inter.noise 2010
noise and sustainability
13-16 June 2010 . Lisbon . Portugal
www.internoise2010.org

Soundscape and core affect regulation

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Abstract
"Why do people make detours through parks?" Or put differently: "Why is being exposed to the stimuli in a park pleasant and restorative." Or even more general: "Why may sounds influence behavior." The answer to these questions may be in the interplay of core phenomena of cognitive science such as: the processes of hearing and listening, different forms of attention, meaning giving and associated effortful and less effortful mental states, core affect regulation, basic emotions, viability and health, and the restoration of the capacity for directed attention. These all contribute in predictable ways to how humans respond to sound (and in general to the environment). The hearing process may deem part of the sound salient enough to be analyzed in full by the listening process that gives meaning to the input through the activation of behavioral options. The selected behavioral options must comply with the demand that they preserve viability and help to regulate core affect (defined as the combination of perceived viability and resource allocation). Any response strategy is influenced by perception-activated basic emotions. Angry behavior is activated when sounds hinder goal achievement. The restorativeness of parks relies on perceptual fascination through involuntary attention capturing of pleasant stimuli in combination with fairly simple perception-action responses. These mental states allow the systems for complex reasoning through directed attention time to return to normal values. Soundscape design should focus on allowing people sufficient opportunities for core affect self-regulation through the creation of fascinating "attractors".

Keywords: Soundscape, auditory cognition, restoration, emotion, core affect.

1 Introduction

This paper addresses the cognitive basis of soundscape research through the question "Why do people make detours through parks?" Urban parks are not only for enjoyment they are also important for restoration [1]. It is still unclear *why* being exposed to the sonic and visual input of parks is pleasant and restorative. This paper approaches pleasure and restoration from the perspective of auditory cognition. Auditory Cognition studies the processes between

sound reception and overt behavior like verbal reports or movements away or towards sources. As part of cognitive science, auditory cognition is interested in the algorithms and representations associated with this process. As such this paper focuses on the functional aspects and not on the way the processes are implemented on the neural substrate.
The essential prerequisite for models that can predict human responses to sound is a notion of what humans actually do when they process sounds. This is an offshoot from a more general question: "What is the role of perception?" This article addresses this question from the perspective that perception is for action [2] while actions must be constrained by the requirement to remain viable (alive) [3].

1.1 Cognitive science and soundscape research

Since auditory cognition studies the causal relations between receiving sound and responding to it, the domain can play a role in soundscape research because this field has a history of establishing correlative—but not yet causal—relations between psychoacoustic measures and behavior (such as filling in a questionnaire after being exposed). These correlative measures have provided useful insights, but failed to answer *why* these correlations exist.
Conversely, the soundscape concept offers interesting challenges for cognitive scientists. One of these is the fact that the soundscape community of, among others, psychoacousticians, architects, urban planners, linguists, and sociologists agree that it is very difficult to do soundscape research in a laboratory. This is a direct result of the definition of the soundscape concept that treats the perceiver not as passive observer, but as observer-participant: the observer is part of the environment and determines through interaction the significance of the environment in life.
This conforms with the most cited definition of soundscape as *"an environment of sound (sonic environment) with emphasis on the way it is perceived and understood by the individual, or by a society. It thus depends on the relationship between the individual and any such environment."* Within the soundscape community there is general agreement that a soundscape is neither just an acoustic environment nor just perceived sound. Essentially, the sound is supposed to stem from a normal, and therefore structured and typical outdoor or spacious sonic environment where the perceiver has "a sense of presence" and can report its significance as for example its (un)pleasantness. In addition, the perceiver constructs a meaningful interpretation of the environment, interacts with it, and gives it a role in life.
Thus a perceiver should not be viewed as passively present, as while listening to recorded music. On the contrary, the observer is seen as an "active participant" who is able to judge and communicate what the soundscape entails for him/her or others, to use and enjoy whatever it affords, and to be annoyed when it is unpleasant or restrictive. Both observer participancy and ecological validity [4] are therefore essential for soundscape research, and both are difficult to approach in controlled conditions. Furthermore a societal task of the soundscape community is to improve well-being on a personal and community level and to prevent expensive infrastructural investments with dubious societal benefit. This entails that the soundscape community deals with direct effects of sonic environments, as well as with long-term effects such as health and community well-being.
This description of the soundscape concept touches on a number of deep scientific notions in the cognitive sciences. One key question is "How to self-generate behavior that allows us to remain viable and healthy in a complex and precarious environment?" Sometimes the current environment guides behavior (as while driving a car), at other moments our behavior relies on complex reasoning tasks (e.g., while working), and yet other moments we simply need to rest and recuperate and select a behavior aimed at enabling this (sleeping, eating, relaxing in a park).
These issues play roles in the decision to make a detour through a park and generally how

we will experience and evaluate our environment. This article aims to propose a framework—centered on modern perception research—that addresses behavior selection in a way that is relevant for the soundscape community as well as for the cognitive sciences.

1.2 Overview of the paper

We will start with a description of perception, with a focus on audition, as the search for behavioral options in the (sonic) environment through flexible attentional processes. A description of how we give relevance and meaning to structures in our environments leads to the notion of core affect and its regulation through emotional appraisal and the selection of behavior. Regulation of core affect, in combination with the properties of attention can then be coupled to restoration through the perception of fascinating stimuli in a safe and immersive context. This allows us to answer the question why specific visual and sonic input can be restorative and worth the detour through the park. And, maybe, it also helps us to develop cognitive sensors that measure the relevant perceptual and restorative qualities of soundscapes.

2 Auditory cognition = hearing + listening + action selection

We all know that the words hearing and listening have subtly different meanings. “I hear music” indicates that I am aware of the presence of the sound-class music. In contrast “I listen to music” entails that I am involved in a more effortful sound analysis activity. We need to become aware of interesting sounds, and we need to analyze some of these sounds in detail.

This difference addresses the core demands of perception in our complex, partly uncontrollable and unknown, and variable environment. Fortunately, our living environment is also structured and to some extent invariant so that it makes sense to acquire knowledge about it to allow reasoning and planning. Our environments are also extremely redundant, which entails an abundance of ways to reach similar conclusions. And finally, much of the world is irrelevant and typically only a small part of its structures needs to be analyzed for behavioral consequences.

It is the task of perception to determine the relevant structures in the world. Sometimes these structures are familiar and expected so that they can be found through an active search—listening—and sometimes these structures are novel or pop-up unexpectedly and can only be determined through a change in the environment—hearing. Audition, therefore, involves a combination of hearing and listening. [5]

Hearing is a background process that is, unlike eyes which we can close, always active. When we sleep we also hear, although responses to sounds depend on the depth of the sleep. We can be woken by sounds that are out-of-context, particularly loud, or that have special significance such as our name, or sounds associated with negative consequences [6]. Sounds that evoke a mental response are called salient. Note that salience is not a signal property but a property given to part of the signal by the hearing process.

The fact that we wake up in these situations shows the function of hearing: it is a filter for (potentially) relevant sounds. Sounds that can pass this filter are judged relevant enough for a more detailed analysis than we, apparently, can perform during sleep. This leads to the quite different process of listening. For listening we need to be awake and conscious.

Dehaene [7] concludes that although we can perform quite complex tasks without being conscious, we need to be conscious for specific cognitive tasks; in particular tasks that require durable information maintenance, novel combinations of mental operations, and the spontaneous generation of goal oriented behavior. Being conscious (or aware) of your

environment entails that you have formed a (durable) mental representation of the environment and its processes. Psychologists call these representations “schemas”. Because intentional goal-oriented behavior is based on the contents of active schemas, the conscious mind aims to remain in sync with the developments in the physical world. Consciousness can therefore be interpreted as our current best summary of the knowledge pertaining to the current mental state of the organism, its environment, and the behavioral options it affords [8].

2.1 Signal-driven and task-driven attention

Perception is the active process that keeps the mental representation in sync with the direct environment while allowing goal-oriented behavior. Closely associated with perception and a prerequisite of consciousness [7] is attention. Attention can be separated in bottom-up, exogenous, or signal driven attention and top-down, selective, [8] directed *[9],* or knowledge driven attention. Hearing corresponds with the signal driven variant that is able to attract top-down attention if part of the signal is deemed salient. Listening corresponds to knowledge driven attention and is a task-oriented process that actively structures the input by applying schemas.

Perceptual processes are therefore continually searching for 1) possible relevance in the environment in the form of salient structures in the input and 2) specific goal- and task-relevant information. Hearing is the auditory component of the first process, listening is the auditory component of the task-oriented process. Listening uses the combination of the “output” of the hearing process and active schemas to search for (i.e., select) evidence that is consistent with learned expectations for the mentally represented environment. This is called schema-based perception. Because listening is both active and knowledge-driven, listening is always aimed at “something”: namely the expectations associated with the schemas. Whenever the input is consistent with our expectation of it, we will perceive an object or concept. This works even if the signal-driven evidence is indicative but degraded by noise (which explains our robustness to background-noise and other transmission effects) or insufficient (something exploited by magicians).

Schema-based perception has a number of consequences. For one we do not become aware of the signal but of our *interpretation of the signal*: we “detect” our expectation and therefore the worldly presence of some part of our knowledge. This is a reason why so-called experts might produce quite differently reports about what they perceive than non-experts. It is also the basis of the difference between interpreting sounds as sources and processes in the world (everyday listening) and analyzing sounds in terms of signal properties like frequency and loudness (musical listening) [10]. The processes differ qualitatively in the type of knowledge required for the task: knowledge about the spectro-temporal patterns imposed by sound sources versus (expert) knowledge about perceptual dimensions of sound. A third consequence is that the separation of foreground (the part of the input that complies with the activated knowledge/expectations) and background (the rest as coarse summary statistics) is task dependent [11]. Audition as combination of hearing and listening can be summarized as in figure 1.

2.2 Behavioral options, meaning-giving, and mental effort

Perception keeps the active mental representations sufficiently in sync with the physical world to allow effective goal-oriented behavior [7]. Perception of a sonic or visual object may have behavioral consequences and therefore be meaningful. The “meaning of something to someone” denotes the personal importance of something. Because this is situation

dependent its importance is defined through the relationship of the individual with its environment; an observation consistent with the soundscape definition. The meaning of something for someone can therefore be defined as the difference in behavioral options with and without taking the perceived object into account. If something affords strict behavioral options it is obviously meaningful. However if not taking it into account does not change behavioral options, it is meaningless. Auditory cognition is aimed at figuring out the most effective behavioral options afforded by sounds. This process, which is here equated with giving meaning to perceived sound, requires an intimate interaction between (auditory) cognition, and the environment.

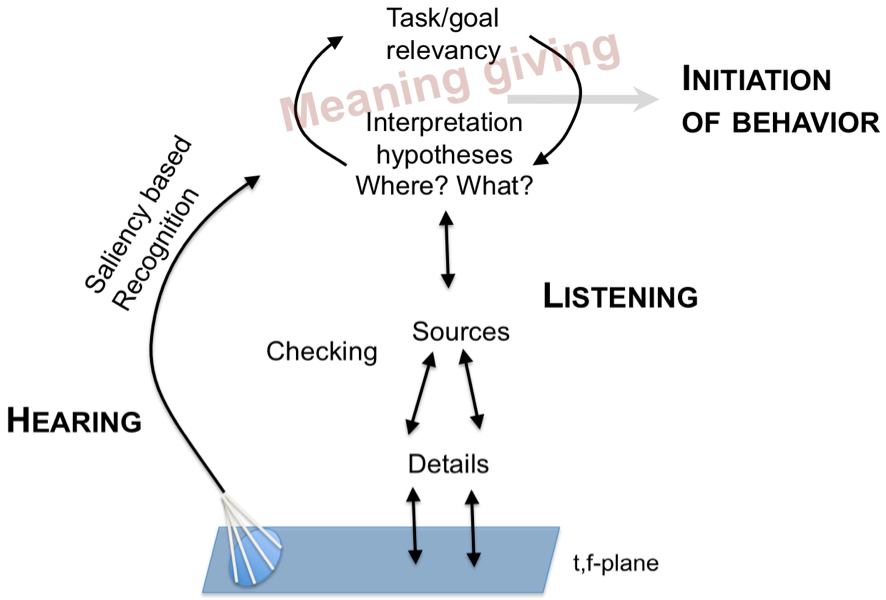

Figure 1 – Audition is driven by evidence of physical sound producing processes in combination with transmission effects. A hearing process leads to a rough physical analysis in the form of “global statistics” and the identification of salient components. These can activate interpretation hypotheses that are to be checked in a process that actively searches for expected patterns in the input. Recognition occurs through a match between signal and expectations. The role of audition is not mere recognition; it also contributes to meaning giving through activating behavioral options, of which the best can be selected. [11]

Different combinations of perceptual input, contexts, and personal goals may lead to qualitatively different forms of meaning giving. One form of meaning giving is evaluating and enjoying the present. For example looking at paintings, listening to a concert, or perceiving a pretty landscape leads to a form of meaning giving in which one has evaluated a pleasant, pervasive, and non-threatening input for which action selection is not crucial. In this case the whole input captures attention in a way that does not require immediate action. Furthermore, the knowledge required to evaluate the environment is closely related and therefore preactivated semantically [12]. This entails that mental states for goal-oriented behavior (here stimulus enjoyment) are consistent with the environment.

While the previous type of mental states is concerned with the present, it is also possible that mental states are instrumental in achieving some desired future state. A typical work situation requires the selection and precise execution of goal-oriented actions in complex environments in which not the whole input, but only specific selections are significant. These need to be selected from a clutter of irrelevant input. Planning goal oriented behavior—and therefore the process of meaning giving—requires directed attention through the flexible activation of knowledge that is not preactivated via perceptual input, but is exclusively task-

specific. This entails that these mental states must overcome the attention capturing effects of perceptual input in favor of goal-relevant mental states. This process is thought to be more effortful due to inhibiting (suppressing) exogenous stimulation and a highly specific activation of goal-relevant mental states through the inhibition of task-irrelevant states [9].

3 Regulating core affect

If perception plays a role in adaptive behavior, the next question to be asked is “where is behavior for?” The answer to this question is personal and situation dependent, but a common constraint on all nonpathologic behavior is that it must preserve or improve viability. Ever so often we have to drink, eat, rest, and recuperate. And during the execution of goal oriented behavior we must prevent hurting ourselves and depleting our physiological and mental resources. Importantly we should preserve viability on both the short term and the long term. The prerequisite of nonpathologic behavior is therefore to avoid low viability and to approach high viability on the longest time-scale possible. In particular behavior with short term perceived benefit, but long-term devastation should be avoided. This poses high demands on the skill to predict 1) the viability consequences of behavior at different time-scales and 2) the resources required to realize this.
In emotion research the combination of the perceived current state-of-the-system and the allocation of resources to maintain or improve this feeling is known as core affect [13]. Core affect is typically depicted as two dimensions conform figure 2.

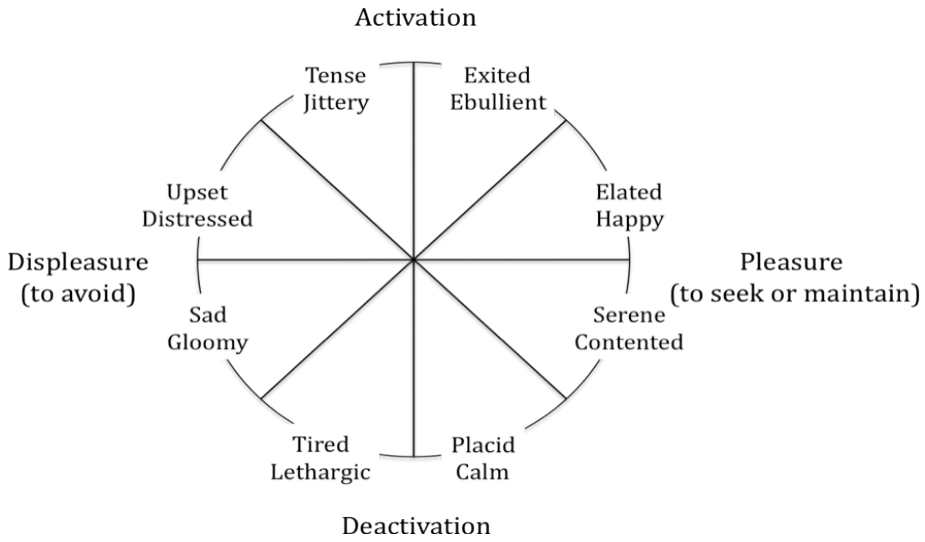

Figure 2 – Core affect combines the horizontal dimension ‘pleasure’ with as vertical dimension the resources made available to improve or maintain the pleasure value. The pleasure value is thought to correlate with perceived viability. Optimizing long-term pleasure leads to increased well-being. The figure is based on [13]

According to Russell “The horizontal dimension, pleasure–displeasure, ranges from one extreme (e.g., agony) through a neutral point (adaptation level) to its opposite extreme (e.g., ecstasy). The feeling is an assessment of one’s current condition. The vertical dimension, arousal, ranges from sleep, then drowsiness, through various stages of alertness to frenetic excitement [13].” Pleasure reflects perceived well-being and can be thought of as a consciously available correlate of viability, while activation corresponds to the energy resources made available for the current situation. According to Russell “people generally (but not always) seek behavioral options that maximize pleasure and minimize displeasure.

Behavior thus involves predictions of future core affect" [13].
The key question of *"what to do when"* is related to the "perception" of behavioral options—as described in the previous section—and emotions, because "emotions not only make us feel something, they make us feel like doing something. [14]" According to Gross[14] "regulated (in part through explicit knowledge based cognitive processes) emotions of different kinds allow us to balance qualitatively different (future) consequences of courses of action and to decide on the initiation of action". The link between emotions, attention, perception, and core affect regulation is strong because "emotions arise when an individual attends to a situation and sees it as relevant to his or her goals." [14]

4 Basic emotions, perception, and behavioral options

Izard [*15*] makes a useful distinction between basic emotions and emotional schema's. "Basic emotions have a direct perception-action link and are not influenced by more complex cognitive functions. Emotion schema's rely on more complex cognitive (and often social) evaluations. Its perceptual–cognitive components are influenced by a vast array of individual and cultural differences in emotion–cognition relations" [15]. According to Izard there are 6 different basic emotions that have a direct perception-action link: disgust, interest, joy/happiness, fear, anger, and sadness. Izard [15] describes a number of shared properties of the basic emotions

- They "involve internal bodily activity and the capacity for expressive behavior"
- The "activation or elicitation of a basic emotion may depend in part on perception (or minimal/rudimentary appraisal) of an ecologically valid stimulus."
- "Feelings derive from sensory processes that tell the organism what is happening."
- "A basic emotion has noncyclic motivational capacities that include the power to influence cognition and action."
- "Basic-emotion feelings provide an ever-ready source of motivation to serve adaptive functions."

Activation or elicitation of a basic emotion may depend in part on perception (or minimal/rudimentary appraisal) of an ecologically valid stimulus" [15]. In terms of behavioral option selection: basic emotions might emerge as tendencies (including bodily action readiness) to pursue particular courses of action. For example disgust and fear are associated with avoidance, while joy/happiness and interest lead to approach and prolonging exposure. In the case of the evaluation of an (sonic) environment and more specifically sound enjoyment or annoyance basic emotions can play a major role in the selection of individual behavior. Table 1 suggests specific behavioral tendencies for each emotion. "

5 Restoration

Attention restoration theory (ART) [9] proposes that after the prolonged use of effortful directed attention—and consequently a high activation component of core affect—it becomes more difficult to direct attention and to suppress exogenous distractions. Since an attentionally fatigued person is prone to make errors [16] and less able to reach desired (mental) goals easily he/she experiences irritability (related to the basic emotion anger, see table 2 and "tense/jittery" in figure 2). Being in an environment that does not pose any demands on directed attention provides time for the inhibitory mechanisms involved in directed attention to return towards a normal state. This restores the capacity for direct attention.

Table 1 – Relation between basic emotions and behavioral options

Basic emotion	Future viability evaluation of behavioral options	Sound related behavioral options
Disgust	For nutrients: do not take in, dangerous, makes you feel bad . For objects/individuals: do not associate with, dangerous, makes you feel bad. Avoid!	A horrible sound is the sound of puking. Unpleasant sounds lead typically to avoidance behavior
Interest	Fascinating. Spend (analysis) time on, of potential importance. Investigate options.	Some sound may capture interest easily (bird-song, music)
Joy/happiness	Plans/expectations works out, control over situation, reached desired result, favorable situation reached or maintained.	Typically, joyful sounds indicate pleasure of others and by implication a safe situation
Fear	Situation not under control, plans might not work, predicted outcome has a high probability to be unfavorable. Take protective measures.	Might be associated with the anticipation of unpleasant or task-detrimental sounds.
Sadness	Plans with positive outcome can be made, but no longer executed due to the absence of conditions that used to exist. New core affect regulation strategies (=behavioral options) must be learned but are not yet available.	Can be associated with the loss of the use of a garden as a source or restoration due to increased traffic. Aim to restore original situation.
Anger	Plans are frustrated or do not work out as expected, situation is not under control due to (in- or external) influences that require action. Prepare for action to increase control.	Can be associated with the occurrence of sounds that disturb activities from reaching desired goals (disturbed sleep → no rest).

According to ART four components [9] are important for restoration through preventing direct attention. “Fascination (use of involuntary, effortless, attention), Being-Away (a physical or cognitive relocation of ones self from everyday activities), Compatibility (a match between the individual’s desired activity/behavior and the environment) and Extent (the scope and connectedness of the environment)” [17]. Together these components ensure effortless immersion in an environment that is pleasant, suitable for the current personal goals, and involves minimal directed attention.

Typically, homes are important in core affect regulation because we can control them to a high degree. It is a place for sleeping and the provision of other restorative experiences to enable recovery and relaxation. This can be achieved through controlling the stimuli that you are exposed to at home. For example working in the garden is one way of immersing yourself in a pleasant environment without the need for complex action planning. A garden offers plenty of opportunities for fascination in the form of birds, beautiful flowers, etc. and the associated behavior consists of straightforward perception-action relations. We can compare the restoration effects of visitors of a motorcycle spectacle, designed and optimized for easy to immersion, with the restoration effects on inhabitants that are exposed to the motor sounds while they engage in the fascination of their garden. See table 2.

While the motorcycle fans enjoy a fascinating and immersive multi-sensory spectacle quite unlike their normal routines, the nearby gardeners suffer an intrusion that degrades the value of every attention restorative aspect of gardening. So while the visitors enjoy a stimulus driven multi-sensory experience in which directed attention plays a minimal role, the inhabitants are forced to suppress the sonic intrusions through an effortful direction of attention to pleasant stimuli that can normally be processed with less effort. In this case one group’s restoration is the other group’s stressor.

Table 2 – Comparison of restoration experiences

ART-components	Visitors motorcycle venue	Nearby inhabitants in garden
Fascination	Multi-sensory spectacle of impressive motor cycles	Motor sounds reduce multi-sensory attractiveness and fascination
Being-Away	Voluntary choice of physical immersion in nonstandard activity	Imposed intrusion interrupts feeling of cognitive immersion in gardening
Compatibility	Venue and day filled with all things motor-sport	Sonic intrusion at odds with wish to enjoy environment
Extent	Whole environment dedicated to motor-sport	Single disturbing factor present, reduces scope and connectedness of garden
Score	**+4**	**-4**

6 Conclusion

This paper investigated causal connections between perception, activation and selection of behavioral options, and the requirement to remain viable and healthy. Maintaining viable in a complex world requires sequencing activities of which some are aimed at interacting with the present situation, while others aim to shape some desired future. For sound perception, this resulted in a core responsibility of soundscape design to create environments that allow people to regulate core affect and in doing so improve perceived viability (pleasure), well-being, and community health.

Humans perceive behavioral options in their environment and although different people may select different behavior, listeners share cognitive abilities and limitations. Ultimately, these limitations and abilities, in combination with the behavioral options the environment affords, determine the influence of an environment on core affect regulation. Each individual should be offered ample opportunities to self-regulate core affect. For planning purposes this entails strict limits on in-house noise exposure to prevent frequent sonic intrusions and to provide ample options for core affect self-regulation. It is important that residential areas offer structural opportunities for effective fascination, so that each inhabitant is free to self-regulate restoration of directed attention to preserve effective goal-oriented thinking. The four ART-components can be used for design purposes. Because the hearing process has the ability to claim selective attention, unexpected, relatively loud, or otherwise potentially significant sounds can effectively disrupt attention restoration. Consequently the sonic quality of an environment is essential for core affect regulation.

In areas where different or competing demands must be met, it will be impossible to allow pervasive fascination. Here it is a health and well-being necessity to create easily accessible spaces where the four ART-components are met. These form the restorative “attractors” for effortless immersion in an environment that is pleasant and suitable for the current personal goals while involving minimal directed attention.

The interesting consequence of this line of thought is that it might be possible to develop a cognitive sensor that can model the influence of the sonic environment on core-affect regulation. Such a system should report the degree to which the sonic environment is supportive for the mental activities humans use for core affect regulation. Such a system should focus on measuring the capacity for fascination and the number and character of difficult to ignore intrusions. It should use these to assess the type of mental states, basic emotions, and behavioral options the environment is likely to elicit. A mismatch between the intended use and the imposed influence on cognitive states indicates opportunities for soundscape optimization.

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