# Whither Workload? Mapping a Path for Its Future Development

P.A. Hancock(✉)

Department of Psychology, and Institute for Simulation and Training,
University of Central Florida, Orlando, FL 32816, USA
Peter.Hancock@ucf.edu

**Abstract.** I present a number of looming barriers to a smooth path of progress for cognitive workload assessment. The first of these is the AID's of workload (i.e., association, indifference, and dissociation) between its various reflections (i.e., subjective, physiological, and performance measures). The second is the manner in which the time-varying change in imposed task demand links to the workload response, and what specific characteristics of the former drive the latter. The third is the persistent but largely unaddressed issue of the meaningfulness of the work undertaken. Thus, does interesting and involving work result in lower workload and vice-versa? If these foregoing and predominantly methodological concerns can be overcome, then the utility of the workload construct can continue to grow. If they cannot be resolved then workload assessment threatens to be ineffective in a world which desperately requires a valid and reliable way to index cognitive achievement.

**Keywords:** Cognitive workload · Neuropsychological assessment · Future challenges

## 1 Introduction

From a radical materialist perspective, cognitive workload is an emergent property of the active brain which is tasked with a mission of survival in an incompletely specified and under-explained world. While I do not share such a philosophical stance completely (Hancock 2015),[1] I am persuaded that this is the most promising foundation from which to take our next pragmatic steps along the path of workload's journey. And of course, this voyage is not one simply of philosophical dispute and debate. Rather, there are many, much more practical everyday issues involved here in solving the problems of cognitive workload assessment. Consider only two examples. First, how do we measure and remunerate cognitive work? We generally accept that in our modern world the cognitive dimensions of work have grown and continue to grow across the global society. We also know that for an economic system to flourish we

[1] I am, rather, a real illusionist. That is, I subscribe to the existence of matter but believe all perceived patterns in such matter are iatrogenic illusion. Such illusions are embedded in the standard narrative of living existence, the final illusion of which is time. As a tool, time can be a useful servant but a poor master.


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have to be able to specify what connotes value. So how we measure, index and reward cognitive achievement is not a question simply for the hallowed halls of academe. Actually, it is front and center on the Wall Streets and Main Streets around the world. A second example of such practical concerns revolves around the issue as to how much cognitive load can one individual, or team of individuals sustain before they become incapacitated and/or unable to respond effectively. Such a concern is central to many systems which inevitably have to place high demands on these operators in both normal and emergency situations. Knowing these thresholds and 'redlines' may well help in alleviating incipient disaster. So, while we behavioral scientists research and discourse about the fundamental nature of cognitive workload, the world awaits. Whether it realizes it or not, or acknowledges this dependence explicitly or not, greater society needs reliable and valid methods to assessment workload.

As an emergent brain state, workload does not stand alone. It has a number of closely related conceptual cousins. Stress, anxiety, and fatigue among many others are each socially recognized cognitive attributes about which sufficient people express sufficient agreement so that we persist in considering them concepts of interest and even states of objective reality. Alongside these 'energetic' descriptors sit allied terms such as (i) attention (e.g., Wickens 2002), (ii) situation awareness (e.g., Endsley 1995) and (iii) consciousness (e.g., Smith and Hancock 1995) each of which similarly describe specific, discrete aspects of emergent states of mind. It is one of the central conundrums of all psychology to distill how each of these concepts relate one to another, and which possess precedence in the materialist cause and effect phenomenology. Questions intrinsic to this multi-dimensional Venn diagram populate our own particular area of scientific discourse since, as a group, we are primarily concerned with understanding human behavior. Thus, questions like, do you have to be conscious to possess situation awareness? Can we pay attention to our own stress to the exclusion of the demands of the greater environment? And most trenchantly for the present discussion, to what degree does attention mediate and/or moderate the experience of workload? Such puzzles tend to concern us particularly. We can all generate potential answers to the foregoing interrogatories, but the degree to which they apply to one single individual (such as yourself for example) and can then be expressed across the whole human population, is one of the primary intellectual challenges that fuels our specific scientific enterprise. And again, the world is watching, as evidenced by almost any of the contemporary, lurid newscasts which tragically revel in the most recent and noteworthy systemic failure in which shortfalls to human response capacities are invoked as the primary causal mechanism (e.g., the ubiquitous, human error).

Conceptual foundations are important of course. However, in the present work I want to explore three very specific and very practical issues which represents barriers to our immediate road to understanding. The first is concerned with what happens when we witness divergent information from our various workload measurement techniques and sources. That is, what happens when differing reflections of cognitive workload disagree with each other. Here, the empirical picture can quickly become very confused and confusing. Thus, I look to bring some order to counteract this confusion and offer a descriptive taxonomy which provides an initial parsing of the panoply of the differing possible patterns that may be observed. Second, I want to offer up some potential reasons for these problematic association-insensitivity-dissociation patterns and some

avenues of potential progress by which we might recognize systematic resolutions. Finally, I want to consider the thorny issue of the meaning of work (and see Hancock 1997). With respect to the latter concern, we have to date, in large part, treated task demand as some rather antiseptic and sterile conception. Either we choose prototypical 'psychological' tasks (e.g., a Sternberg memory task) and then claim that results derived from such experiments somehow generalize to actual work contexts, or we explore some specific, complex (often military) mission whose generality is highly limited. Even for these two putative 'testbeds,' the value and meaning of the work itself can vary wildly. The source of motivation in such research investigations is often extrinsic to the task (e.g., course credit, TDY completion). The nature of the work undertaken, whether adverse and imposed, or pleasant and sought by the individual, is rarely factored into workload assessment. Here, I want to argue for the important, if daunting, inclusion of this dimension of meaning into our future deliberations. I conclude with some observations concerning specific future avenues of progress and remarks about the continuing importance of workload, even in a world that is threatened to be overrun with automation and autonomy (Hancock 2014; 2017).

## 2 Associations, Insensitivities and Dissociations: The AID's of Workload

One of the greatest challenges to be faced by the evolving workload domain concerns the degree of convergence, and/or divergence, and/or insensitivity across the multiple approaches that have been employed to measure it. The three primary reflections of workload have traditionally been couched in terms of (1) primary task performance (2) subjective perceptions and (3) physiological responses (Hancock and Meshkati 1988; Meshkati et al. 1989; Moray 1979). Each of these respective categories has, contained within it numerous possible elements (i.e., specific methods such as, TLX, fNIR, Error Rate, etc.). Thus, primary tasks are typically indexed by representations of Efficiency, Error, Time, etc. We have extensive experience with response speed and response accuracy and have reason to believe that we have a solid foundation in such forms of assessment (see e.g., Fitts 1954; Hancock and Newell 1985). Similarly, we have some decades or more experience in eliciting subjective perceptions of events. Finally, and to a degree more recent, we have vastly increased our armory of physiological assessment techniques. This increase is especially the case as new brain imaging capacities have come on line. Let us then examine the patterns that can accrue when we employ the full array of these measurement techniques to attack any particular problems to hand.

To accomplish this, let us imagine for a moment, a fairly straightforward experiment. Across a defined period of time, the imposed demand of some particular task is sequentially increased. Perhaps this is a driving task with the driver going from a quiet sub-urban backwater onto an urban arterial and then onto a crowded, multi-lane freeway. The context, pro tem, is not constrained and so you are free to imagine your own example from your own specific domain if you wish. Now we look at the outcome workload response. Here, we expect to see primary task measures show some form of systematic decline, especially as the demand progressively increases. Perhaps the

variability of steering, reflected in lane positioning, goes up in the case I have cited. Perhaps response time to unexpected ambient events slows and/or exhibits greater error. Although the driver may adapt to such imposed demands, to the degree possible, we might well envisage that eventually some reflection of the progressively increasing task demand will become evident in changes in primary task response efficiency. Now imagine that we ask that driver for their subjective assessment of this same progression. We might well anticipate that on the leafy back roads they experience little perceived workload but that it would increase with the transition to the arterial roadway and then subsequently again to the freeway experience also. This direct mapping between the primary task response and the subjective assessment is an example of what I have called *association* (Hancock 1996). Now, suppose we also had the opportunity to measure certain established physiological reflections of cognitive load and that these measures also confirmed that the lowest workload occurred in the lowest demand and the highest workload in the highest demand condition. This would be an example of what I term here, *double association* (see Fig. 1). In workload terms, so far so good. However, such associations and especially these double associations do not always occur. In fact, such associations appear to be far from ubiquitous.

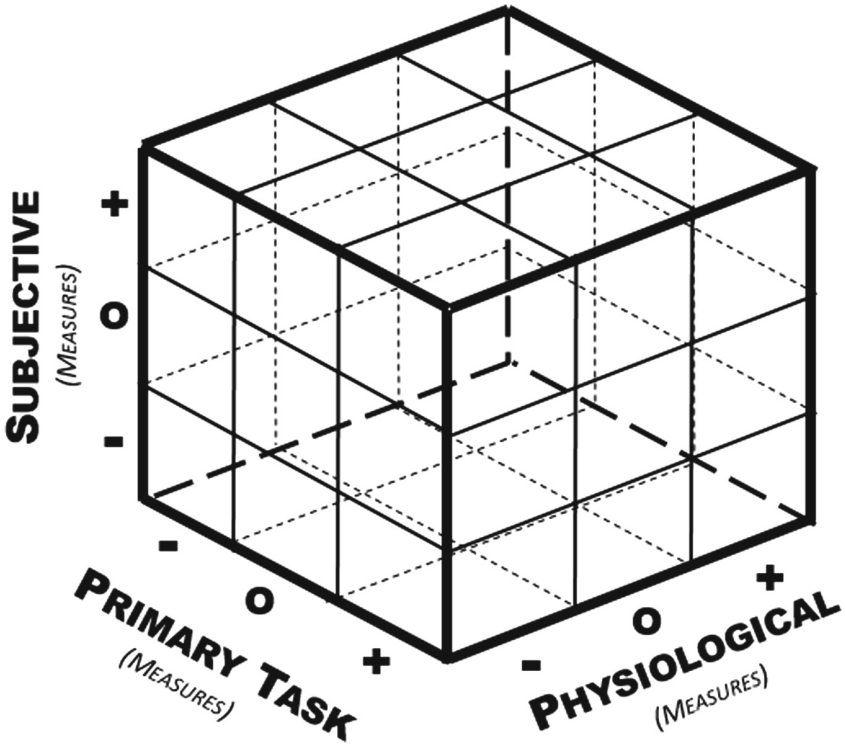


**Fig. 1.** The response to imposed task load by the three primary measures of workload, viz: (i) primary task performance, (ii) subjective response, and (iii) physiological processes. Patterns of association, insensitivity, and dissociation can be plotted within the identified taxonomic matrix.

So, let us now take an intermediate case. Here again, the degradation in primary performance efficiency tracks along with the increasing task demand, but now when we ask people for their subjective assessment, they report no difference between the three driving conditions. This is an example of what I have termed *insensitivity*, and to be explicit, this case specifically it refers to *subjective insensitivity* since the expectation is that both primary task performance and subjective response will track imposed task demand. While there may be, and indeed are, many reasons why the link between the task response and subjective perceptions of workload fail to agree, let us leave explanatory constructs to the side for the moment and return to them later so that we can complete the full descriptive picture. You might very well note, however, that in this latter case of subjective insensitivity we still retain that other arrow in our investigative quiver in the form of the aforementioned physiological measures. Let us further suppose here that these latter measures now accord with the pattern of primary response, but which relationship do we believe? Do we assume a form of scientific democracy and go with the majority vote? But this may not be advisable, for after all, as Gilbert (2005) has noted, in many ways it is the subjective reaction of the individual which is the principle measure of concern since they actually compose the very experiences of life. It leaves us in a methodological (and theoretical) quandary. But there are further descriptive patterns yet to consider.

The illustration in Fig. 1 shows responses to imposed task demand by the three primary measures of workload, viz: (i) primary task performance, (ii) subjective response, and (iii) physiological processes. As a result of increasing task load, primary task performance can show an improvement (+), stay the same (o), or decrease (−). Similarly, subjective responses can indicate that with increasing task load the individual can think the task is harder (−), the same (o), or even easier (+). The same pattern adheres to physiological reflections (see Fig. 1). When workload responses track to external task load we have *association*s, when reflections of workload do not change with task load we have *insensitivities*. Finally, when workload measures contradict the increase in the externally imposed task load (e.g., the task load increases but the operator reports that it is getting easier), then we have *dissociations* (see also: Yeh and Wickens 1988). Doubled associations, insensitivities and dissociations are also possible as we shall see.

Now suppose, for the sake of consistency, that primary measures still directly co-varied with what we have previously identified as increasing task demand[2]. But now, the driver reports progressively less subjective workload, even as the primary tasks measures indicate exactly the opposite. This represents an example of what I have previously termed *dissociation* (Hancock 1996; see also Yeh and Wickens 1988). It is not enough here that these differing reflections of workload do not agree (for that pattern can also include insensitivities). Rather, they must actively contradict one another. We might again choose to appeal to our suite of physiological reflections (if we have taken them) as some form of arbiter, but in this specific instance, they provide

[2] Of course, exactly how we determine, a priori, what represents increasing 'task demand' is itself an issue fraught with the problem of subjective assessment. For the present example, I have based the arguments on an assumption of increasing demand but need to acknowledge the potential flaws in this foundation.

no determining pattern. I refer to such collective disagreements as *double dissociations*. These cases provide very problematic outcomes for our science. Of course, they are not so prevalent in our experimental library as might be expected from pure random distributions of outcomes. Understandably, positive associations are reported much more frequently that these other patterns. However, there may well be a very considerable '*file-drawer effect'* in operation here. That is, we all have the tendency to report the positive results. We also have a tendency to report consistent results, not through some malevolent motive, but through the natural tendency to seek a coherent narrative for our immediate findings. Further, in the editorial process, we are often encouraged to provide a concise results section in which null associations (e.g., insensitivities) are often 'lost' or excised in the process.

Nor is this the worst case of dissociation or insensitivity. Imagine for a moment that you have taken several reflections of each of the three major methods. You have recorded both TLX and SWAT for subjective reflections, HRV and fNIR as physiological measures, and time and accuracy as primary task response characteristics. Now suppose that you encounter dissociations and insensitivities *within* each of these three orders of measure. What do you do? How do you pick and choose between the intra-method dissociations and insensitivities and the inter-method dissociations and insensitivities? And, of course, some of the intra-method disagreements will now negate some of the inter-method disagreements. This represents a conceptual, methodological, and even moral conundrum. As a conscientious researcher, which do you choose? It is why I refer to this whole concern as the AIDs of workload. Of course, as is clear from the foregoing observations on inter- and intra-method conflicts, the illustration in Fig. 1 underestimates the complexity of this overall issue. While it does not feature the inter- versus intra-method concern, critically, it does it illustrate the perennial and problematic issue of time. Hence, all such patterns of association, insensitivity, and dissociation are contingent upon the time-scale at which they are elicited. What are associations in one selected epoch can become dissociations in another. This is particularly the case with punctate or monetary performance measures (e.g., reaction time) compared to, for example, subjective measures which are often summed (in memory) across a much longer period. As we shall see in the coming discussion, there is strong reason to believe that each of these methods (and each of their component elements) possess their own inherent time-scale and that certain, if not many, of the associations, dissociations and insensitivities are contingent upon such temporal differences. And to pile pain upon pain, I now have to return to the vexing issue of context.

The reader will recall that, pro tem, I suspended contextual considerations. I did this so that we could consider a full (if static) taxonomic description of all the general AIDs patterns that can be experienced. However, I cannot pass over the issue of context without at least some words of caution. There are many ways in which the context of operations influence the workload response beyond the primary performance demand alone. Humans are no simple linear transducers of imposed (input) loading (Hancock and Warm 1989). Rather, their non-linear responses are complex and time-varying. Efforts to understand contextual influences, in all their diversity and profundity has, in our science, led to a more ready focus on the 'systems' approach to practical problem resolution (see e.g., Carayon et al. 2015). In respect of such 'systems' perspectives,

perhaps one of the primary, proximal concerns here revolves around the adaptive capacity of the exposed individual. As I noted earlier, to a degree externally imposed cognitive task demand can be absorbed by the inherent buffering capacity of the engaged respondent with little or no overt evidence of change. To this extent, in the middle ranges of externally imposed task demand, it is reasonable, at least a priori, to hypothesize no significant change in any reflection of cognitive workload. Thus, in driving a vehicle, which is predominantly a satisficed task, we may register no extra variation in lane position, no overt change in throttle behavior, and even exhibit capacities to respond to multiple tasks at modest levels of roadway demand without any clear decrement. Drivers themselves may feel no different, and measures such as heart rate variability will also exhibit no significant change with minor variations in imposed task demand. This evidence of workload insensitivity to putative changes in objective, externally imposed task demands does not then mean the individual is oblivious to, or careless of, the task in front of them (and see Hancock and Caird 1993). It simply means that the demand is insufficient to disturb what has been traditionally identified as homeostatic balance. The simple fact here is that there is quite a large range of externally imposed demands that will not induce workload changes in our grosser measures. It may even be difficult in signal to noise terms, to pick up even minor response variations via even much more sophisticated neurophysiological techniques. Thus, the very assumption of a baseline of association is not necessarily a simple or straightforward one. Being enmeshed in this forest of methodological mysteries, can we find a systematic path forward? I think there is reason for hope that, in this case, we can.

## 3 Dimensions of the Workload Response

In the battle to increase our comprehension of, and use of, cognitive workload measures however, we should not seek to engage all of our forces on all fronts at the same time. We need a road map for progress, but this does not mean dawdling along the path to gorge on the putatively attractive "low hanging fruit." What we require is a principled exploration of the strengths and weaknesses of the respective tools we possess. One important step along this path can be achieved by evaluating the respective properties of the workload signal. Again, for illustrative purposes, I have shown this in Fig. 2. Here, an operator's response proves to be a combination of certain intrinsic underlying rhythms (both acute and chronic) which are then adapted to the time-varying environmental presentation of information. This compromise between internal and external states is periodically updated as the individual seeks to calibrate their response to the external demands that surround them and the goals that they themselves possess. This action-reaction synthesis forms a general picture which acts as an over-arching framework for the driving influences which are then more fully specified in Fig. 3.

Figure 2 shows the compromise then between certain intrinsic operator rhythms, which are driven by first, the internal variations and second, the imposed demands of an external environment. Each of these have been expressed as a function of information rate. Since intrinsic rhythms are overwhelmingly dealt with by implicit processes and

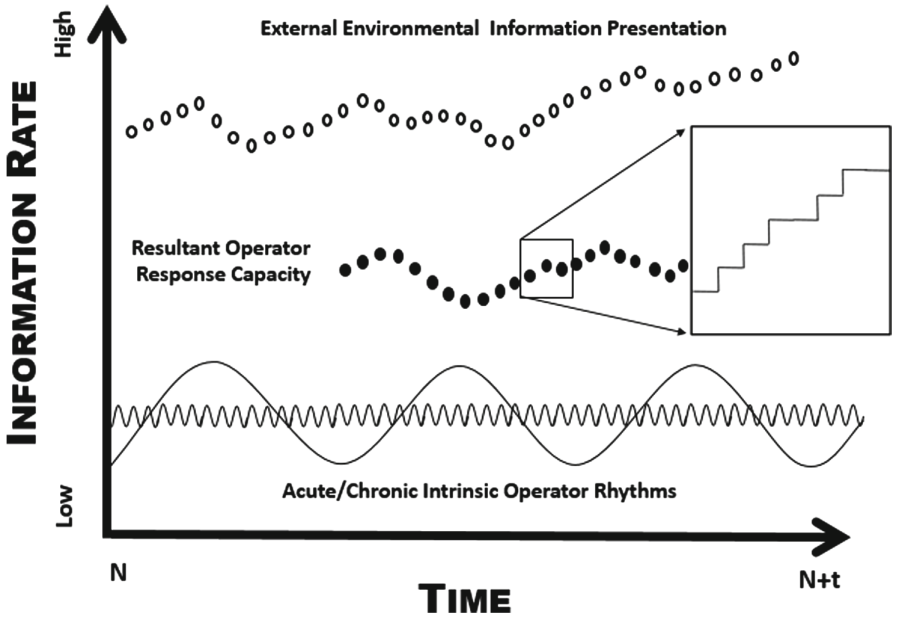


**Fig. 2.** Compromise between certain intrinsic operator rhythms driven by internal variations of differing intrinsic frequencies (rhythms at the bottom of the illustration), and the imposed demands of an external environment (shown at the top of the illustration). The outcome is the resultant, momentary operator capacity

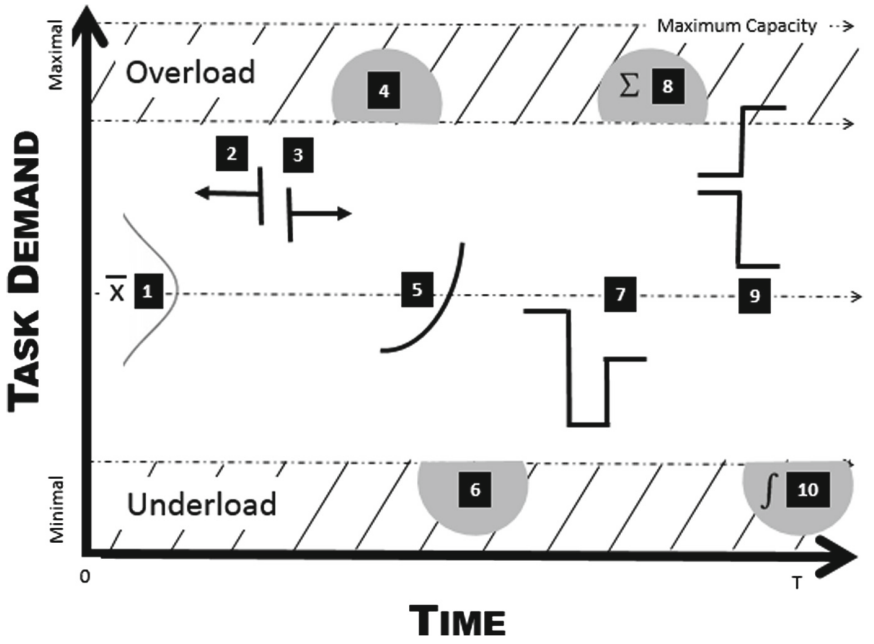


**Fig. 3.** Some of the major demand characteristics that feature in eliciting workload response.

are relatively regular in nature, they provide little in the way of explicit and formal information (surprise). In contrast the external environment provides constant surprise and the actions of the operator often actively seek such an important sources of novelty and process it to the limits of their own individual capacity. The window in the illustration features the step-wise nature of such up-dating processing as iterative epochs of demand are resolved and updated in memory. Based upon the forgoing general conception, we can now begin an examination of a number of potential triggers of the workload response. Each of these are contingent upon the changing nature of dynamic task demand. I have provided a limited number of examples of these triggers, sufficient to engage discussion, but not so many as to exhaust it.

### 3.1 Trigger 1: Standard Statistical Properties of the Overall Pattern of Demand

We can begin with the typical and traditional reflections that we have used. These are composed of the standard statistical (moment-based) representations of demand distribution. I have shown these as the mean and standard deviation, denoted by Carayon et al. (2015) in Fig. 3. It may be that cognitive workload responds to any one of these single moment of the distribution (e.g., mean, SD, skewness, kurtosis, etc.), or it may be that workload responds to a concatenation of more than one of these together (e.g., coefficient of variation) which thus prove influential. Our knowledge of these influences represent the largest body of reported understanding at the present time. But note here that each of the cited distributional moments are time dependent. That is, their absolute values co-vary with the time epoch over which they are recorded. We believe in trends such as 'regression to the mean,' indicating an assumption of stability across time or multiple observations. However, as regards to determining what specific element of each statistical moment underlies the workload response we may have to look further than such aggregated data to moment by moment response.

### 3.2 Trigger 2–3: Prospective of Retrospective Demand Patterns

What has begun to receive more experimental focus alongside the traditional mean and standard deviation scores are the influences of retrospection (Fitts 1954) and prospection (Flach and Voorhorst 2016). The former effect is a reflection of the influence of memory. We might take it as evident that human beings are influenced by their memory but there are powerful theories of human performance (e.g., signal detection theory) in which the effects of memory are compartmentalized. My protestation here is that both immediate (acute) experience and prolonged (chronic) memory contents each have effects on the perceived workload of the moment. Since retrospection is thought to play an important role, so prospection also exerts potential influences. Each of these effects (Fitts 1954; Flach and Voorhorst 2016), can be envisaged as reflections of hysteresis. Such hysteretic effects have been the topic of a series of recent investigations (see Jansen et al. 2016; Morgan and Hancock 2011; Prytz and Scerbo 2015). These studies demonstrate, generally, that the remembered past and

prospective future, experienced by the individual, each exert significant effects upon the current level of cognitive workload. Such tendencies have been explored previously (see Hancock et al. 1995) but it is only now that a more systematic body of evidence is emerging. A strong step toward progress in workload research would be to generate a much fuller comprehension of these temporally distal influences on momentary reactions.

### 3.3 Trigger 4–6: Effects of Peak Experiences

If the memory of past events in general is pertinent to the momentary experience of workload, it may well be that especially meaningful memories (or prospective anticipations for that matter) disproportionately affect the summed experience of workload across a particular interval of performance. We see evidence of this in some of Kahneman's work on pain perception during surgical procedures involving partial anesthetization (Kahneman 2011). By controlling incidents of peak pain, the overall experience is rated as less aversive than when some moments of excruciation are permitted. The analogy with workload, expressed in trend (Gilbert 2005), suggests that minimizing such peaks of overload could reduce the overall workload reported. Precisely whether this amelioration is a good thing in relation to operator assessment in mission critical situations is open to discussion. For example, it might be misleading to underestimate exactly how arduous a particular task is solely by altering or manipulating these rare 'peaks' of demand. Those designing such missions or tasks in the future might then be misled into under-estimating the workload experienced. However, such minimization may be valuable for mitigating some longer-term adverse health effects of high workload. The principle here, which applies to overload, is presumed to also be reflected in epochs of underload (Hancock 1997).

### 3.4 Trigger 5–7: Sensitivity to Rates of Change

One of the more well-established principles that we do have in the behavioral sciences is that humans frequently prove more sensitive to change rather than the absolute level of a stimulus array. If we translate this principle to the way in which task-load and cognitive workload are linked then the rate of change in demand may be more influential on perceived load than any stable, absolute level (e.g., mean demand). This rate of change characteristic is shown as (Hancock 1996) in Fig. 3. This curve is meant to be representative of all such differentiates, including all rates of change (e.g., curve acceleration) also. Of course, many of these dimensions (Carayon et al. 2015; Fitts 1954; Flach and Voorhorst 2016; Gilbert 2005; Hancock 1996) follow or replicate descriptions of tracking behavior in motor control. However, for cognitive reactions, the association is rather less intimate since many imposed tasks are more punctate in nature. In terms of such discrete changes in demand, the step function shown in Hancock (2014) is representative of all such shifts in demand. This might, for example, be the equivalent of adding a secondary or even tertiary task in driving. Such things as answering a phone or responding to GPS instructions occur as momentary variations in

task demand. In general, such demand profiles alter in the form of a square wave, rather than a continuously varying analog signal such as the primary demand of vehicle control which is, of course, a tracking task itself.

### 3.5 Trigger 5–7: Consciousness of Challenge and Recovery of Stability

In the same way that perceived workload may be sensitive to 'peak' demand (or of 'peak' underload) so it may be the absolute number of such memorable experiences in any one performance session (Hancock 2015) that represents the key value that ties perceived workload to imposed task load. Further, it may well also be where the level of stability is established following any demand perturbation that is of prime importance (Hancock and Ergonomics 2017). Lastly, of the present examples I have illustrated (see Fig. 3), it may be the totality of the time spent in acute underload or acute overload which proves critical for the mapping between imposed demand and experienced workload (Hancock and Caird 1993). As noted, these ten instances are examples only and do not represent an exhaustive listing (and see Longo 2015). Yet, some further comments are warranted. Firstly, the natural and intrinsic time-scale of each of the varying methods of workload assessment means that some such workload reflections will respond almost instantly. In contrast, others will possess a much longer latency between the variation in task load and the outcome workload response. Some measures, of course, are a summary of experiences across the whole task, mission, or operation. Others occur within milliseconds. Our science must distinguish these differing latencies in order to assure that dissociations are not merely categorical, time-scale errors. The illustration given in Fig. 3 shows the various characteristics that could drive the outcome workload response. On the ordinate is the time of exposure, on the abscissa is the fluctuating level of dynamic task demand. Workload may be driven by any of the moments of the task load distribution across the epoch of interest (1). It may also be sensitive to retrospective performance (2) or anticipated load (3). It may be especially sensitive to peak events (4) or rates of change (5) or calibrated to periods of acute underload (6). Workload may be driven by sudden, momentary step functions (7), the sum of overload experienced (8), or the pitch of recovery; whether within or outside stable limits (9). Workload may be sensitive to the total amount [as opposed to discrete number of 'peak' events (10)]. This is not an exhaustive listing but indicates the complexity of what can drive the workload response.

## 4 The Meaning of Work in Works of Meaning

In trying to understand workload as a response to task demands, we have to possess a strong grasp on what the nature of those demands are. In short, we have to understand the meaning of work (Hancock 1997). In the pragmatic aspiration to capture the 'scientific' flavor of workload, we have largely, albeit sometimes implicitly, relied upon behavioristic antecedents and engineering conceptions of work. Ever since Smith (1776), this perspective has rendered work as relatively colorless transformations of states of matter and/or information. As with Henry Ford and Frederic Taylor, it is often

easy to even inadvertently 'dehumanize' work when we approach it from this stance. The unit of analysis is the level of work productivity and the degree of happiness or misery of the worker involved, within a strict interpretation of such a view, is largely superfluous. Of course, one wants to know about the health and efficiency of one's workforce, especially as it pertains to avoiding errors and failures. But the inner mental life of that working individual has about as much meaning to the production as the noise produced by moving machinery that surrounds them. In the end, however, this antiseptic view of the worker is self-defeating. For the worker is also the consumer. Like the illusory separation of church and state, one cannot dispassionately and effectively parse the totality of the human experience, however financially or pragmatically convenient it may be to do so.

The issue of meaning is bought into even more stark contrast when information is the currency of work. This is not to say that skilled physical workers cannot, and do not, find great meaning and satisfaction in some expressions of their work also. Assuredly they do. However, our modern world tends much more to be a cognitive enterprise and here the flexibility of the proximal tool. Most often the computer makes cognitive gratification all the more likely. What we have not done in workload assessment is to sufficiently value, nor sufficiently evaluate this hedonic dimension of the workload response. In the same way that we can ask whether beauty is a contributor to the optimization of design, so we can also ask whether satisfaction is a governor of perceived workload? That is, do individuals engaged in appealing, self-sought and interesting work experience different workload responses even to the same task? Put another way, can we find ways in which to make even the most rote task interesting and appealing (at least for someone)? Here, I am advocating that we can. Further, I believe we can accomplish this *by design* (and see Hancock et al. 2005). Obviously this requires that we venture from the fairly certain waters of physical workload evaluation (e.g., lifted weight, lift frequency, etc.), across the less well mapped regions of cognitive workload assessment, where we are today, to the rough and daunting passages of assessing what connotes meaning. But we will not be alone in this venture (see Flach and Voorhorst 2016).

Like the specification of beauty, the quantification of the aesthetic and the mathematics of desire, the concatenation of the hardest of hard sciences alongside the softest of soft sciences currently sounds strange in our ears. I believe it will not ring so to our progeny. I have no recipe for exactly how the full determination of meaning is to be established and this is our forthcoming challenge. I simply assert that if we do not embrace this challenge, our science will remain impoverished, incomplete, and ultimately disappointing. This is especially true for its predictions of real world behavior where, without the incorporation of such critical dimensions as meaning, it is almost certainly bound to fall short. Finally, I might ask whether had I made this narrative more interesting and involving, you would have had a lower frustration (workload) reading it? I think the case is clear, our persuasions toward a task influence how we react to its demands and even whether we perhaps choose ever to perform such work again. On an optimistic note, I do believe that we can make substantive headway in this dimension of workload assessment.

## 5 Summary and Conclusion

Assessing just how hard someone is working when the primary form of demand requires principally cognitive as opposed to muscular response, is an issue that remains to be resolved. This situation accrues from our knowledge that brains are more difficult to understand than muscles. The problem is a non-trivial one since such assessments underpin the very way we conceive of work and look to reward those who accomplish it. What I have chosen to address in the present chapter have been rather concrete methodological barriers that still exist which prevent us from achieving our desired state of knowledge. Emphasizing problems can be a pessimistic enterprise and so in these final remarks I want to point to a more positive perspective.

First let me say that I do not see any of the present challenges that I have raised as being insuperable. As far as I am concerned, none of the three challenges represents a 'show-stopper.' The association, insensitivity, dissociation (AIDs) issue is indeed a difficult one, but with some resolution to the intrinsic time-scale of measurement problem there is no reason to believe that we cannot conquer the methodological cohesion issue. That being so, even patterns such as double dissociations and multiple insensitivities can still prove informative. Our knowledge is not always predicated upon the positive results but the negative and null ones also. If all such patterns are context-contingent (i.e., they work in one mission scenario but are completely different in another workplace context) then we are in deep waters indeed. However, the commonalty of the human performer and the design-ability of the work environment, provides hope that such radical, situation to situation divergences will not be ubiquitous. In this respect, I offer a roadmap for future progress (see Table 1).

**Table 1.** A principled roadmap for future workload research

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|---|
| Proximal Challenges |
| • Distill patterns of pairwise comparisons of primary task, subjective and physiological reflections within a single, real-world performance relevant task (e.g. PVT) |
| • Compare the pairwise bases against three-way evaluation of the same common task |
| • Evaluate whether common patterns elicited from the above persist in more complex contexts |
| Medial Challenges |
| • Establish whether the patterns of association, indifference and dissociation (AIDs) map to the intrinsic frequency of the methods used to elicit them |
| • Compare and contrast intra-method AID observations with inter-method AID observations. Then, employ appropriate meta-analytic screening to guide targeted experimentation |
| • Define method-driver vs. task-driven influence. Compare and contrast different workload drivers intrinsic to the profile of imposed task demand |
| Distal Challenges |
| • Seek a validated measure of meaning |
| • Evaluate the affective dimensions of work in contrast to the 'objective' dimension of imposed load |
| • Generate a unified theory of cognitive workload. Calibrate to the spectrum of operator individual differences. Link to a context sensitive model to derive workload prediction |

The meaning question is of a different order of concern. What this demands is that we become more catholic in our thinking and look to incorporate dimensions of experience that do not sit well with mathematics, computation, modelling, and the general perception of what makes things 'scientific.' Affect has always been our stock-in-trade (Hancock et al. 2002). Yet, we have often shied away from terms like affection, interest, beauty and the like. Sometimes we have sought to disguise our interest through the invention of new terms which are sufficiently ambiguous and imprecise to allow us to explore the former, meaningful terms and yet retain a sturdy veneer of scientific respectability.

We must now throw off any such need for approval from our wider peers in the academy and embrace such difficult and demanding integrations fully. Questions such as: does a beautiful task necessarily impose lower levels of cognitive demand? Can we regulate perceived workload through designed interest? While still somewhat strange to us, these question will be those that tax our progeny. I believe the challenges of cognitive workload assessment are set before us. I believe our science is mature enough to embrace these cross-disciplinary challenges. In short, I am optimistic about our future.

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