Infant Development: Perspectives from German-Speaking Countries

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A Systems Theory Perspective

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Attachment theory may claim three lasting merits: It has freed love from the sexual bias affixed to it by psychoanalysis. It has upgraded bonding behavior from a secondary to a primary motive contrary to the notion of learning theorists. And it was a main step in a due development of ethological motivation theory from energetic and hydraulic models toward a systemic approach.

Bowlby (1971) has defined attachment as a form of distance regulation, or more exactly, of seeking and maintaining proximity to caregivers. Surprisingly enough though, neither he nor his followers have ever attempted to seriously apply the formalism of systems theory to analyzing the motivational dynamics of this distance regulation. However, Bischof (1975) pioneered this approach without eliciting much resonance. Some other authors were stimulated to make use of block diagrams (e.g., Bretherton; 1985, Waters & Deane, 1982), but the hypotheses thus visualized remain verbal and nonquantitative in essence. The technique of biocybernetical systems analysis is obviously hard to acquire for psychologists. The present chapter is partly meant as a tool to familiarize readers with this form of theorizing. Moreover, it is supposed to outline some further extensions of the original theory, which are subsequently referred to as the “Zürich model of social motivation.”

Speaking generally, social motivation refers to the fact that attachment is not an isolated system; it is inseparably intertwined with a larger body of motives controlling intraspecific transactions. Among these motives are social fear and social exploration, that is, behaviors designed to regulate distance and contact with strangers. Moreover, attachment is from early childhood, and markedly in puberty and adolescence, counterbalanced by a propensity to avoid ego-suffocating symbiosis, that is, by a tendency to detach from the caregiver. Last but not
least, we find sexuality and a claim for autonomy and competence among the motives intimately interwoven with attachment. It seems obvious that the causal network of all these motives requires a biocybernetic approach to be quantitatively analyzed, including the techniques of simulation and estimation.

The first part of this chapter briefly summarizes the principles of the model developed by Bischof (1975). The second part works out a mathematical realization of the model on the simplest possible level and derives predictions concerning the child's behavior in certain relevant situations. It thereby encounters some counterintuitive, but empirically testable implications of the theory, which would hardly ever become obvious from a purely verbal description. A third part deals with a refined version of the model. Finally, some examples of simulation and estimation based on the refined model are presented.

THE STRUCTURE OF THE MODEL

Basically, the model postulates three interacting motivational subsystems: the security system, the arousal system, and the autonomy/sex system (see Fig. 3.1).

The Security System

The security system controls the behavior toward social objects in as much as they are familiar. Familiarity of a conspecific, particularly if dating back to earliest infancy, indicates this conspecific is in all probability a close blood relative and therefore, for sociobiological reasons, inclined to supply prosocial support. The emotional response to familiarity is therefore assumed to be a feeling of security (s).

The model stipulates the existence of a detector capable of sensing the degree of familiarity (F) of a given object. In terms of information theory, the output of this detector increases directly with the object's redundancy or, what is the same, inversely to the object's entropy (or "collativity" in the sense of Berlyne, 1960).

A second input variable contributing to the feeling of security is supplied by a detector sensitive for the relevancy (R) of the given object. Relevancy is a measure defined to score highest when the object is an adult, high-ranking conspecific. Submissive behavior of the object, replacement of an adult by a baby, or replacement of a human partner by a transitional object like a teddy bear or a security blanket, all reduce the output of the relevancy detector.

Apart from qualities like familiarity and relevancy, it is mainly the distance (x) between the child and the caregiver that determines how much security the latter engenders. Far away helpers are less capable of providing effective support than helpers nearby, and this simple relation is reflected by the degree of experienced security provided by them.

To summarize, the construct of security refers to a hypothetical emotional
FIG. 3.1. The Zurich model of social motivation. Abbreviations: $z =$ location of object, $y =$ location of subject, $x = z - y =$ vector pointing from subject to object (see Fig. 3), $||| =$ distance, $H(x), H'(x) =$ psychological proximity, $\text{Det} =$ detector, $R =$ relevancy, $P,P' =$ potency, $F =$ familiarity, $1-F =$ novelty, $s =$ security, $a =$ arousal, $C =$ autonomy claim, $D =$ dependency, $E =$ enterprise, $A =$ activation (appetence or aversion), $l =$ incentive, $M =$ momentum, $\Delta C =$ acclimatization. For further explanations see text.
variable monotonically increasing with familiarity, relevancy, and proximity of an object. Among those three variables, proximity is the only one that the subject can control, consequently the obvious way to provide a homeostasis of security will result in distance-regulating behavior.

Homeostasis requires a reference value, against which the controlled variable can be matched. In the case of security homeostasis, this reference variable is conceived of as the degree of dependency ($D$) felt by the subject. The more dependent subjects feel, the greater their craving for security and hence their propensity to remain in close proximity to a familiar and preferably high-ranking conspecific. It is reasonable to assume that dependency, thus defined, decreases with growing age and maturation.

As long as dependency exceeds security, an appetence for security (positive $A_s$) is maintained, which induces the child to show attachment behavior, that is, to reduce the distance to a caregiver. The opposite situation, frequently encountered in puberty, results in an aversion against security (negative $A_s$) and thus, in an avoidance of the familiar caregivers (surfeit behavior). The absolute magnitude of appetence or aversion, regardless of sign, is referred to as the tension or activation of the security system.

Appetence and aversion vary only in intensity, they are one-dimensional, scalar quantities. But organisms also require information about where to head in order to increase or reduce security. They want information about the location of sources or sinks of security in the social field. The input variable providing this information is obviously vectorial, that is, a two-dimensional variable defined either by Cartesian coordinates or an angular direction (pointing to the familiar object) and a magnitude (having, in the simplest case, only two possible values, 1 or 0, depending on the object's visibility). This vector is called the incentive component ($I_s$; vectors are denoted here and elsewhere by underlined symbols).

Both incentive and appetence/aversion determine the resulting motivational momentum ($M_s$, labeled "impulse" by Bischof 1975). This in turn determines the direction and velocity of security motivated locomotion. In a final common pathway, denoted as the subsystem of motor integration, the momenta of different motives are combined by way of superposition, time-sharing, or other forms of behavior programming.

The Arousal System

The less familiar a relevant object detected, the stronger involved a second homeostatic system becomes, called the arousal system. The paradigmatic case here is the encounter with a high-ranking, adult human stranger. The arousal system releases either a withdrawal (fear behavior) or an approach enabling the subject to explore the source of arousal. Very familiar objects, like the mother, have difficulties activating the arousal system; they can do so to a certain degree,
though, by behaving in an unpredictable way such as playing "peek-a-boo" with the child.

Basically, the arousal system can be conceived of as analogous to the security system, and, what is more, it can utilize all three detectors of the latter. Arousal ($A_r$) like security, is hypothesized to increase with the object's proximity and relevancy. And because the familiarity detector also provides information about how novel or strange an object is, arousal can be inversely connected to the output of this detector as well ($1 - F$).

It is worth noting that our model regards the arousal system, like the security system, as homeostatic. This runs counter to a widespread notion into which exploratory behavior, which is governed by the arousal system, is in some way antihomeostatic. This notion stems from a misconception of homeostasis. Homeostasis means a permanent attempt to match the actual amount of a quantity to a standard given by a reference variable. This reference, analogous to dependency in the security system, is labeled enterprise ($E$) in the arousal system. Just as in the security system, we then may distinguish between an aversive and an appetent behavioral response. Aversion against arousal (negative $A_a$), and hence, fear behavior, results from arousal exceeding the setpoint of enterprise. If, however, arousal falls short of enterprise, an appetence for arousal (positive $A_a$) develops, which obviously leads not against exploratory behavior but rather directly toward it due to the system's homeostasis. This kind of behavior is to be expected particularly in puberty and adolescence if, as we assume, enterprise increases with age and maturity of the individual.

The Compound System

It goes without saying that the security and the arousal systems do not work independently of each other. Lewis and Michalson (1983, p. 237) failed to comprehend the message of the 1975 paper when feeling invited to remind us of the functional interconnection of both behavioral programs. This is precisely what the systems' approach is all about. Actually, both systems respond to the same stimulus situations, and the quantitative processing of the involved inputs leads automatically to effects such as an intensified attachment behavior toward an available caregiver produced by fear-evoking stimuli, or the caregiver serving as a secure base for exploratory ventures.

If Lewinian barriers prevent tension reduction either in the arousal or in the security system, an auxiliary apparatus responsible for unspecific coping reactions becomes involved. The main strategies of this system are labeled invention (i.e., searching for a detour), aggression (attempting to destroy the barrier), or supplication (begging someone else to remove the barrier). The model does not predict which one of the three coping responses is performed in a given context because it is mainly a result of the individual's learning history. The coping
system carries some functional similarities to Freud's *ego apparatus*, which is pursued in the present chapter.

Finally, the security and the arousal systems do not develop independently during ontogeny. The reference variables, *dependency* and *enterprise*, can be assumed to be negatively correlated, and to covary with the individual's age and maturity. Young infants are strongly dependent and only modestly enterprising. They need the presence of a security-providing caregiver in order to start exploring the environment and to acquire competence. Later in development, usually around early adolescence, this pattern changes: Waxing independency and enterprise now demand and allow separation from the familiar partners and the establishment of new relationships. Finally, after adolescence, the two reference values are supposed to level out.

**The Autonomy System**

The interdependence of the two reference values *D* and *E* suggests that both are causally connected. The model assumes a third variable underlying this connection. It carries the label of *autonomy claim* (*C*) and refers to a need for feeling competent and being respected by others. In the present context, this chapter does not discuss the systems theory of autonomy control to its full extent, because the positive social feedback involved here brings up certain stability problems (for details, see Bischof, 1985). The following are five basic axiomatic assumptions concerning our variable:

1. Autonomy claim is assumed to be the crucial issue at stake in all rank-order altercation; it is therefore functionally connected with reactant display and submissive behaviors.
2. Autonomy claim is a reference variable for the amount of aspired success; it is intimately related to achievement motivation.
3. Autonomy claim correlates positively with sexual motivation.
4. Autonomy claim affects enterprise in a direct, and dependency in an inverse sense.
5. In addition to the three external coping strategies named in the previous section, a state of high activation of either the security or the arousal system can also be reduced internally by way of what McFarland and Houston (1981) referred to as *acclimatization* (*AC* in Fig. 3.1). This mechanism amounts to the strategy of letting the reference variable adapt to the controlled variable, rather than vice versa, as usual. Thus, autonomy claim may be induced to intensify in a state of sustained overarousal or attenuated under conditions of overprotection involving too high a level of security.

Only assumptions 4 and 5 are pursued further in the present chapter.
3. A SYSTEMS THEORY PERSPECTIVE

FIG. 3.2. Mathematical realization of the model for the general case of multiple social objects, without inclusion of coping mechanisms. Abbreviations: \( i \) = subscript of objects, \( \Sigma \Delta \tau = \text{integration over time increments} \ \delta \tau \). All other symbols same as in Figure 3.1. For further explanations see text.

ELEMENTARY MATHEMATICAL REALIZATION

The motives specified and their postulated cross-connections may look quite plausible, but as soon as we really want to test the model's predictions in concrete situations, simulations are unavoidable. For this purpose we have to couch the model in a mathematical form, which is as realistic as necessary and as simple as possible (see Fig. 3.2).
Familiarity

The theory assumes that the degree of an object’s familiarity is a central point in social motivation. Thus, we start with the detector responsible for providing this information. Let the detector DetF assign to every perceived object (subscript i) a familiarity coefficient $F_i$ ranging between 0.0 (entire novelty) and 1.0 (utmost familiarity). In the mother’s case ($i = 1$), we assume this coefficient to be rather high ($F_1 = 0.9$). Additionally, we introduce a stranger ($i = 2$), who will be understood to be fairly, although not entirely, alien ($F_2 = 0.4$).

It should be noted that the familiarity coefficient is hypothesized to be a fixed perceptual attribute of the object in question, not varying with distance. Loss of familiarity due to difficulties in recognizing remote objects is disregarded. Another simplification concerns the fact that, in real life, the familiarity coefficient of a certain object is liable to change as a function of time spent with this object. In order to avoid this complication, we choose the timespan of our simulation short enough to allow us to neglect familiarizing processes. To summarize, we treat the familiarity coefficients of our simulation objects as constants. In the same vein, we disregard the possibility that one and the same object, say the mother, may apply different behavioral strategies and thereby vary her familiarity.

Relevancy, Proximity, and Potency

In a second step we consider relevancy. Similar to familiarity, the output ($R_i$) of the relevancy detector is understood to be an invariant attribute of the perceived object itself. Again we chose a range from 0.0 (entire irrelevancy) to 1.0 (relevancy of an adult conspecific in uncontested alpha position). Any adult conspecific showing no signs of submission is therefore highly relevant, that is, well capable of engendering security and/or arousal in a child.

Next we turn to spatial behavior. We define the subject’s location by a radius vector $y (= [y_1, y_2])$ originating from a fixed reference point arbitrarily chosen somewhere in the two-dimensional field of interaction (cf. Fig. 3.3). Equivalently, the location $z$ of the object is defined. By vectorially subtracting $y$ from $z$, we arrive at a third spatial vector $x$, which refers to the object’s position in the subject’s egocentric perspective. This is the input of the locality detector $Det_{Loc}$ in Figure 3.2. Its magnitude $|x|$ is equivalent to the distance $x$ between subject and object.

Both security and arousal provided by a social object decrease with growing distance, and they do so according to an unknown, though presumably monotonically decaying function. For the sake of comfortable simulation, it is useful to introduce a standard function that is monotonically decaying, but allows to adjust the slope of decay. The most simple function coming to mind here is a hyperbola. We thus define the output of the proximity detector as

$$H(x_i) = \frac{r_*(x_{\text{max}} - x_i)}{r_*(x_{\text{max}} - x_i) + x_i x_{\text{max}}^2}, \text{ if } x_i < x_{\text{max}}, \text{ and else } H(x_i) = 0 \quad (1)$$
$H(x_i)$ may be regarded as a measure of psychological proximity. It decreases with growing distance ($x_i$) between the $i$th object and the subject, and has the special properties of becoming unity for zero distance, and vanishing for any distance equal to or greater than a limit given by $x_{\text{max}}$. The parameter $r$ determines the slope of decay of the function. In simulation, $x_{\text{max}}$ and $r$ have to be chosen according to empirical plausibility. Figure 3.4 shows the shape of $H(x_i)$ used in the simulation to be described subsequently.

The next construct to be introduced is named potency ($P_i$). It is defined as the product of proximity and relevancy:

$$P_i = R_i - H(x_i)$$

Potency is a compound measure for those inputs that contribute indiscriminately to security and arousal.
Incentive Vectors

The regulation of social distance requires information about the direction of potent social objects. We have therefore introduced a two-dimensional (i.e., vectorial) construct called incentive. For obvious reasons, we need two separate incentive vectors, pointing toward the focus of security in the social field, or toward the focus of arousal, respectively. A question arises regarding the magnitudes of these vectors. Conceivably, an incentive vector might have only two states, that is, for the object being undetectable, and unity otherwise. But there is indication in favor of a more sophisticated relation: The incentive strength seems to correspond to the identifiability of the object. This amounts to the assumption that the magnitude of the incentive vectors is again smoothly decaying with growing distance, like potency, though not necessarily according to the same hyperbolic function. We therefore state, in analogy to (1)

\[ H(X_t) = \frac{r*(x_{\text{max}} - x_i)}{r*(x_{\text{max}} - x_i) + x_i*x_{\text{max}}} \text{, if } x_i < x_{\text{max}}, \text{ and else } H(x_i) = 0 \]  

(3)

For the sake of simplicity, we regard the range of visibility \( x_{\text{max}} \) as equal to the value chosen in (1), but we provide for a separate slope parameter \( r' \) not necessarily equal to \( r \).

The security and arousal incentives exerted by a certain object \( i \) \( (I_{si} \text{ and } I_{ai}, \text{ respectively}) \) are then defined as vectors pointing toward this object and having the magnitudes

\[ |I_{si}| = P' - F_i \text{ and } |I_{ai}| = P' - (1 - F_i) \]  

(4a,b)

with \( P' = R_i - H'(x_i) \)  

(4c)

Let us assume that the encounter between the subject and two social objects of different familiarity \( (F_1 = .9, F_2 = .4) \) occurs in a rectangular room, with each object, if present, resting at a fixed place. Equation (4a) will then assign to any given point \( y \) in this room a set of \( n \) security incentive vectors \( I_{si} \) \( (1 \leq i \leq n; n = \text{number of objects present}) \), whose resultant \( I_s \) is computed according to

\[ I_s(y) = \sum_{i=1}^{n} I_{si}(y) \]  

(5)

Vector \( I_s \) represents the total incentive force acting on the security system, if the subject happens to dwell at location \( y \). Figure 3.5 shows the field of security incentive vectors \( I_s \) when the mother alone is present, and when the mother and a stranger are simultaneously exposed to the subject. Quite analogously, equation (4b) will yield \( n \) different arousal vector fields \( I_{ai} \), whose superposition \( I_a \), defined analogous to (5), specifies the arousal incentive situation at any given point in the room.
FIG. 3.5. Vector field showing the spatial distribution of security incentive forces ($f_s$). $y_1$ and $y_2$ = space coordinates. (a) Mother (empty square) alone. (b) Mother and stranger (solid square) combined. Arrowheads denote direction of $f_s$ vectors. The magnitude of a vector is symbolized by the areal size of the arrowhead. B = Buridan’s point (see text).
As Figure 3.5b indicates, the incentives exerted by mother and stranger may cancel each other if the components happen to point in opposite directions. This is exactly the case at point B. We propose to call it Buridan's point (in honor of Buridan's donkey, who starved to death being trapped halfway between two equally attractive hay heaps), although it is actually a point of labile equilibrium unlikely to be occupied for a protracted time interval.

Joint Familiarity Atmosphere

The next question to be answered is how secure, or aroused, respectively, a subject feels at a given point in space, provided again that more than a single social object is present. A plausible hypothesis is to define a scalar field called joint familiarity atmosphere, according to the following statement

\[
F = \frac{\sum_{i=1}^{n} P_i \cdot F_i}{\sum_{i=1}^{n} P_i}
\]

The joint familiarity atmosphere \( F \) produced by \( n \) objects, that is, will be taken to be the arithmetic mean of the single-object familiarity coefficients weighted by their respective potencies. Contrary to the \( F_i \)'s, then, which are fixed attributes of the objects \( i \) regardless of their position in space, the quantity \( F \) is contingent on the distances \( x_i \) between the subject and its social objects: The farther away an object is, the less is its contribution to the total atmosphere of familiarity present at the subject's location.

It may be noted that by being based on the mean of the given familiarities, the joint familiarity atmosphere remains bounded within the limits of 0 and 1. If, say, a child and the mother are alone in a room, the atmosphere will be more or less satiated with familiarity, and will remain so if the father joins the dyad. However, a stranger entering would, according to (6), reduce the joint familiarity markedly.

Joint Potency

The question of limitation is more tricky in the case of the joint potency. An algebraic summation of all given potencies would imply a counterintuitive linearity. Low potencies may summate, but two highly potent objects (e.g., two parents within reaching distance) can scarcely be assumed to be exactly twice as potent and thus providing twice as much security as one of them alone. We therefore require a formula that yields quasi-linear addition only for low poten-
cies, but a satiation effect when the total approaches an upper limit. The statement

\[ P = - \prod_{i=1}^{n} (1 - P^i) \]  

fulfills this requirement. When computed according to this formula, the joint potency \( P \) of \( n \) objects will never exceed an upper limit of \( P_{\text{max}} = 1.0 \). It will asymptotically approach this limit with increasing \( n \), or with \( P_i \)-values approaching \( P_{\text{max}} \), and it will equal \( P_{\text{max}} \) as soon as any one of the components equals \( P_{\text{max}} \). All these properties make quite good sense and render equation (7) an appropriate model assumption. The choice of the special value \( P_{\text{max}} \) equalling unity, thus equalling the maximum possible potency that a single social object may attain according to equation (2), is arbitrary but does not engender any qualitative peculiarities in the model's behavior.

Security and Arousal

Equations (6) and (7) immediately allow us to compute the net values of security \((s)\) and arousal \((a)\):

\[ x = P - F \quad \text{and} \quad a = P - (1 - F) \]  

These equations assign scalar quantities of security and arousal to any given point in space, thus defining scalar fields that can be represented graphically by a set of contour lines. Figure 3.6 shows the s-field under the condition of mother alone and mother with stranger.

Figure 3.7 illustrates the same situation as Figure 3.6b, with the spatial manifold being reduced to a one-dimensional cut through the s-field along the shortest connection between mother and stranger. The components of security engendered by mother or stranger alone are inserted for comparison. As the reader may remember, the stranger is moderately familiar \((F_2 = .4)\), such as the lady from the house over the street. When this stranger appears on the scene of the mother-child dyad, security as the product of joint familiarity and joint potency decreases in the vicinity of mother, as the figure reveals. Next to the stranger, however, his appearance causes security to rise above the values evoked by mother alone. The exact shape of the curves depends on the parameters chosen in equation (1), and also on the distance between mother and stranger. But qualitatively, we can now see why, in a highly dependent infant clinging to the mother’s apron strings, objects of low familiarity are likely to reduce security and thus to even further intensify clinging behavior. In a state of higher independence, where a greater distance to mother is preferred, the same condition raises the security level above the one provided by mother alone, and thus renders the subject even more audacious to contact the stranger.
FIG. 3.6. Scalar field showing the spatial distribution of security (same situations as in Fig. 3.5). Contour lines denoting amount of $s$ in 0.05-unit steps. Two particular contours for $s = 0.5$ and 0.75 are marked by heavy lines (broken or solid, respectively). For further explanation see text.
Appetences and Aversions

The next step is to compute the activation components of the security and the arousal systems. These are denoted as $A_s$ and $A_a$, respectively. Their equations follow immediately from Figure 3.2:

$$A_s = D - s$$
$$A_a = E - a$$

As can be seen, the $A$-values are positive whenever the actual amount of security or arousal falls short of the corresponding reference variable. Positive $A$ values, then, mean appetence while negative $A$ values denote aversion.

In the previous expressions, dependency ($D$) and enterprise ($E$) can be chosen arbitrarily, because the model does not imply any assumptions regarding their intensity, except that they are confined to the range of 0.0 to 1.0, which are also the limits of $s$ and $a$. For example, a rather highly dependent infant ($D = 0.75$) will be liable to dwell on the heavy unbroken contour line in Figure 3.6 because this locus alone would specify zero activation in the security system ($A_s = 0$). The region enclosed by this line, where security is higher than 0.75, is a field of (mild) surfeit of security, whereas in the area outside, the infant is subject to different degrees of separation anxiety. As a comparison of Figs. 3.6a and 3.6b
reveals, introducing a stranger contracts the 0.75 contour line, thus entailing a
closer association with mother. That this effect vanishes with lower degrees of
dependency is indicated by the heavy broken line in Figs. 3.6a,b, which depicts
the locus for $A_s = 0$ under the condition of reduced dependency ($D = 0.5$). When
the subject has reached this stage of development, the introduction of a stranger
will no longer prompt approach to the mother (cf. also Fig. 3.7).

**Momentum Vectors**

According to Figure 3.2, the momenta ($M_s$ and $M_a$, respectively) exerted onto
the subject's locomotor mechanisms by the security and arousal systems follow
from a multiplication of $A_s$ or $A_a$, respectively, with the corresponding incentive
vectors at the Subject's location:

$$
M_s = A_s - I_s \quad \text{and} \quad M_a = A_a - I_a.
$$

(10)

Computed for all points in space, the motivational momentum again defines a
vector field. Figure 3.8 presents an example of the $M_s$-field under the condition
of $D = 0.5$. In this figure, the solid vectors indicate surfeit of security, whereas
the empty vectors tend to increase security and are therefore attachment-moti-
vated. At the thin broken line in both figures (locus for absence of activation; $A_s
= 0$), and at the asterisk in Figure 3.8b (Buridan's point), no locomotor mo-
dentum acts on the child, as far as the security system is concerned.

**Motor Integration**

All procedures carried out up to this point for the security system must be
repeated accordingly for the arousal system. Thus, after choosing a particular
value for enterprise, we may compute a vector field analogous to Figure 3.8,
with solid centrifugal arrows (centered mainly around the stranger) denoting fear,
and the empty centripetal arrows (in more or less respectful distance from the
stranger) denoting curiosity.

For the sake of simplicity, we assume that in the block “motor integration” of
Figure 3.1 the arousal momentum is superimposed with the security momentum
of Figure 3.8 or, in other words, that the final distribution of motivational forces
directing the infant's locomotion is a result of simple vectorial summation.
Nevertheless we have to keep in mind that, in order to reconcile divergent
momenta of different motives, other and more complex forms of behavioral
programming are very likely to occur, particularly competition and time sharing
as investigated by McFarland (1974, 1976). Theorizing in these more advanced
fields, however, should be guided by empirical research that, in our problem
area, still remains to be carried out.

Finally, the resulting momentum is mildly dampened by adding some friction,
in order to improve stability, and then integrated over time to yield the subject's
FIG. 3.8. Vector field showing the spatial distribution of locomotor momenta, as exerted by the security system \( M_s \). Situations (a) and (b) same as in Fig. 3.5. For further explanation see text.
new location $y$. As indicated in Figure 3.3, $y$ is then subtracted from $z$, thus closing the feedback loop of proxemic homeostasis.

EXTENSIONS OF THE MODEL

The "Pool" Hypothesis

Homeostatic systems are normally devised to be stable. That is to say, when all disturbing inputs remain constant, the system is supposed to reach a steady state. It may oscillate for a while around this state, but these oscillations are expected to be dampened and should sooner or later come to rest. Translated into our case we would expect that, provided there exists a locus for zero activation of both the security and the arousal system, the subject, once having arrived there, should relax, as long as the social objects do not change their position either.

This expectation is valid as far as long-term simulation of general ontogenetic trends, or of time-invariant social organization is concerned. But it is not suitable when it comes to predicting the dynamics of real-time behavior. Children’s actual distance control is characterized by a significant instability: The child keeps oscillating in an undampened fashion around its hypothetical steady state without ever resting in it. Mahler, Pine, and Bergmann (1975) referred to this phenomenon as emotional refueling, thereby unintentionally hinting at a possible systemic explanation of the instability mentioned. Suppose the constructs of security and arousal, as defined in the previous version of our model, would not refer to quantities that enter into motivational activation in a proportional way, but rather would determine the rate in which this activation changes. Security, for instance, would then behave like a kind of "fluid" feeding into a leaking "pool," with dependency determining the aperture of the drain. The fluid level in the pool would be behaviorally controlled such as to remain close to a neutral mark. Any deviation above or below this mark is experienced as security aversion or appe­tence, respectively (see Fig. 3.9a). For arousal, an analogous pool would be postulated with enterprise as the variable controlling the drain.

Mathematically, the process described is called a (temporal) integration (cf. Fig. 3.9b). Another integration occurs at the site where momentum is transformed into location $y$, thus the feedback loop postulated contains a double integral that, for systemic reasons, is essentially unstable and would therefore account for the locomotor oscillations actually observed.

In order to allow for the proposed refinement, we have to modify equation (9) in the following way:

$$A_s(T) = \sum_{t=0}^{T} (D - s)t$$ and $$A_a(T) = \sum_{t=0}^{T} (E - a)t$$ (11)