler [3], who "... focused on contemporary philosophers..." noted that "... the views I am criticizing suffer from a deep ambiguity in terms such as 'desire', 'want' and their cognates". Almost a decade later Frankfurt [4] called the notion of desire "rampantly ubiquitous" and wrote:

Moreover, its various meanings are rarely distinguished; nor is there much effort to clarify how they are related. These matters are generally left carelessly undefined in the blunt usages of common sense and ordinary speech.

The level of ambiguity in understanding desire is such that the validity of the notion of desire itself is sometimes questioned or even denied outright. For example, DeLancey [5] wrote:

Since my concern in this book is with basic emotions and other motivational states, I will on several occasions discuss the inappropriateness of the philosopher's notion of desire; it is hard to overestimate the harm that this notion has done to moral psychology, action theory, and other aspects of philosophy of mind.

... (for example, there are many kinds of motivational states, but no generic one corresponding to the philosophical notion of desire)....

However, as Marks [1, p. 10] carefully noted:

...it may well be the case, as I believe, that there remains a single, significant, psychological phenomenon appropriately named "desire." If so, then it is this – desire proper – which, ultimately, constitutes the subject matter of the theory of desire.

His belief is shared by the author of this paper.

2 HEDONISTIC APPROACH TO DESIRE

Schroeder [2, pp. 27-31] identified two main types of the desire theories - motivational and hedonistic; he considered hedonistic theory to be superior to the motivational¹. Indeed, the hedonistic approach to desire has a very long and impressive history. Aristotle [7] directly defined desire through pleasure: "Everything, too, is pleasant for which we have the desire within us, since desire is the craving for pleasure" and the same can be said about Spinoza [8]. As formulated by Mill [9] "...desiring a thing and finding it pleasant, aversion to it and thinking of it as painful, are phenomena entirely inseparable or, rather, two parts of the same phenomenon." Schroeder [2, p.27], referring to this Mill's opinion, wrote "Mill is not the only distinguished historical figure to have considered such a view." Schroeder further elaborated: "Hobbes, Hume, and Kant apparently had similar thoughts, though interpretation of these thinkers is difficult" [2, p. 185].

In line with his clearly hedonistic definition of desire as "the craving for pleasure" quoted above, Aristotle [7, 2.2, 1378a 31-3,] not only defines anger as a desire for revenge [10], [11] or retaliation [12], but also provides rather detailed descriptions of what it means at the hedonic level [7, 1.11, 1371a; also see 2.2, 1378b]:

Revenge, too, is pleasant; it is pleasant to get anything that it is painful to fail to get, and angry people suffer extreme pain when they fail to get their revenge; but they enjoy the prospect of getting it.

It is important here to note that desire for revenge (anger) involves a positive hedonic change, transition from the hedonically negative to the hedonically positive state experienced even while imagining 'the prospect of getting it'.

Aristotle's hedonistic approach to desire was echoed by Locke who defined desire as follows: "The uneasiness a man finds in himself upon the absence of anything whose present enjoyment carries the idea of delight with it, is that we call desire" [13]. Desire for Locke is also about the hedonic gap between the more negative hedonic level ("uneasiness") of the state of the desiring subject without an object of desire and the more positive hedonic level ("enjoyment") with it. As for Aristotle, Locke's interpretation of desire is also about the positive hedonic change associated with the desired phenomenon.

The vital fact of the matter here is that such a hedonic gap, a positive hedonic change associated with the object of desire is a regular property of the subjective experience of desire. This is true for the "low" physiological desires as well as for the "high" psychological desires. This sameness allows one to express desire for an action, power or sex metaphorically as being "action or power hungry," "hungry for the loved one."

3 FORMULAS OF DESIRE AND ITS STRENGTH

The model of desire presented in Ovsich [15], [16], [17] and discussed here is based upon the Hedonistic Principle declaring that animals and humans alike are driven by a striving to maximize pleasantness of their internal state (Pleasantness of the State of a Subject or PSS² here). The direct inference from the Hedonistic Principle is that (one of) the most important characteristics of any phenomenon for a subject driven to maximize PSS is how much this phenomenon maximizes (or minimizes) PSS. For the human subject it should also mean that words and expressions describing PSS changes ought to be notable and widely used.

Ovsich proposed that terms such as 'desire,' 'want,' and their cognates describe PSS change (Δ PSS) associated with (caused by) a phenomenon:

1. expressions calling a phenomenon X 'desirable', 'wanted'

etc., for the subject S characterize X as a factor of maximization of PSS for the subject; that these expressions associate X with the positive $\Delta PSS_{S,X}$;

- 2. X associated with negative $\Delta PSS_{S,X}$ is called 'undesirable', 'unwanted';
- 3. X associated with zero $\Delta PSS_{S,X}$ is called indifferent, though sometimes it is called undesirable in the sense of the lack of desire.

The common feature in cases two and three is a non-positive (zero or negative) change of PSS ($\Delta PSS_{S,X} \le 0$) or an absence of the positive change of PSS. It indicates, that,

- a subject reports a presence or absence of desire for a phenomenon depending upon the presence or absence of the positive change of PSS associated with that phenomenon;
- what is usually called 'desire' of X is a positive change of PSS associated with X;
- an object of desire is a factor of PSS maximization.

From the hedonistic viewpoint it is quite clear why a positive rather than a negative or zero change of PSS is used as the bases for terms 'desire' and 'want' describing PSS alteration. According to the Hedonistic Principle, a subject is looking for maximization of PSS that is represented by a positive PSS change, $\Delta PSS_{S,X} > 0$. The use of the negative prefix to describe something as 'Undesirable', 'Unwanted', points to the opposite (negative) to the positive PSS change that subjects are seeking or to the absence of the positive PSS change.

¹ He also added "the third face of desire" - his own "reward and punishment" theory of desire that was sharply criticized - see, for example, review of Katz [6].

² Pleasantness/valence is a complex variable. Emotions and a number of sensations, possess their own pleasantness of specific modality. All these P/U can be experienced at the same time and are represented by a complex structure, that changes at every given moment. We call it here a Pleasantness of the State of a Subject (PSS. PSS is quite close to what is called a Valence of the Core Affect in [17, [18]. For more details see [16].

If we interpret desire as an algebraic variable that can be positive or negative (where the 'desirable X' means that X is an object of the positive desire and 'Undesirable X' means that X is an object of the negative desire), then we can define the desire of X in general as a term describing a change of PSS (Δ PSS_{S,X}) associated with X. Here is the definition of a desire: a subject's (S) desire for X is a word to describe a change of the Pleasantness of the State of this Subject (Δ PSS_{S,X}) associated with (or 'caused' by) the perception or imagination of X. Desirability of X for S is an ability of X to maximize/minimize PSS that is characterized by Δ PSS_{S,X}.

Below is the formula of desire that incorporates all three types of the Δ PSS, and where S is a subject experiencing desire, X is an object of desire, Δ PSS is the change of the Pleasantness of the State of the Subject:

$$DESIRE_{S,X} = \Delta PSS_{S,X}$$
(1)

The above definition and formula of desire are consistent both with hedonistic/utilitarian approach to desire and with the contemporary point of view, that "...the primary linkage of the notion of desire to a notion other than itself is to the notion of affect – pleasure or displeasure in the widest sense" [19].

A desire is often characterized or measured by its strength. Both positive and negative desire can be experienced as strong or weak. This means that the strength of desire is a sign-independent characteristic of desire. Therefore, a mathematical sign of the magnitude or an absolute value (|value|) should be applied to express strength of the subject's (S) desire for X ($\Delta PSS_{S,X}$):

Strength of S desire for $X = |DESIRE_{S,X}| = |\Delta PSS_{S,X}|$ (2)

Experimental support of this model of desire is demonstrated in [16].

4 NEED AS A PERIODIC/CYCLICAL DESIRE

Experiencing a need means feeling the corresponding desire. As Audi [20] wrote, "Human needs are innate and quickly give rise to desires". S. L. Rubinshteòin [21] has declared that *desire is a concrete form of the need's existence*³. If a subject experiences a desire for X repeatedly or regularly it is usually said that the subject *needs* X. This is clearly demonstrated by the needs that emerge and cease to exist with age or during changing conditions, for example, the needs for sex, smoking, or drugs. The origination/disappearance of such needs is acknowledged when the corresponding desire begins/ stops being regular or repeated. *Need is a term used for a periodic or cyclical desire*. This is true for all kinds of need including any need for food, sex, activities, drugs, etc.. A need is characterized by the strength and frequency of its desire.

Need, being a cyclical process is like a 'wave' of desire. All needs have definable features. Dissatisfaction of any need of a subject negatively affects PSS, and this decline of PSS grows with time. At the same time, P of perceived or imagined objects of this need's satisfaction for the subject goes up. These two aspects are easily recognizable in the following description of Bertrand Russell [22],

...it seems clear that what, with us, sets a behaviorcycle in motion is some sensation of the sort which we call disagreeable. Take the case of hunger : we have first an uncomfortable feeling inside, producing a disinclination to sit still, a sensitiveness to savory smells, and an attraction towards any food that there may be in our neighborhood.

This means that the hedonic gap between PSS without the object(s) of a need satisfaction and PSS with it grows. *This gap is a desire and its magnitude is its strength*.

Satisfaction of any need of a subject produces exactly opposite effects: PSS grows as a result of satisfaction of a need and P of the objects of this need's satisfaction goes down. As the hedonic gap of desire gets smaller, desire gets weaker all the way down to the satiation point when Δ PSS of desire becomes equal to zero – desire is satisfied, and then disappears. At this time, the opposite side of the desire cycle starts again.

5 ATTENTION AND HEDONISM

Another direct inference from the Hedonistic Principle is that the more a phenomenon influences the process of PSS maximization the more attention should be paid to it. The effect of X on the process of PSS maximization is measured by the magnitude of the PSS change ($|\Delta PSS_{S,X}|$) associated with X, that according to the above model of desire is the

Strength of S Desire for $X = |DESIRE_{S,X}| = |\Delta PSS_{S,X}|$.

In the first approximation, attention of a subject S toward a phenomenon X can be considered to be simply proportional to the strength of desire for it:

$$ATT_{S,X} = k|(\Delta PSS_{S,X}| = k|DESIRE_{S,X}|, \quad (3)$$

where k is a positive coefficient of proportionality.

The model of attention to a 'single' phenomenon above is a sheer abstraction, because in reality a subject always perceives multiple phenomena. This model, however, represents an approximation of a real situation, where the subject concentrates mainly on one phenomenon in the center of attention. The higher the percentage of total attention paid to the phenomenon in the center of attention, the closer this model comes to reality.

There are some situations when a phenomenon is singled out and placed in the center of attention. This occurs in a process of choice making when the elements of choice are appraised by a subject and attitudes toward them are formed one by one, until a 'new' phenomenon catches the attention of a subject and is appraised or perhaps an 'old' phenomenon is re-appraised. This also happens when a phenomenon becomes 'the chosen one' and is placed in the center of attention, while all competing phenomena are pushed to the periphery of attention. At this early stage of this analysis, all but the one 'central' phenomenon will be disregarded.

³ Translated by Ovsich.

6 ATTENTION TO A SINGLE PHENOMENON

Let's analyze the formula of attention (3) to see if it describes different situations correctly.

Case #1. $\Delta PSS_{s,X} > 0$ or $DESIRE_{s,X} > 0$ In this the case X is a factor of PSS *maximization*, meaning that the subject wants X.

IF $\Delta PSS_{s,x} > 0$, DESIRE $_{s,x} > 0$ THEN ATT $_{s,x} > 0$

According to the formula (3), $\text{ATT}_{S,X}$ increases/decreases if the positive desire $\text{DESIRE}_{S,X}$ increases/decreases. The greater the desire for X by a subject the more attention is paid thereto.

Case #2. $\Delta PSS_{S,X} < 0$ or $DESIRE_{S,X} < 0$

In this case, X is a factor of PSS *minimization*, meaning that the subject does not want X.

If
$$\Delta PSS_{s,x} < 0$$
, DESIRE $_{s,x} < 0$ then $ATT_{s,x} > 0$

The formula $ATT_{S,X} = k|DESIRE_{S,X}|$ illustrates that the stronger the negative desire for X (the more bothersome or undesirable X is) the more attention is paid to it.

Cases #1 and #2 show that according to the formula (3) a subject pays attention to both desirable and undesirable phenomena. The more desirable or undesirable it is – that is to say, the greater the strength of the (+) or (-) desire for the phenomenon, the more attention will be paid to it.

The substance of this matter is that *eliminating the* sources of PSS minimization is just as important for the hedonistic process as acquiring the sources of PSS maximization because of the integrative character of PSS. Adding \$100 to an account affects its balance in the same way as canceling a \$100 debt. A subject's concentration on the sources of a positive Δ PSS for their *exploitation* as well as concentration on the sources of a negative Δ PSS for their *elimination* are equally important for this process of PSS maximization. Attention paid to X doesn't depend on the sign of Δ PSS_X or a desire for X but only on the magnitude of the PSS change that is the strength of desire for x. In summary, attention paid to X is *sign-independent* of whether X is desirable or undesirable, but depends only on the strength of desirability/undesirability of X.

Case #3. $\Delta PSS_{S,X} = 0$ or $DESIRE_{S,X} = 0$

If
$$\Delta PSS_{s,x} = 0$$
, $DESIRE_{s,x} = 0$ then $ATT_{s,x} = 0$

If X is indifferent to a subject (meaning that X doesn't affect the PSS maximization of a subject, that there is no + or desire for X) then a subject won't pay any attention to X. No attention at all is paid to the hedonically indifferent phenomena.

A graph for attention as a function of desire is a vertical "V" with its point at the zero of the crossing of the horizontal axis of desire and the vertical axis of attention.

7 HEDONISTIC RESOLUTION OF THE FRAME PROBLEM

Though Case #3 above is the least important hedonically, it is the most important statistically. At any given moment, animals, including humans, do not pay attention to the great majority of phenomena accessible to them because they are indifferent to them. This allows them to concentrate on the small percentage of phenomena that are important for their existence and well-being. Zero desire experienced toward indifferent phenomena that require no attention is a powerful filter and eliminator affording great protection for the limited resources of a small creature facing an endless Universe. This is the essence of "... the human talent for *ignoring* what should be ignored, while staying alert to relevant recalcitrance when it occurs" [23].

I would suggest that imitation of this mechanism and the mechanism of hedonic orientation in general is key to the resolution of one of the fundamental problems of Artificial Intelligence, called "the qualification problem" by McCarthy [24], usually called a "frame problem", and described by Dennett [23, p. 161] as follows:

What is needed is a system that genuinely *ignores* most of what it knows, and operates with a wellchosen portion of its knowledge at any moment. Well chosen, but not chosen by exhaustive consideration. How, though, can you give a system *rules* for ignoring - or better, since explicit rule-following is not the problem, how can you design a system that reliably ignores what it ought to ignore under a wide variety of different circumstances in a complex action environment?

I agree with McFarland's point of view [25]:

It is worth noting that animals do not suffer from the frame problem, and this may be because they have a *value system* (see Chapter 8), the cost and risks involved in their decision-making acting as constraints on their behavior.

The above analysis of the formula (3) for attention shows that this formula gives an accurate basic description of some fundamental features of attention. It correctly illustrates the fact that both positive and negative influences on a subject's PSS get attention, and that the degree of attention to a phenomenon is proportional to the magnitude of its desirability. It is fair to say that at least in some measure this formula applies.

8 ATTENTION TO MULTIPLE PHENOMENA

In reality, a subject is always simultaneously perceiving multiple phenomena, because the fact of the matter is that at any given moment the attention of a subject is distributed between a multitude of simultaneously perceived phenomena⁴. I propose that the total volume of attention of a subject S perceiving n phenomena at the moment t (ATTtotal_{s t}) can be described as the sum of attention paid to

⁴ See, for example, Damasio [26].

5

each of them:

$$ATTtotal_{s.t} = ATT_{s.t.1} + ATT_{s.t.2} + \dots + ATT_{s.t.n}$$
(4)

Now, let's merge it (4) with formula for attention to a single phenomenon (3) by replacing every component of the right part of (4), representing attention to one of the n phenomena, with its expression from (3):

$$\begin{aligned} & \text{ATTtotal}_{s,t} = k|\Delta \text{PSS}_{s,t,1}| + k|\Delta \text{PSS}_{s,t,2}| + \ldots + k|\Delta \text{PSS}_{s,t,n}| = \\ & = k|\text{DESIRE}_{s,t,1}| + k|\text{DESIRE}_{s,t,2}| + \ldots + k|\text{DESIRE}_{s,t,n}| \\ & (5) \end{aligned}$$

This formula (5) clearly demonstrates that attention is distributed between n simultaneously perceived phenomena unevenly, in accordance with the magnitude of their desirability 5 .

9 CENTER OF ATTENTION

Attention has its periphery and its most focused or 'brightest' area which is usually called the 'center of attention'. Let's assign numbers to perceived phenomena in descending order from 1 to n, in accordance with the volume of attention paid by a subject to each of them:

$$\operatorname{ATT}_{s,t,1} > \operatorname{ATT}_{s,t,2} > \ldots > \operatorname{ATT}_{s,t,n}$$

Thus, the number one (ATT_{s,t,1}) will be assigned from now on to the phenomenon having the most attention or being at the center of attention. According to the formula (5), this indicates the phenomenon with the largest positive or negative influence on PSS change $|\Delta PSS|$ - the one that is most desirable or undesirable, i.e. corresponding to the strongest desire:

$$\begin{array}{c} \operatorname{ATT}_{s,t,1} > \operatorname{ATT}_{s,t,2} > \ldots > \operatorname{ATT}_{s,t,n} \\ \operatorname{or} \\ |\Delta PSS_{s,t,1}| > |\Delta PSS_{s,t,2}| > \ldots > |\Delta PSS_{s,t,n}| \\ \operatorname{or} \\ \operatorname{DESIRE}_{s,t,1}| > |\operatorname{DESIRE}_{s,t,2}| > \ldots > |\operatorname{DESIRE}_{s,t,n}| \end{array}$$

10 GENERAL FORMULA OF ATTENTION

There is one more general feature of attention that has to be taken in consideration: attention has an upper limit. In the words of Csikszentmihalyi [27]:

The main assumption I shall be making is that attention is a form of a psychic energy needed to control the stream of consciousness, and that attention is a limited psychic resource (p. 337).

This means that at any moment (t) there is a maximum or an upper limit for the attention of a subject S (ATTmax_{s t}) and

that at any moment t this maximum is not less than the total attention of a subject:

$$ATTmax_{s,t} \ge ATTtotal_{s,t,1-n} =$$
 (6)

$$= k|\Delta PSS_{s,t,1}| + k|\Delta PSS_{s,t,2}| + ... + k|\Delta PSS_{s,t,n}| =$$
$$= k|DESIRE_{s,t,1}| + k|DESIRE_{s,t,2}| + ... + k|DESIRE_{s,t,n}|$$

It is important, that the general formula of attention (6) includes within itself the formula for attention to a single phenomenon (3) as a particular case corresponding to the situation when n equals to 1:

$$ATTmax_{s,t} \ge ATTtotal_{s,t,1} = k|\Delta PSS_{s,t,1}| = k|DESIRE_{s,t,1}|$$

There are the following variables in the general formula of attention:

- 1. a subject S;
- 2. t time;
- 3. ATTmax_{s.t} (maximum of attention of S available at t);
- 4. ATTtotal_{s,t,1to n} (total disbursed attention at t);
- 5. $|DESIRE_{s.t.n}|$ (strength of desire of S for n at t);
- 6. n number of the phenomena perceived by S simultaneously at the moment t.

Let's find out how this formula works with different combinations of values for these variables/parameters and how the formula's implications reflect reality.

11 UPPER LIMIT OF ATTENTION

According to the formula (6), if the left part of equation becomes smaller, then the right part has to be lessened as well too. It can be reduced by the number (n) of phenomena that are paid attention to, and/or by a decrease of the magnitude of their desirability for the subject:

if ATTmax_{s,t} $\rightarrow 0$ then ATTtotal_{s,t} $\rightarrow 0$; and (k|DESIRE_{s,t,1}|+...+k|DESIRE_{s,t,n}) $\rightarrow 0$

It can happen because:

$$n \rightarrow 0$$

and/or
|DESIRE_{s,t,1}|, |DESIRE_{s,t,n}) $\rightarrow 0$

This corresponds to what can be observed in reality. ATTmax_{S,t} represents the upper limit of attention of a subject S available at the moment t. If it grows, a subject is able to pay even more attention to the same number n of perceived phenomena or can increase their number. Conversely, if ATTmax_{S,t} is diminished, then a subject ought to pay less attention to the same number (n) of phenomena and/or has to decrease their number.

ATTmax_{s,t} goes down when a subject gets tired. For example, with the subject getting more and more fatigued,

I suggest that in the first approximation k is the same for all the simultaneous objects of attention from 1 to n.

desirability of the current activities and attention paid to them decrease. One loses the desire to do anything. The only desire that remains at this point is to do nothing, to get rest, to pay no further attention to anything at all.

12 CHANGE OF DESIRABILITY AND ATTENTION REDISTRIBUTION

Here we will consider what happens with distribution of attention if desirability of one of the n simultaneously perceived phenomena changes.

Case #1, Change of *positive* desirability of the phenomenon X; $DESIRE_{s,x} > 0$.

If any positive value gets larger, then its absolute value or magnitude is also enlarged. So, if positive desire grows, then its magnitude or strength ($|DESIRE_{S,X}|$) also gets larger. According to the formula (3)

$$ATT_{sx} = k |DESIRE_{sx}|$$

attention towards the phenomenon grows together with the strength of the desire for it or with its desirability.

With the additional attention paid to one of the n phenomena, that particular one will move up in the 'attention hierarchy'; it will earn an attention 'promotion'. This phenomenon would change its place in the row of the decreasing attention levels corresponding to n different phenomena perceived at the same time t.

$$\operatorname{ATT}_{s,t,1} > \operatorname{ATT}_{s,t,2} > \dots > \operatorname{ATT}_{s,t,n}$$

Its position will move from right to left in the above formula and its number placement (from 1 to n) will decrease until it becomes the number one phenomenon in the center of attention. The reverse process, an attention 'demotion' can be said to occur according to this formula when the strength of desirability of the phenomenon diminishes.

Attention 'promotion' and 'demotion' as prescribed by this formula does take place in reality. A good illustration of such a promotion is provided by taking note of a growing desire corresponding to an ongoing unsatisfied need. Such a desire strengthens until it gets into the center of attention of a subject together with those objects and ways of its satisfaction. This situation has been analyzed from a different point of view in the prior discussion of need.

In the course of satisfaction of a need the reverse process takes place. Desire gets weaker, and the attention paid to the objects and actions of satisfaction for this desire decreases, and as such, these objects and acts move out from the center of the subject's attention to its periphery and finally completely out of range. The center of attention gets overtaken by other phenomena.

Case #2. Change of *negative* desirability (undesirability) of the phenomenon X: $DESIRE_{S,X} < 0$.

If any negative value gets more negative, then its absolute value or magnitude is getting larger. So, if negative desire grows, if its object gets more undesirable, then the magnitude or strength of its undesirability ($|DESIRE_x|$) gets

larger. The formula (3) shows that attention towards the phenomenon grows together with the strength or magnitude of its *undesirability*.

As in the case #1, with the additional attention paid to one of the n phenomena, that particular one will move up in the 'attention hierarchy', will earn an attention 'promotion'. This phenomenon would change its place in the row of the decreasing attention levels corresponding to n different phenomena perceived at the same time t.

$$\operatorname{ATT}_{s,t,1} > \operatorname{ATT}_{s,t,2} > \dots > \operatorname{ATT}_{s,t,n}$$

Its position will move from right to left in the above formula and its number placement (from 1 to n) will decrease until it becomes the number one phenomenon in the center of attention. The reverse process, an attention 'demotion' can be said to occur according to this formula when the strength of *undesirability* of the phenomenon diminishes.

A good illustration of the cases where attention grows toward *undesirables* is provided by any kind of the increase of discomfort or unpleasantness, for example strengthening of toothache or hunger pangs. The more unpleasant and undesirable something becomes for a subject, the more attention is drawn thereto. The less unpleasant and undesirable it becomes due to the action of a painkiller or food intake, the less attention is paid thereto.

Comment about cases #1 and #2.

The similarity in changes of attention in the above cases one and two illustrate the independence of attention paid to a phenomenon from the positive or negative value sign of its desirability. It is also interesting that the dissatisfaction of a need can serve as an example for both cases. An object of a need's satisfaction, as well as corresponding subjective state both get an attention promotion that escalates during the time of the ongoing need dissatisfaction. An object of need (for example, food) rises in the attention hierarchy through an *increase* in the desirability of this object while the specific subjective state of the dissatisfaction of that need (hunger, thirst, etc.) gets an attention promotion through the *decrease* in the desirability for that specific state.

In these cases, nature uses *both* of its major tools of orientation - positive and negative in order to drive a subject to satisfy a need. It pushes a subject *away from* the subjective state of dissatisfaction of a need and simultaneously *pulls toward* the object or way of its satisfaction. It makes the current state of the dissatisfied subject unpleasant and thus undesirable while at the same time, making the objects of satisfaction that much more desirable.

13 HEDONIC "PRICING" AND REDISTRIBUTION OF ATTENTION

According to the Hedonistic Principle, animals and humans alike are driven by hedonic striving to maximize their PSS. Therefore, a major tool of their orientation is their hedonic 'pricing' through attaching a factor of Pleasantness/Unpleasantness to a phenomenon in order to establish it as positive or negative factor of PSS maximization and determine its desirability. By using variants of reward and punishment, like the carrot and stick scenario, both nature and society affix hedonic sticker-prices of what is pleasant or unpleasant and set values on good and bad. Adjustment of this P or hedonic 'pricing' is a most significant instrument in the alteration of animal and human orientation and choice. This adjustment has been experimentally studied by Cabanac [28], [29], who called it "alliesthesia" [28, p.1105]:

In order to avoid using a whole sentence saying that a given external stimulus can be perceived either as pleasant or unpleasant depending upon signals coming from inside the body, it may be useful to use a single word to describe this phenomenon. I hereby propose the word alliesthesia (8) coming from esthesia (meaning sensation) and allios (meaning changed).

Let us suppose that a subject perceives the same n phenomena for a given time when $ATTmax_{s,t}=ATTtotal_{s,t}$, but attention that is required for one of n phenomena grows.

$$\begin{aligned} & \text{ATTmax}_{s,t} = \text{ATTtotal}_{s,t} = \\ & \text{ATT}_{s,t,1} + \text{ATT}_{s,t,2} + ... + \text{ATT}_{s,t,n} \\ & \text{k}|\text{DESIRE}_{s,t,1}| + \text{k}|\text{DESIRE}_{s,t,2}| + ... + \text{k}|\text{DESIRE}_{s,t,n}|. \end{aligned}$$

This formula shows that as one of the n phenomena (number $x \le n$ gathers more attention, then the other (n-1) phenomena will have less attention left to them. If maximum of available attention (ATTmax_{s.t}) is not used up $(ATTmax_{s,t} < ATTtotal_{s,t})$, then the total disbursed attention (ATTtotals,t) can be increased up to the level of ATTmaxst. Now is the time for a subject to become more alert. Conversely, if maximum of available attention is already used up (ATTmax_{s,t} = ATTtotal_{s,t}), then the total of available attention (ATT_{tot}) must be redistributed. If the remainder of attention is not enough for the rest (n-1) of the evident phenomena, then some of them will receive no attention at all. Hence, a reduction of the number (n) of the perceived phenomena takes place. At this point, attention becomes more focused or narrowed. If attention to x grows so great that it requires all of the available attention of a subject, then all of it has to be spent on X only:

$$ATTmax_{s,t} = ATTtotal_{s,t} = ATTmax_{s,t,x}$$

It may be that an adult deeply concentrated on inner thoughts or a child running after a ball may not pay enough attention to that oncoming car. The more concentrated a subject is on something, the more difficult it will be for anything else to catch one's attention. And conversely, if the concentration of attention for a subject is low, then any new phenomena can easily get to the center of attention. For example, a bored child in the classroom is just looking for anything new to switch attention to.

A good example of the narrowing down of attention is the case where a basic need of a subject has not been satisfied for a long period of time. (A 'long' period of time can here be probably defined as a multiple of the regular or average period of time between satisfactions of this need). In this case, objects and images of the subject's need become more and more desirable and demand more and more attention. They gradually push everything out of the center of the subject's attention to the periphery until they have completely taken over. Eventually the objects and images of the subject's need become 'super-values' for that moment. Think toilet.

This converges with one of the basic postulates of Ethology, as described by Cabanac [30], because the strongest desire corresponds to the 'most urgent need' of this postulate: "One basic postulate of Ethology is that behavior tends to satisfy the most urgent need of the behaving subject (Tinbergen, 1950; Baerends, 1956)".

14 CHANGE OF THE OBJECTS OF ATTENTION

In reality, a subject constantly perceives new phenomena. An important distinctive quality of new phenomena is the unpredictability of their appearance. At any moment, new phenomenon can appear and make demands on a subject's attention. The following redistribution of attention, possible promotion of a very hedonically important phenomenon to the center of attention can be as sudden as its appearance. The stage of the attention distribution described by the equation

$$ATTmax_{s,t} = ATTtotal_{s,t} = ATTmax_{s,t,x}$$

can be reached at once in case of an unforeseen extreme danger or excitement.

For example, while walking down the street one perceives numerous objects but pays little attention to most of them. A subject can see many cars on the street and pay them no attention at all. But the distribution of a subject's attention changes right away with the recognition of a friend inside a car, or when it seems that one of these cars is going to hit the subject.

15 COMPUTER MODELING OF DESIRE, NEED AND ATTENTION

Formalization of any process in clear mathematical terms makes it possible to create its computer model. I believe it can happen with the proposed hedonistic models of desire, need and attention. Together they represent a considerable part of the choice mechanism of the autonomous, hedonistically driven system. Let's call such a system a "*hedonicus*".

One of the advantages of the computer/robotic implementation of a *hedonicus* is the similarity of its design with some features of its initial creator – *Homo hedonicus*. This similarity should offer ease of the *hedonicus-to-hedonicus* communication because they will speak the same language.

16 CONCLUSION

This article presents closely linked mathematical models of desire, need and attention. They are simple, intuitive and, to the best knowledge of the author, are the only hedonistic/ mathematical models of desire, need and attention available. The author believes that they can be accommodated in the design of autonomous systems.

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