# The significance of exposure to music for the formation and stabilisation of complex neuronal relationship matrices in the human brain: implications for the salutogenetic effects of intervention by means of music therapy

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## 9.1. Introduction

The human brain is not to be compared with a machine which is 'produced' according to a specific construction plan and whose structure and function can be deduced by the inspection of this plan or of the individual components which have been fashioned according to it.

In trying to understand the brain, we must think not in terms of linear cause and effect relationships, but rather we are dealing with complex, multi-modal networks which are related with each other in many different ways and which exercise a mutual influence on one other. The connections involved are not generated according to genetic programmes, but develop in the course of the brain's formative process on the basis of experience and according to the frequency with which they are implemented. Furthermore, the networks which are created at a given time can be modified afterwards throughout the brain's 'operational life' as the need arises by newly emerging usage and activation patterns ('usage dependent plasticity').

Therefore the development of the brain must be understood as a self-organising process which is directed ■ in part ■ by interaction with the outside world. In the course of this process individual 'items' of experience are registered in the form of neuronal relationship patterns. More than all other factors, the prevailing psychosocial development conditions are crucial for the structural development of a child's brain.

Even before birth, while the emergent brain is establishing more and more links to the outside world, the interconnections and activation patterns which are laid down and develop at that time are increasingly subject to influences from the outside world which are transmitted via various sensory interfaces. When activation patterns are repeatedly triggered by such sensory impulses, this results in the stabilisation of certain neuronal interconnection matrices ■ [>Weicht vom Original etwas ab.] ■. From this time onwards

brain development no longer takes place in isolation, but is at first increasingly determined by sensory input from its intrauterine environment and later by that received from the prevailing domestic surroundings. This dependent relationship then remains in effect indefinitely (Hüther 2002).

Notwithstanding the complex interconnections existing within the brain, it is possible to identify individual areas which correspond to specific types of activity. That is to say, if a person engages in any kind of activity, this is reflected in the activation of dedicated regions of the brain, and this brain activity can be displayed with the use of functional imaging techniques. However, the fact that hearing and speech are associated with the activation of the language centres of the left-brain hemisphere does not allow the inference that this region is *the* seat of human language. A network, which is specialised in the recognition and generation of words, can only develop according to the degree to which a person has the opportunity to learn speech and learn about the meaning of words during his or her childhood. Correspondingly, every other complex activity which a person directs with the help of the brain must also be practised, 'run in' and anchored in the form of patterns of neuronal connectivity.

This applies, as well, to a person's attitude to and interaction with music, i.e. with his or her ability to recognise certain tones and sequences and also to reproduce them. Both listening to music and playing musical instruments have far-reaching consequences for people's thinking processes, their feelings and their actions. For this reason both receptive and active intervention using music therapy can be employed in order to induce psychoaffective states within patients which have a beneficial effect on psychotherapeutic processes (Hüther 2004). The consequences of such interventions, in the form of both medical and therapeutic instruments, can be measured with the help of various different indicators. On the physical level these range from variations in the activity of the autonomic nervous system, the cardiovascular system and the endocrine system to characteristic alterations in the immune system (Spintge and Droh 1992, Taylor 1997). The point of departure for all these changes in activity levels is to be found within the neuronal networks which participate in the control of such integrated regulatory systems in the patient concerned.

Until only a few years ago it was not possible to prove the existence of such changes within the brain. However, the time is now ripe for gathering new insights in this area of study. Neurobiologists are not only identifying and describing the processes of listening to, recognising and producing music as being especially complex achievements of the central neuronal processing apparatus, but they have also begun to analyse the processes taking place in the brain in more detail. The latest studies in this area utilise the cerebral processes involved in listening to music as a model for the investigation of complex psychoaffective and cognitive achievements (Koelsch and Siebel 2005).

But these neurological findings also underline the limited use of the evermore detailed descriptions of the effects of music on the brain, at least in respect of understanding or making understandable the ways in which music can have a therapeutic effect. It is far more important to improve our understanding of how the neuronal networks and synaptic connections

involved in processing musical information are formed in the course of the brain's development and to find out how and by what means these networks are linked with lower regions and other networks which have been established either previously or at the same time. Finally, to understand how the interconnection patterns formed in each individual development stage themselves become the basis for the next phase of synaptic link formation in all the associative, subsequently maturing parts of the brain.

## 9.2. Neuronal anchoring of auditory experiences

The impulses which are transmitted from the auditory nerve to the auditory centres located in the brain stem result in an activity pattern specific to the respective acoustical perception, especially in the *colliculus inferior*. The more often similar acoustic signals lead to the formation of such an activity pattern, the more firmly the associated synaptic links will be confirmed and reinforced. In the course of this early (■ pre-natal)* ■ 'construction phase' for neuronal networks those synapses which are not reused, or only seldom reused, are dismantled again. This formation process in which specific interconnection patterns are distilled from an originally broad-based surfeit of synaptic links has been termed by neurobiologists "usage-dependent synaptic ■structuring//regulation//plasticity■". ■ [>bitte bestätigen]■ The strategy of providing for a superabundance of synaptic linking possibilities followed by a usage-dependent stabilisation process for certain linkage patterns on the basis of auditive perceptions leading to the generation of corresponding activity patterns is also employed later, after birth, in the maturing networks of the auditory system in the thalamus and the auditory cortex.

■ * „(pre-natal)" wurde hier eingefügt, um einen sinnvollen Zusammenhang mit „. . . vollzieht sich später, **nach der Geburt**, auch . . . " im Folgesatz herzustellen. ■

Thus on all three levels – at first in the brain stem, then in the thalamus and finally in the sensory cortex – specific, usage dependent, structured synaptic interconnection patterns arise which are both caused by and reflect the acoustic perceptions received up to a given point in time. These primary, stabilised synaptic patterns form in turn the starting point for all extensions, refinements and supplements which may come about through additional acoustic input. Especially on the level of the most recently established representations of acoustical signals in the particularly pliant networks of the auditory cortex, modifications of this kind can be brought about by means of individual training throughout a person's life.

In cases where abnormal development of or damage to the hearing organs or nerves prevents the generation of acoustic activation patterns and therefore also the stabilisation of corresponding synaptic interconnection patterns, it is not possible to create these primary representations in the respective brain regions retrospectively with the same degree of complexity. Even when people suffering from such conditions can be treated to correct the original deficit, e.g. by means of a cochlear implant, they can still only process the acoustic signals which they are now able to receive to a very limited degree.

## 9.3. Functional linking of hearing experience with other sensory experiences

A sensory perception only becomes meaningful when it can be connected with other perceptions or experiences which are being made or have been made in the same context. This is true, as well, for the sense of hearing. Neurobiologists term such an event, when two or more different sensory channels are activated simultaneously through a given experience, 'functional coupling'. In all probability there is no such thing as an acoustical perception which is not coupled in some way or other with another perception received at the same time via another sensory system. Thus coupling is the rule, not an exception – and that is the case right from the beginning, i.e. as early as the pre-natal phase of development, when the respective networks are formed in usage dependent processes.

Through the physiological union of the unborn child with its mother a connection exists with her mental state as well. In respect of hearing this has the following significance: The mother's voice informs the unborn child of her emotional state; as the latter changes, so do her heart rate, her respiration and the hormone levels in her blood. Thus the voice is tied in with shifting rhythmical experiences originating with speech and heartbeat, in addition to vibrations via tactile experience and the effects of hormonal fluctuation.

This means that pre-natal hearing, in this case of the mother's voice, occurs simultaneously via several senses, and it is anchored in the brain through this connection pattern as a comprehensive experience (as a 'gestalt').

For instance, when the mother is excited, her organism produces more stress hormones (adrenaline/cortisol), the oxygen supply is modified, the heart rate accelerates and the abdominal wall tenses up, restricting the unborn child in its freedom of movement. At the same time, the mother's tone of voice may become higher, louder, and shriller. This alteration in the characteristics of the voice is noted by the child, which associates it with the distress or sense of being threatened which it experiences in that situation. On the other hand, when the mother is relaxed and in a balanced state, the child experiences a harmonious sense of being provided for, it is itself relaxed and the corresponding feelings are also coupled with the mother's now calm and tranquil voice.

The extent to which and the way in which a mother's voice changes according to her emotional state varies. Through the coupling process described here, in which changes in the mother's voice are brought together with other somatosensory experiences, the changes gain an individual connotation for the unborn child.

The same applies, of course, to all other hearing experiences, including those emanating from without, ranging from listening to music to loud quarrelling. A slammed door need not necessarily be something stressful, but when it becomes associated with a bodily experience which is felt as stress and which is not then dissipated by a subsequent calming experience, then it will become firmly linked with that experience and correspondingly internalised.

After birth, such coupling phenomena become more diverse and can be more plainly observed. In this respect the coupling of speech, song or music with distinct, associated and simultaneously activated physical experiences can be easily demonstrated: in positive cases these could consist of rocking and swaying, stroking and moving, satiation and the satisfaction of basic needs. All these bodily experiences become inextricably linked with the voice of the mother, with her speech melody, with individual words or with her song. As a baby's ability to process optical stimuli matures, changing facial expressions and gestures on the part of the initial key carers are connected with the acoustic signals coming from the same source. Thus the parents' behaviour at this stage determines the patterns which remain activable in the context of later experiences.

Through coupling phenomena of this kind the perceptions made by the child (in either especially pleasant or especially unpleasant situations) via various sensory organs are not only connected with each other, but also with the feelings which they engender. In this way they are anchored in the brain as a complete 'matrix' formed of linked neuronal networks and synaptic interconnection patterns. The more intensely the emotional centres in the limbic system are activated as well, the stronger will be the bond which develops between them and the most powerful sensory impressions in a given situation, i.e. that which is seen, heard, smelled or felt. And the greater the variety of different sensory perceptions involved in an experience at one and the same time, the more diverse and complex the matrix will be which is anchored in the brain.

### 9.4. Links with higher associative achievements

A new perception, a new item of knowledge or a new experience can only become anchored within the brain when the activation pattern generated by the newly received stimulus can be associated in one way or another with existing interconnection patterns and corresponding activation patterns. At every moment of the development of a brain, the currently available pool of knowledge ■ and experience ■ provides the basis for 'capturing' and accommodating new input.

Every fresh sensory perception and every new experience must go through this process of being linked with existing interconnection patterns, associated with what has gone before and finally being integrated. Whenever such a process is successful, the extended pattern itself becomes part of the basis for all subsequent connection and assimilation processes. In this way, every person gains not only increasing levels of competence in individual areas during his or her early childhood, but also an ever more extensive and complex ability to make more connections. Furthermore, insofar as a child is able to connect more and more sensory experiences with each other, it becomes more able to 'grasp' those phenomena in its life which lie beyond the senses: the invisible, the inaudible, which cannot be felt directly.

These ■ capabilities/experiences ■ are in the realm of the meta-cognitive. They are anchored on the most complex association levels in the human brain, in the so-called

prefrontal cortex. This is the home of our inner attitudes, our concepts of self-efficacy and of ourselves, of our ability to predict the future course of events, to plan our actions or to control our impulses.

These meta-competences cannot be taught or learned by rote, but can only be anchored in the brain through our own gamut of experiences. Interestingly enough, early experience of music, listening to musical sequences, singing and playing musical instruments such as drums all represent especially effective ways of creating a foundation for the later development of the highly complex areas of meta-competences. As these activities all have a procedural character, they facilitate the formation of an inner understanding of chronological sequence. That which has just been (what is past) allows the prediction of and expectations in respect of what is still to come (the future). Thus music imparts an inner sense of continuity, of the dependability of and involvement in that which is, i.e. Now: Now contains the echo of what has been and it is the starting point for what is yet to be.

Therapeutic experience has shown that an even, steady rhythmical structure conveys a sense of security and continuity. That tempo which we find most soothing in musical works corresponds to the normal rate of a calm pulse, namely 60 beats per minute. This is the received knowledge of great antiquity: All cultures make use of it in their lullabies, but also in more modern esoteric or meditative music.

Thus the harmony and rhythm of music picks up on prenatal experience. But it also develops this pool of experience by means of irregularities. Breaks in harmony and changes in rhythm can become part of a light-hearted interplay between what is already known and what is new. And on the foundation of a basic sense of emotional security, what is new and foreign can be approached with optimistic curiosity rather than apprehension.

Rhythm, especially, creates continuity and a sense of security through the instrument of reliable repetition. It is at the root of what Milton Erikson termed 'basic trust' (1974). Our most fundamental experience of rhythm is, from a biological point of view, holistic, for all life is determined by the pulsating influence of a rhythmical Nature. In the attempt to understand the effects of rhythm at the commencement of infantile perception of sound, we may view it as the regular, alternating sequence of beat and pause. It represents the combination of presence and absence within a temporal framework. Thus it may well be that even before the very beginning of consciousness, the consistently repetitive alternation of beat and pause is one precondition for the development of dependably internalised chronological patterns. This rhythmical continuity experienced during the intrauterine phase of life could be a necessary preparation for a child's capacity to explore and then cope with irregularities in a confident manner. And this process is crucial to subsequent mental development.

To sum up the phenomenon of primary rhythmical experience: At a very early age knowledge of variation, pauses or irregularities becomes anchored not only through biologically determined rhythmical experiences but also through the voice and thus the speech patterns of the mother.

## 9.5. Communication and anchoring of social resonance experiences

The relationship of a mother and a nursing baby is characterised by vocal interaction, whereby the vocal pattern is a reflection of the basic style of communication between them. At four months, characteristic patterns have developed which allow predictions to be made in respect of the bonding patterns which will have emerged after one year and the cognitive development after two years (Beebe 2004). Interestingly enough, both 'over-perfect' and too little responsivity can lead to insecure bonding patterns. 'Too little' in this case means overlong pauses and the breakdown of contact. At the other end of the scale, going out of one's way to achieve perfectly timed responses generates confinement and prevents flexible interplay. A baby can only develop reliable bonding patterns on the basis of flexible ups and downs, with communication breakdowns followed by happy reunion. It is the process of restoration of the relationship which lays the ground for the flexibility which later life will demand. To this, Beebe asserts that during the 'now-moments' and 'moments of encounter' which will be referred to later a form of knowledge – a perception of the other's current state – becomes reflected in oneself. This reflection is so exact that auto-perception and hetero-perception correspond. Such moments of conformity in encounters with others – i.e. seeing oneself in others – promote the formation of autonomy ■ Urheberschaft ■ and identity.

The basic units of implicit experiential knowledge are 'moments of encounter': emotional experiences which take place both in company and in seclusion – and which alter the implicitly felt, inter-subjective pool of experience. This is experience in the moment of its inception. Stern (1992) underlined the fact that we too often see experiences and feelings as 'snapshots' and fail to take account of the inner flow, of a forward moving river of experience. He refers to the inner performances which reflect this dynamic process as 'vitality affects'. These so-called 'dynamic time-shapes' can be connected with movements, sensations and other perceptions and they take place simultaneously, as in a musical score – polyphonically and polyrhythmically. In a similar way to the 'states' ■ [<Im Englischen wirkt dieser Begriff an dieser Stelle recht leer. Eine besondere Bedeutung von 'States' ist nicht offenbar.] ■ in their dynamic subtlety and transience – both characteristics of sound and music – vitality affects reflect the resonant matrix ■ Schwingungsgestalt ■ of the inner world of experience (Stern 1992). The vitality affects generate 'temporal feeling shapes', characteristic 'dramatic lines of tension' which are described with the use of musical metaphors such as musical phrases. They attempt to capture the impression left by sensations or the inner contours of feelings. Damasio describes this quality of experience in terms of 'background feelings'. For him, even more so than for Stern, such feelings are closely bound up with the physical body (Damasio 2001).

In this way a baby becomes acquainted with the world – in an atmosphere of mutuality, simultaneity and the sharing of affects and feelings. This remains a part of our experience for the rest of our lives; however, it becomes overlaid by explicit forms which consciously determine our later life.

Positive experience of relationship represents a life-long protective factor (Bauer 2002); it can even prevent a genetic predisposition towards aggressive behaviour from developing

(Moffitt 2002, Teicher 2002). Relationship experiences made in earliest childhood give rise to a basic framework which colours the whole of the life which follows. It is this stage that determines whether a person can rely on social relationships and expects these to be helpful to him or herself – or whether he or she develops into an 'independent' loner because of the disappointed anticipations of infancy.

Research into earliest childhood has concentrated much effort on the question as to how nursing babies can have such discriminating powers of differentiation, how they can perform crossmodal linking and how they are able to play such an active part in their relationship with their human environment. To provide a possible explanation for these phenomena, the existence is assumed of the so-called 'inter-subjective motivational system' in addition to the bonding system (attachment motivational system) (Watson and Gergely 1999). The mirror neurons, too, may play a role here (Gallese 2003). Neurophysiological research results suggest that familiarity, repetition and expectability all have a decisive influence on the organisation of neuronal functions and interconnections. The capacity for synchronisation is congenital and exists as a genuine human need in an inter-subjective context. The ■ processing of ■ these experiences provides for the necessary preconditions which enable a person to self-synchronise ■ sich mit sich zu synchronisieren ■ in later life, for instance when he or she is fully preoccupied with a given activity (Pöppel 2005).

In order for changes to take place, a moment must emerge in which two people meet, reach a state of resonance with each other, synchronise with each other and in this way achieve regulation.

The Boston Group ■ [<vieldeutige Bezeichnung? Vgl. 'Boston Consulting Group', http://www.thebostongroup.com/, Boston Working Group, Boston Search Group usw.] ■ has coined the term 'now moments' to describe these encounters in which a reciprocal link – a 'meeting of the minds' – occurs between two self-organising systems. At such moments the whole world of experience of those participating, their thinking and their feeling, is raised to a higher level (Stern 1992).

With music, while playing particular musical compositions or just improvising, such moments can transpire practically on their own. For music is a vehicle through which people can connect with each other with a special intensity, in a certain resonance, in the context of a rhythmical and/or dynamic 'happening'. Playing music in a group succeeds when those participating show an inner willingness to become involved, to enter into a state of resonance with the others and with the music. This cannot be brought about by an effort of will – it is an interactive experience, it implies active listening, affective reasoning and response. The significance of resonating with others, of 'being on the same wavelength' can be seen very clearly with improvised music in a therapeutic context: Two people meet, achieve resonance, synchronise with each other and 'something' sorts itself out – feels different, is no longer as it was before. Here it is evident that encounters of this kind are prerequisites for the experience of *now moments* which in turn provide a starting point which enables a therapeutic process to begin.

In this sense, the experience of music is the experience of relationship. This can be used for therapeutic purposes because of the way in which it allows people to let themselves be touched, reached and in their inmost depths moved (Schumacher 1999).

Music therapy works with a person's precognitive and emotional aspects, which enables access to very early patterns of experience, including prenatal ones. ■ [Original: "interauterine = intrauterine? Erfahrungsmuster"] ■ This embedded body of experience can be rediscovered through music. Where a person's world at this early age was intact, there exists a healthy foundation which can be used and strengthened to beneficial purpose. We experience this as a process of being 'inwardly moved'; old yearnings reawaken, a feeling arises which heartens, strengthens. On the basis of this feeling, we can engage in the task of redesigning our thought and behaviour patterns.

## 9.6. Salutogenetic effects

### *9.6.1 Concluding remarks in respect of practical music therapy*

But what is the use of all these astonishing neurobiological findings to a person who, in the end, has become ill through the effects of the life which he or she has been leading?

In conclusion, some examples of the effects of intervention using music therapy follow to provide a possible answer to this question.

Music, like speech, is used in all human cultures as a medium for communication, to aid in organising social life and to bond the members of social groupings together. Therefore music therapy, like conversational therapy, looks back on a long tradition as a form of psychosocial therapy used to aid the healing and reintegration of group members. Today, music therapists usually work in close cooperation with physicians and psychotherapists together with patients, either on an individual or on a group basis. With the help of free, structured or partially structured sound improvisations and a variety of receptive techniques patients are given the means to become aware of their feelings and conflicts in a non-verbal manner and also to express them. Their conscious awareness of these aspects is then consolidated in subsequent counselling sessions.

Frequently, music therapy is also used with the aim of resolving internal tension and triggering resonance and harmonisation effects, which can prevent the spread and escalation of non-specific states of fear and agitation. To bring about these calming effects three factors are of special significance: familiarity, rhythm and order. The familiarity of received music allows for associative connections to be made with internally stored images which impart a sense of security and 'being in good hands'. When a patient absorbs a rhythm and uses it as a tool for performing inner work, this can bring about resonance phenomena of great power. Synchronisation effects take place which emanate from the auditory cortical regions and spread to associative and motor areas, influencing and augmenting each other. In this way

activity patterns generated in very diverse regional networks of the brain can be synchronised and harmonised with each other. This effect is experienced as the unification of thought, feeling and action, both on an individual level and by a group which is bonded together through a common rhythm (social resonance).

Another health promoting component of music consists in its inherent order, which can be perceived by a listener or actively expressed by those playing instruments. This structure, consisting of repetition and alternation, of the development and rediscovery of a familiar theme, supplies precisely the preconditions necessary for the activation of emotional-cognitive processing: through the unexpectedness of what is new, through familiarity with what is known and through the creative act of ongoing evolution. This effect can be best exploited and most effectively implemented in the context of improvisation for therapeutic purposes. By providing the patients with tools with which they can express affective conditions through rhythm and sound, they become empowered to communicate their emotional state in a non-verbal way. As this happens in an environment without evaluation and without constraint on the part of the therapist, patients can become aware of their present feelings, express them and in the course of an interactive process they undergo the experience not only of being understood by another person, but also of receiving a response from them. By engaging in this non-verbal dialogue, patients can grasp that they can exercise a modulating influence over their own affective states. As a result, the patients' grasp of their own self-efficacy concept is strengthened on the level of affective regulation. The unfamiliar experience of finding access to and being able to express their own stored feelings, i.e. discovering a new mode of communication, together with the exploitation of the harmonising, synchronising and resonance generating effects of music, causes stimulation of emotional centres which most patients regard as beneficial. The increased production of neuroplastic neurotransmitters associated with such activity promotes confirmation of the neuronal interconnection patterns which are activated through corresponding priming processes. In this way it is possible to create the conditions which are a prerequisite for the modification of a person's personal world of experience, thinking patterns, feelings and actions through continuing psychotherapeutic treatment.

On the basis of these observations, the following three propositions may be put forward to substantiate the salutogenetic effects of intervention by means of music therapy.

#### 9.6.1.1 1st proposition

Listening to pleasant music, actively playing musical instruments or singing causes physical alteration of the brain in the form of a harmonisation and synchronisation of the neuronal activation patterns which have been generated in various cerebral regions. These effects can be expected to be all the stronger in accordance with the degree of enjoyment associated with the musical experience, with the degree of openness with which the person concerned can approach such an experience and with the extent to which he or she can

allow free associations to arise ('to dream'). The more these harmonisation influences can pervade the subcortical regions responsible for the organisation of integrative bodily control systems (limbic system, hypothalamus, brain stem), the greater the reconstitutive effect on structures such as the cardiovascular, neuroendocrine, vegetative and immunes systems which have become disrupted by tension, anxiety, stress, etc. The long-term influence of these effects is determined by the extent to which they 'reverberate' within the person concerned – as inner experiential images, as melodies which continue to play in the person's imagination, etc.

The harmonising and synchronising effects of music can be utilised specifically in order to
■ mask/cover up/overcome fears and sensations (e.g. pain caused by medical intervention) and for the relief of tension (e.g. to ease anxiety while preparing for medical intervention). Also, they can be transferred from one person to another (e.g. when a parent sings or plays an instrument for a child).

#### 9.6.1.2 2nd proposition

Musical experience (listening, playing, singing and also imagining music being played) brings about a reactivation of previously suppressed activation patterns in associative and emotional centres, or aids their reconstitution following disruptive occurrences. The subjective perception of these effects is described in terms of 'relief' and 'revitalisation' by those concerned. In this way, previously suppressed conceptions and desires can be reactivated and, in some cases implemented as well (activation of the noradrenergic 'attentiveness' system as well as the dopaminergic 'motivation and reward' system).

This is the effect which is harnessed for use as a 'collective motivation amplifier' in ritual preparation of forthcoming activities (war drums, marching music, and also pop and rock concerts) and in order to generate specific mental conditions (films, advertising).

#### 9.6.1.3 3rd proposition

Whenever listening to or playing music or the singing of melodies causes the activation of subcortical emotional networks and centres in the brain, this is accompanied by increased production of neurotransmitters: in particular, of those neurotransmitters which contribute to the amplification, reinforcement and priming of all the neuronal interconnections which are primarily involved in this emotional activation.

This applies to the priming processes of the sensory-motoric regulating systems activated through learning to play an instrument, to the enhancement of fundamental processing of auditive perception, but also to the strengthening of bonds between people (playing music or singing in a group) and to the affirmation of healing mental pictures and inner motivation.

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