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Chapter 4

Elaborations of the Multiple-Resource Theory of Attention

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The multiple attentional resource theory represents a construct that, in its time, served to unify two fundamentally disparate views of human performance capacity (Wickens, 1980). Subsequently, the theory has had a particularly strong influence on the practice of human factors, especially in system development, where it arguably remains the strongest behavioral heuristic for interface design. This confluence of contribution to both fundamental theory and practical application served to facilitate the impact of multiple resources and Wickens's influence on the domains of both human factors and experimental psychology (and see Carswell [2005]). Here we provide elaborations on the original theory. In doing so, we seek to generate a wider vista of discourse with respect to the notion of separable components of human attention and, potentially, the individual experience of consciousness and reality itself.

THE HISTORIC CONTEXT

To a large degree, science proceeds in fits and starts. Most often there is an original, observation-driven theory that encourages structured experimental investigation and then slowly, as the empirical database assembles, inconsistencies between prediction and recorded behavior begin to emerge. With respect to the original theory, it is often the case that an almost intolerable dissonance arises that acts to goad subsequent theorists to propose new formulations to straddle the more extensive behavioral landscape revealed by preceding experimental evaluations. In this sense, virtually all good theories contain—as part of their intrinsic structure—the seeds of their own destruction. Those theories that do not contain this characteristic often prove essentially untestable and, although they may be ubiquitous, such theories are most often also fundamentally vacuous (for a more extensive discussion of a particular example, see Hancock and Ganey [2003]). Thus, although new and sweeping insights permit a general brisance of understanding, they can only be accomplished effectively by those steeped in the problem and intimately familiar with the nuances and inconsistencies of the current state of knowledge. In a true sense, such individuals are always in debt to their forebears and this is the veridical meaning of Newton's observation that, "if I have seen further, it is by standing on the shoulders of giants" (Andrews, Riggs, Seidel, et al., 1996). In essence, one has to know one's problem to generate solutions to one's problem.

It was thus in the latter part of the 1970s that Wickens, among others, approached the conundrum of human attention that was then interpreted in terms of two major theoretical perspectives. The first perspective was derived from the early, linear information processing models (e.g., Broadbent, 1958) whereas the more recent "resource" conception emphasized an energetic, fluid formulation (e.g., Kahneman, 1973; and see Freeman, 1948). Wickens's thorough understanding of the attention literature at this juncture allowed him to encapsulate this vast sweep of issues and findings, and so provide a structured synthesis that subsequently dominated the literature for many years. The added benefit of his formulation was that it also represented a strong design heuristic that amplified the impact of the theory well beyond the literature in experimental psychology alone. However, like all true theories, it did not remain static and unchanging, but sought to encapsulate new findings as the structure and tenets of the theory itself also evolved (Wickens, 2002). By introducing differing and extended interpretations of the various multiple-resource model axes, we hope to indicate some avenues of possible future progress through which to enlarge this useful framework.

PAYING ATTENTION

Single-channel approaches to information processing were identified largely during the late 1940s and early 1950s, when the first blush of formal information theory penetrated into the psychological sciences (Fitts, 1954; Miller, 1956; Shannon & Weaver, 1949). Attention, as an issue, was somewhat of a problem for these early-stage models (Broadbent, 1958; Welford, 1967). The solution to this problem was to link the concept of attention to a filter, a bottleneck, or some form of "rate-limiting" element somewhere in the progressive processing chain. Unfortunately, contradictory experimental findings led to much dispute about the nature of this bottleneck and its relative location in the identified sequence (Moray, 1967; Treisman, 1969; Wachtel, 1967). These issues, although leading to a series of ingenious experiments, never really reached a definitive conclusion, and it was during this time that an alternative conception arose. In contrast to the processing filter approaches, the resource notion of Kahneman (1973) presented an energetic perspective on attention. In this conception, degrees of processing resources could be directed to a task, compared with an all-or-none allocation that a completely pristine stage model implied. These processing resources have been conceived as either "pools" of energy or as "processing units." (For a review, see Szalma and Hancock [2002].) After its initial formulation, debate continued over whether there was only one such attentional resource (Kantowitz & Knight, 1976) or several such resources (Navon & Gopher, 1979). The protestation of a single resource pool is supported, if by nothing else than the general principle of parsimony (Kantowitz, 1987). So, if predictions from a single resource model could be shown to emulate the empirical data satisfactorily, then multiple-resource models would be overelaborative and thus redundant (although see Bronowski [1966] on the potential fallacy of parsimony).

One can, for example, cope with many of the potential problems that appear to face single-resource conceptions by use of switching strategies and thus finesse the issues of limitations by transferring the problems of attention expressed in the spatial domain to an alternative "answer" expressed in the temporal domain. In short, if a single-resource pool model is formulated that can switch sufficiently quickly and effectively between the tasks, it can emulate the output from most forms of multiple-resource models. It remains an open question, and one very relevant to Wickens's conception, regarding whether the current "landscape" of empirical data can still be accounted for by a single-resource model as originally conceived by Kahneman. Of perhaps even greater importance is Kantowitz's (1987) further observation that multiple-resource approaches are simply *too* powerful. That is, they have sufficient explanatory degrees of freedom open so that almost any pattern of data may be encapsulated by the appropriate manipulation of the variables proposed. We return to this observation later in our discussion because it is directly relevant to our own proposed extensions.

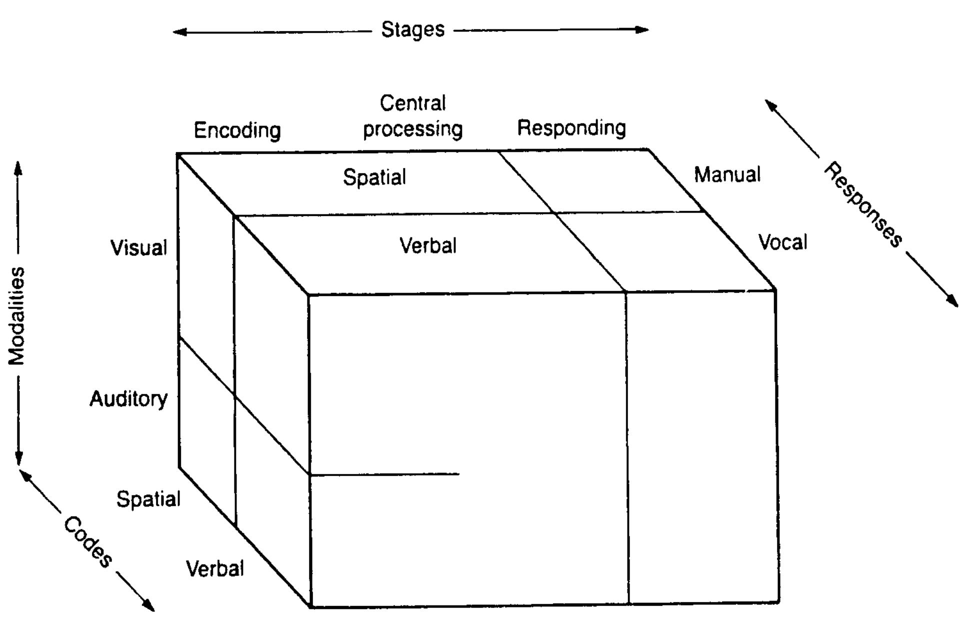

FIGURE 4.1. The classic Wickensian "box model" of human attention, and design heuristic for information and response distribution for the human operator. After Wickens (1980).

The modal multiple-resource approach is crystallized in Wickens's conception, rendered colloquially as the "box model" (Wickens, 1980). From this conception, shown in Figure 4.1, multiple attentional resources were identified upon the basis of three fundamental dimensions. The first dimension was that of *processing stage*. This is essentially a temporal axis reflecting the concern for the sequence of encoding, decision making, and response, which is made seriatim in traditional stage models (even though the potential for parallel processing was considered by Wickens). A second identified axis was that of *processing code*, consisting of the verbal and spatial components of a task. The final axis was that of *processing modality*, which was separated into the visual and the auditory senses. These respective differentiations were made essentially from post hoc interpretations of experimental data derived largely from procedures using a dual-task paradigm. In noticing occasions when two tasks failed to interfere with each other's performance, a prediction that, by the way, is impossible from a strict unitary resource formulation, Wickens used the concept of *difficulty insensitivity* to help distinguish the resource structures given in Figure 4.1 (and see Wickens et al., 1981).

Together with the concept of functional cerebral space (Kinsbourne & Hicks, 1978) and the differentiation of resources as advocated by Navon and Gopher (1979), Wickens (1980, 1987) was able to define a hybrid model that solved many of the contemporary questions and impasses that largely concerned the division of attention. Theoretically, it remains an unresolved question regarding whether this new formulation was able to account for the range of then-existing experimental data because of its more close affiliation with actuality (which would be what all good theorists would try to achieve), or whether a major degree of its power came from the greater number of explanatory degrees of freedom intrinsic to a formulation that advocates a multiple-factor versus a single-factor construct. This, of course, is intrinsic to all such elaborations of a unitary factor theory, as has been seen in developments in the concepts of IQ (Sternberg, 1982), arousal (Eysenck, 1967), fatigue (Hancock & Desmond, 2001), and other similar energetic constructs in human behavior. Independent of these meta-theoretical considerations, Wickens's formulation proved to have a substantial and long-lasting impact in the realm of human factors and system design.

There have been a number of critiques and commentaries on the theoretical, methodological, and existential characteristics of the multiple resource model. (See Damos and Lyall [1986], Navon [1984], and Sarter [this volume], among others.) Numerous concerns remain unresolved. For example, in multiple task situations, who or what decides on the priority between tasks that do have some degree of resource overlap? If no such mechanism can be illustrated in the model, then it becomes purely reactive, lacking purposiveness and intentionality. How could such a passive formulation represent the personally active process of attention? Speaking of attention, the multiple-resource model is, strictly speaking, only an architecture. It does not tell us what attention actually is. Are these supposed resources only a metaphor, or do they represent some actual form of "brain" fuel? And given this, to what degree does neurophysiological evidence inform what this fuel might be? Furthermore, Wickens (2002) himself noted that the visual channel is not a simple unitary one, but now is better suited to a bifid division between focal and ambient modes. Very recent evidence also suggests that the auditory channel can be divided into two elements, as well. Wherefore multiple resources if the resources simply keep proliferating? These are important questions, but we do not have space to address each one. Rather, what we wish to achieve is an examination of certain specific elaborations of the model that allow us to extend its generality and consider the impact of these elaborations, mostly in the theoretical realm, but partly in terms of practical issues, as well.

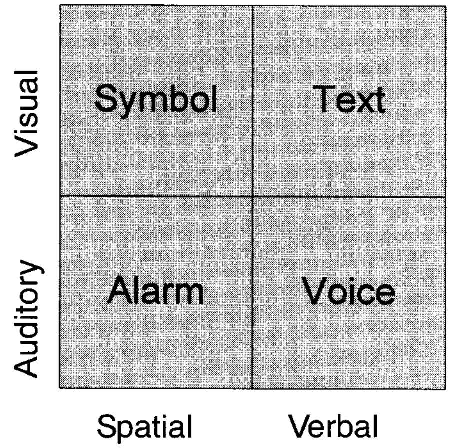

FIGURE 4.2. Examples of members in the four end cells of the box model. A simple auditory alarm tone in the spatial code is expanded into a voice stimulus in the verbal realm. Similarly, a visual symbol is transmuted to text as the change is made from a spatial code to a verbal code.

ROTATING THE BOXES

We have shown the classic representation of the Wickens formulation in Figure 4.1, but the first question we can ask is whether it need necessarily be expressed in this specific orientation, form, and structure. Can we take Wickens's original architecture and make small initial changes to provide a somewhat differing perspective? We suggest that indeed we can do so.

Processing Codes

When Wickens presented his original model, he elaborated upon the nature of the end axes of Figure 4.1 and expressed these in the form we have shown in Figure 4.2. The examples shown within each box represent specific cases of the combination of the vertical and horizontal axes shown. As we will continue to emphasize, it is these sort of exemplars that subsequently allowed usability and human factors professionals to use this conception as a design heuristic. However, let us take one step back to see this compartmentalization from another perspective.

Considering the processing code axis in greater detail, in the original formulation it lay on the base and was divided between spatial and verbal components. However, this horizontal differentiation implies a qualitative distinction between the two. But is this qualitative distinction justified as being necessarily so? We suggest perhaps not. In fact, it can be easily argued that any verbal representation can be given as an abstraction of the spatial dimension. Let us consider this in a little more detail. With respect to speech (voice), this is considered a form of verbal code. However, in reality, speech is actually the complex distribution of energy in space–time, and because we shall deal with time later as a vital element of one of the other dimensions, we might be justified in treating verbal representations as special forms of temporarily enduring spatial codes. Similarly, if the verbal code is expressed in the visual dimension, it is viewed as letters, words, sentences, and the like (or more generally, text). However, a passage of text, such as this sentence, is only a particular, convention-based form of geometric ordering of marks in a particular spatial configuration. Therefore, text is also actually a particular form of abstraction of graphic markings. Thus, if each form of the verbal code is viewed as particular, high-level abstractions of spatial codes (in reality spatiotemporal codes), then we can rotate the boxes so that this is now graphically represented as a hierarchy of such abstraction. This rotation

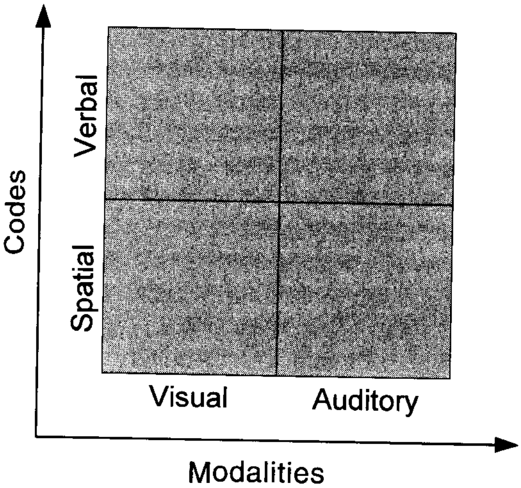

FIGURE 4.3. The box model rotated 90° to emphasize the emergent relationship between the respective codes.

(only for the left-facing "end" axes of the multiple-resource model) now appear as shown in Figure 4.3. There is, however, a secondary advantage to this rotation. The new base axis is now modality, and although it is true that different sensory systems transduce different ranges and forms of stimulus energy, their parsing into the classic sensory systems is probably more logical because there is no necessary abstraction from vision to audition and so on. The hierarchical abstraction of codes now fits appropriately on the vertical axis.

However, we have not yet reached the end of the issue of processing code. We suggest that if the verbal level is actually an abstraction of the spatiotemporal level, then there are other possible abstractions beyond the verbal. We see at least three other levels: the informational level, the symbolic level, and the meta-abstract level. Perhaps an example will be useful in differentiating these levels. Consider the United States Declaration of Independence. When approaching the document in the National Archives in Washington, DC (although the document is now, unfortunately, very faded and, as a consequence, almost illegible), it is evident that there are spatiotemporal graphic markings on the physical document itself. Furthermore, it is also evident that these graphic images are arranged in the form of (English) words. These observations are evident to *anyone* who sees the document, regardless of their ability to read or write English. However, to a non-English speaker, the words themselves, when expressed either in the visual or the aural form, are essentially meaningless. There are examples of this beyond the visual sense—for example, the tactile–kinesthetically expressed dot patterns of Braille to the uninitiated. In contrast to the non-English speaker, the individual familiar with English will find a vast amount of information contained in the document. Thus, information, which is always a combinational property of individuals and the environment in which they find themselves (Hancock, Szalma, & Oron-Gilad, 2005), is a level beyond verbal expression alone. Therefore, we now have an abstractional sequence from spatial, to verbal, to an informational level.

However, the extrapolation of codes extends even further. Continuing with our specific example, the Declaration itself is much more than simply another bit of paper. For the people of the United States, and arguably for many others around the world beyond the borders of America, the Declaration has great symbolic significance—*as an object in and of itself*. Indeed, as good designers know, items in the world created by human beings most often have symbolic value as well as spatiotemporal continuity, verbal appellation, and informational content. Thus we can add to the spatial, verbal, and informational levels an additional symbolic level. Lest anyone believe that we are absolutists about this, we do not see an exclusive requirement to attach symbology to every possible material item. In this respect, we are not equating this level of extraction to Aristotle's material form of cause. However, having ascended this far, can we go higher?

We believe that, indeed, we can go one level higher still. This level is the one we have labeled the *meta-abstract* and it is the apex of the abstraction process. Although representative of all the levels we have been discussing, the Declaration itself goes one step beyond this. It is symbolic *beyond itself as an entity*. Thus, although the physical document itself is of great (monetary) value, its true value goes well beyond any financial valuation. People can, and do, see in this document intangibles such as freedom, liberty, and hope made manifest. The exact antithesis of this meta-level representation may be seen, for example, in a German document of the Second World War authorizing transportation of Jewish individuals to concentration camps. This latter document would also have all the attributes at each abstraction level appropriate to those fluent in German. However, at the meta-level, the moral attribution is evidently very distinct from the former example, as is the origin of the motivation in its earlier conceptual form. This is crucial to understand, because it means the implications for cognition and, subsequently, reality can vary according to interpretations derived at each level.[1] The problem, of course, is to perceive and be able to attend to these abstraction levels in the context of the natural ambient environment and not simply to restrict this idea to human manufacturing alone (Hancock, 1997). Thus, in the ways we have indicated, and of course potentially in ways we have not, processing codes go well beyond the simple "spatial" and "verbal" differentiation given in Wickens's original formulation (Wickens, 1980, 1987).

At this juncture, we should acknowledge two caveats. The first is that there is no necessary reason for all objects, entities, or creations in the environment to have attributes at each of these levels of abstraction. As Freud is once alleged to have remarked, "Sometimes a cigar is just a cigar." Second, it remains unresolved as to what degree upper levels of representation are contingent upon the sensory channel through which they are first assimilated. We suspect that this sensory dependence grows progressively weaker the higher up the code hierarchy one progresses. At the highest level we suspect there is very little degree of resource differentiation, if any division exists at all. This is certainly an area that future work can address. That we can then comprehend and incorporate these new levels of code abstraction into the design of technology is a crucial insight. Through this elaboration, we can now see that the act of creation embodied from the first conceptions of design to the ultimate manifestation in actual manufacture are not "neutral" events that simply act to make an object, item, or thing (Illich, 1973). Rather, they are part of a collective enterprise in which this multiple layering of meaning and apperception play a central role in creating what we see and understand our world to be (Hancock, 1997).

With respect to the "pools" of attentional resources as Wickens conceived them, whether there is a differentiated pool of visual attention for each of these levels, separated from an auditory attentional resource pool, is a debatable issue. In our view, this issue (e.g., can one differentiate between seeing and hearing a conception such as hope?) is one that remains to be explored in much greater detail in future considerations of the nature of attention and its relation to consciousness. Hopefully, these issues will form a greater focus of a more detailed discussion relating theories of human behavior to the wider vistas of human action. We note, in passing, that our elaborations are no criticism of Wickens himself, because as a theorist he could only work with the data then at hand. And indeed, Wickens (2002) himself has indicated that his

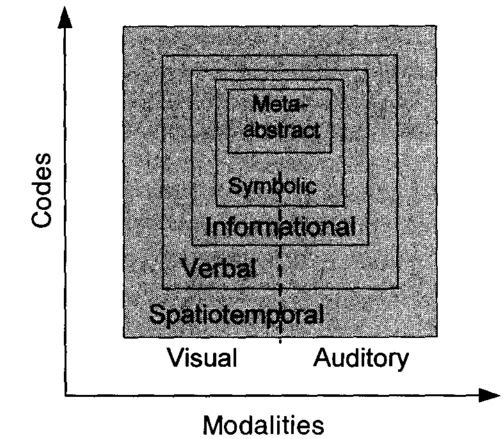

FIGURE 4.4. The processing codes revised. The codes are now presented as an abstraction hierarchy.

1980 model was based on "a sort of meta analysis of a wide variety of multiple task experiments in which structural changes between task pairs had been compared, and found strong evidence that certain structural 'dichotomies'... behaved like separate resources" (p. 162). Proliferation of the putative number of "resources" at the time that Wickens first published his model may well have discouraged then-contemporary scientists from subsequent experimental evaluation. Hopefully, future advances will explore our code extensions of the model in the way that Wickens's original postulation triggered empirical enquiry. Thus, the addition of these hierarchical code extraction levels now provide us with an adjustment to Figure 4.3 that we now show in Figure 4.4. This representation implies that not all code levels are necessarily of equivalent importance and that there is a necessary nesting of levels involved, as well.

One interesting speculation that comes from this hierarchy of abstractions concerns the notion of human language development itself. Although pictographs and orthographic symbology represent our earliest recorded history (e.g., Lascaux, and so on), speculation about early human language must, perforce, be more tentative. However, it is possible to propose that both picture symbology and subsequently print, together with spoken language, resulted from the ability to expand into the functional "space" available. This notion of "space" is somewhat different than the much more spatially and neurally constrained idea of functional cerebral space (e.g., Kinsbourne & Hicks, 1978), but the notion of a general ecological niche representing room for expansion is fundamentally relevant to both ideas. It implies that as the state of understanding grows and the pressure to increase the precision of

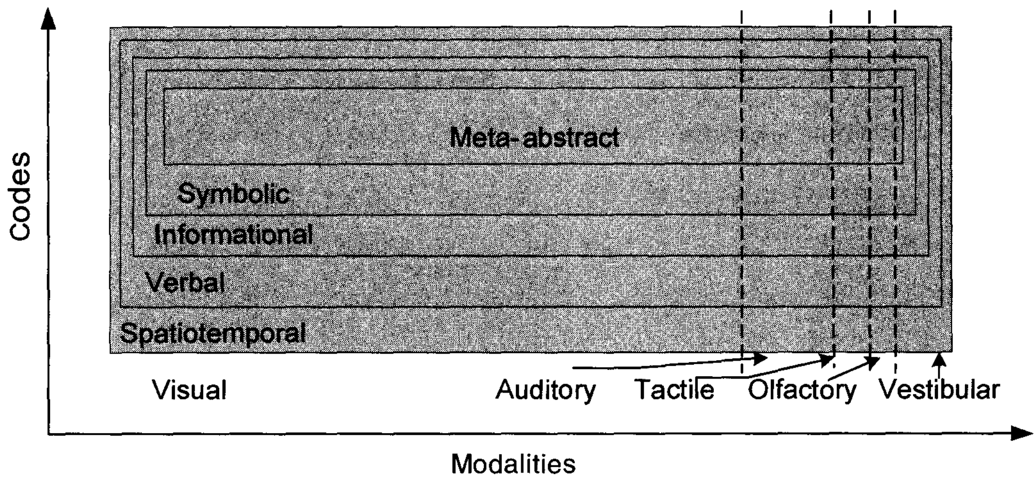

FIGURE 4.5. The elaboration of the now base modality axis combined with the processing codes' abstraction hierarchy.

communication increases, another level of the hierarchy is exploited and/or created. It is feasible, then, to suggest that human–machine interaction forms the basis for the next level of abstraction, and that human factors can be the language to interpret that next emergent abstraction (Hancock, 1997).

Coding levels are never completely crossed, in a factorial sense, with modality. In Wickens's original formulation (Fig. 4.1) the separation between the modalities was maintained only for the earliest stage of processing. Thus, one would expect the spatiotemporal, verbal, and perhaps informational levels to be used predominantly in the encoding stage, where the input data are frequently differentiated by modality. However, the symbolic and meta-abstract levels would be likely to be engaged largely at the central processing stage. One would therefore not necessarily expect to encode "hope" along different modalities, but encoding of the letters or sounds would be differentiated at that level. An area in need of both theoretical and empirical exploration within the multiple-resource model is how data from each modality is integrated into information for central processing. Such theorizing is underway (Hancock et al., 2005), but integration within the Wickens conception is needed to clarify the process of transition between the "boxes," especially those represented on the processing stage axis.

Processing Modalities

Having considered processing code, let us now consider the new base axis, which is processing modality. In identifying the visual and auditory modalities, Wickens specified the two major avenues through which individuals assimilate sensory information. However, this does not exhaust the number of possible modalities. There are obvious extrapolations to the tactile, olfactory, and kinesthetic senses, whereas others such as thermal sensation and pain can also be identified. It is important to note that the processing modality axis is *not* subject to the potential for an infinite regress, but rather is limited to the known array of sensory transduction systems. In human beings, vision dominates (Sivak, 1996). Thus the size of the boxes should be adjusted to reflect this dominance of, and contribution of, each particular modality. This adjustment for importance is illustrated in Figure 4.5. Clearly for different organisms, the relative contribution of each modality changes—the ascendancy of olfaction in tracker dogs being perhaps a pertinent example (Budiansky, 2000). Because we eventually seek to conclude here that the derived universe of extended Wickens boxes actually composes the model from which any organism derives its own personal "reality," it is important to understand that there are significant cross-species differentiations with respect to how these resources are assembled. That reality therefore also varies between individuals within any single species, as well as across species, has not escaped our notice. More could certainly be said about the ordering, the impact, and the integration of the respective sensory systems, and the neuroscience of these capacities would well inform a "corticotropic," rather than box, representation. Again, this opens a fruitful vista of opportunities through which to seek an integration of the elaborated resource model with the ongoing efforts in neuroscience to try to plot the geography of consciousness.

Processing Sequence

Initially it may appear that the temporal axis that subsumes the processing sequence is somewhat less contentious and less amenable to expansive discourse than either processing code or processing modality. However, this is not so. Indeed, such is the complexity of the way in which the temporal nature of processing occurs that we can provide only a brief commentary on this issue here, but see Hancock and colleagues (2005). It is necessary to divide this sequence into preprocessing, processing, and postprocessing stages. Initially during the preprocessing stage, data are simply embedded in the range of distributed environmental energy. This range extends across the electromagnetic continuum and is a priori independent of any particular transducer (observer). The energetic representation ascends to *information* only within the sensory transduction range of the exposed individual. It is among these *latter* expressions that a stimulus array is available to be selected (Gibson, 1979). The principles by which individuals select among a number of possibilities are still being distinguished; however, it is clear that attention is the key process in such selection. Attention is implicated not only in information selection, but with modulating feedback effects from response. It has been suggested that information flow rate needs to be modulated in the same manner that other physiological systems require stable rates of stimulation (Hancock & Chignell, 1987). This form of sensory balancing requires the "narrowing of attention" when in overloaded situations and the "broadening of attention" when experiencing comparable levels of underload. Wickens (2002) himself acknowledged that his model only accounts for overload and that underload is not included in the original formulation. This is a crucial omission because, by logic, half of the picture is left out if underload is neglected.

For most applied contexts, it is likely that the original Wickens model, which consisted of verbal and spatial coding, is sufficient, and therefore this matrix is still effective in the majority of applications. However, the formulation fails when higher levels of abstraction are required. The operators need both *to acquire these higher levels of abstraction* (via training and experience) and *to find value in using them*. Under stress, operators choose to process information via the lowest code level (spatiotemporal and verbal) and therefore are faster in processing but also more error prone in response (Hancock & Szalma, 2003). The extended model can account for underload and variations in workload. For instance, underload may tax the lower levels via the lack of stimulation. The operator adopts a top-down strategy to self-regulate. This observation implies that operators actively seek to regulate resource levels, not merely have them just react passively to external demand. Attending to higher levels in the abstraction hierarchy implies more attention to internal processes, and operators are again more likely to miss the more fundamental spatiotemporal and verbal cues.

It therefore seems unlikely that optimal real-world design requires visual processing to occur in complete silence, or optimal auditory processing to occur in the dark. Indeed, redundancy and cross-talk between channels appears to be an important design aspect and implies crucial permeability between Wickens's mode differentiations to generate a full reality. Post-processing and feed-forward and feedback loops provide control on the whole sequence and imply the future selection of stimuli and decisions to be made can be largely predicated on past actions because, as noted elsewhere, memory is primarily for the future (Hancock et al., 2005). The responding component of the processing stage may also be presented in a hierarchical way. We currently propose the two lower spatiotemporal and verbal levels; however, higher levels such as self-regulation and effort can also be suggested. Further research is required to determine the abstraction levels of responding. As this discussion progresses, the box model appears to become more of a streaming matrix from perception to action, rather than a tank-like repository of "pools" of attention (Fig. 4.6).

Response Modes

Minsky (1986) opined that the model of reality that connected consciousness was actually an emergent property of what he called a "society of mind." By this he meant that the unity of consciousness was a functional illusion that only retained a phenomenological wholeness as the byproduct of the consensus of multiple contributory processes. If we accept this conception, it is not too much to see the current extensions of Wickens's boxes as the psychological expression of these respective mind's "citizens." True, one can have the same functional description of this interaction via cortical areas at the neurophysiological level, but it is our

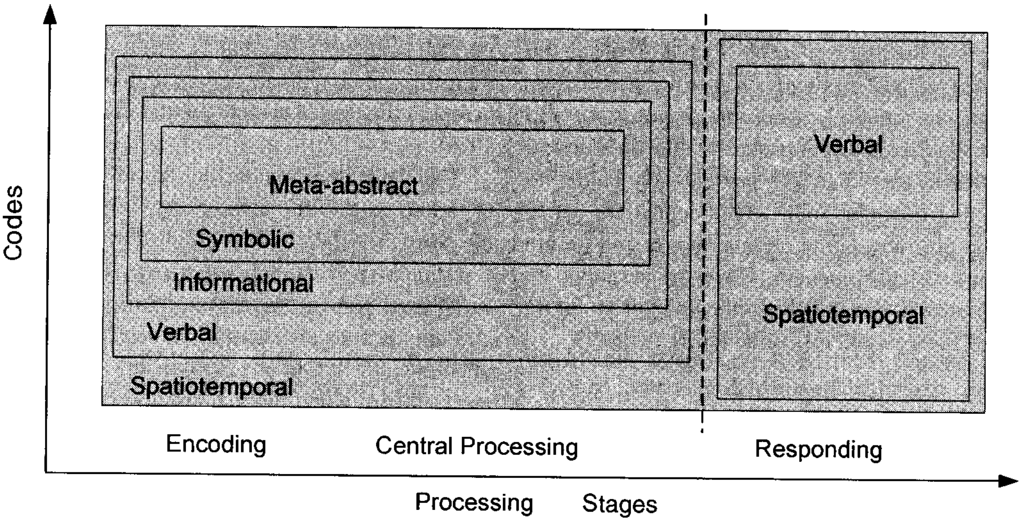

FIGURE 4.6. The general elaboration of the side of the rectangular box model, omitting the dimension of the processing mode for the sake of illustrative convenience.

contention that the box model is the foundation of its psychologically expressed companion. In the same way that Penfield and Rasmussen (1950) distinguished a *sensory homunculus*, we believe that the elaborated Wickens model becomes an *attentional homunculus* (but does not bear the philosophical burden of the naive interpretation of a homunculus). The sensory homunculus differentiates various parts of the body on the basis of innervation level, yet retains the idea of the body as a single, "whole" entity, so we believe the "attentional" homunculus performs the same function, but in this case the phenomenological whole that is experienced represents the fundamental sense of "reality." In this way, the elaboration of the original Wickens model is much more than a mere extension to a notion of attention, but might be more fully appreciated as a significant foundation of consciousness. The issue of time remains very central to this elaboration (Hancock & Szalma, 2005).

The Issue of Explanatory Degrees of Freedom

Earlier in the chapter we promised to return to the issue of explanation and the degrees of theoretical freedom problem. With n + 1 degrees of freedom, one can easily explain any system with only n degrees of freedom. This hardly constitutes an "explanation," because all one has done is to introduce a slightly more complex description of the same system, merely expressed in another language. All of the great discoveries of science have been those that accounted for large swaths of the Universe with expressions of breath-taking simplicity and very few (if any) degrees of freedom. Achievements beyond this become the realm of genius. With respect to the multiple-resource notion, it is evident that the addition of an increased number of resource pools constitutes greater explanatory degrees of freedom. The question one has to ask is whether the larger range of findings that can now be accounted for is worth the trade that has been made. This issue lies not merely at the heart of theory itself; it has a direct impact on the way in which theory is used in real-world situations. There are some advocates of the "wrong and strong" school in application areas. That is, such individuals acknowledge that a theory is not right (and they may well be justified in this in that no theory is ever right, and even scientific laws are sometimes flawed) (Hancock & Ganey, 2003), but it contains sufficient specificity so that effective approximations of behavior can be derived and used. This is also very much an engineering staple in that engineers do not seek to explain the whole world, just sufficient amounts of it to be able to effect the change they desire safely and efficiently. From this perspective, the inflation of resources from one to many is only justified if an unequivocal benefit is evident. It is our opinion that Wickens's conception justified this expansion and thus did not illegitimately cut Occam's Razor. We are far less sanguine about our own formulations. We have suggested here several extensions to the resource conception, the prime effect of which is to expand the number of potential resource pools enormously. Although these may be intuitively reasonable proposals, we also begin to deal in conceptions such as the symbolic and the meta-abstract that will prove much harder to define and quantify. Such recommendations act to blur the precision of the original notion and we are very aware of this concern. However, resolution to such issues will certainly be forthcoming from future inspired theorists and experimentalists.

SUMMARY AND CONCLUSIONS

Despite valiant efforts, the conundrum of attention as posed initially by James (1890) still remains to be resolved. In some ways, the show has now moved on from the original Wickensian notion of the late '70s and early '80s. Now, new, largely neuropsychological conceptions have been promulgated and popularized. However, in many ways, what seems to represent progress is often simply the same ignorance expressed in another jargon or, more properly, another paradigmatic language (this being the fate of most human knowledge, of course). Wickens's elaboration of attention was actually another in a long and tried tradition in psychology (especially the energetic aspects of psychology) in which a unitary concept (e.g., attention, IQ, arousal, fatigue, memory, and so on) has been broken into component elements that better explain the nuances of the empirical landscape, but often only at the expense of proliferating explanatory degrees of freedom. Eventually, this leads to a fractionation and balkanization that leaves theorists unhappy and experimenters confused and frustrated.

Attention is not all of consciousness. The recent pragmatic expression of the operational face of consciousness—situation awareness—has been defined as the external face of consciousness directed beyond the self (Smith & Hancock, 1995). We know consciousness is more than attention, because evidently stimuli find their way into long-term memory without attention necessarily being directed to them. These characteristics of memory cause surprise when attention is drawn to their subtle penetration (Schacter, 2001). However, much of what the individual recognizes as reality has to be conveyed through the refined portals of attention, and much as attention can be divided between the different elements of the external and internal landscape. Fortunately, we do not experience these divisions as separate phenomenological realities, except in the case of evident mental illness (Gardner, 1976).

That the sensory homunculus describes innervations of various parts of the sensory cortex does not negate the experience of the body as a unified whole. Similarly, that stimulus perception by different sensory modalities in different parts of the sensory environment occurs also does not negate attention or reality as a unified phenomenon. As Gibson (1966) rightly noted, one can erect a theory of perception based upon the exceptions or the illusions, but such a theory would make a very poor heuristic for any organisms' survival or its prosperity in any environment. Similarly, one can believe in diverse attentional pools and the nonconscious processing of stimuli, because the data support such contentions, at least to some degree. However, reliance on them would make a poor guide for designing any practical technical system with which an attentive human could have to interact. In the end, the Wickens box model has served to guide us toward a greater enlightenment on the issue of attention. In recognizing his unique contribution, we now need to proceed more vigorously toward theory and design based upon what humans *should* do, rather toward a future based upon economically driven, efficiency-inspired mandates about what human beings *can* do. If this transition can be realized, then our science will have truly served its ultimate purpose and attention, fractionated or not, will have been directed appropriately.

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Note

1. Parenthetically, it introduces a very important but complex argument concerning the nature of entropy. For the physicist, the transformation of both documents,

if someone burned them, would be exactly equivalent. As is evident from our discussion, for the psychologist, for the sociologist, in fact for the everyday individual, these respective acts would be regarded very differently indeed.

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