Ergonomics Research Techniques

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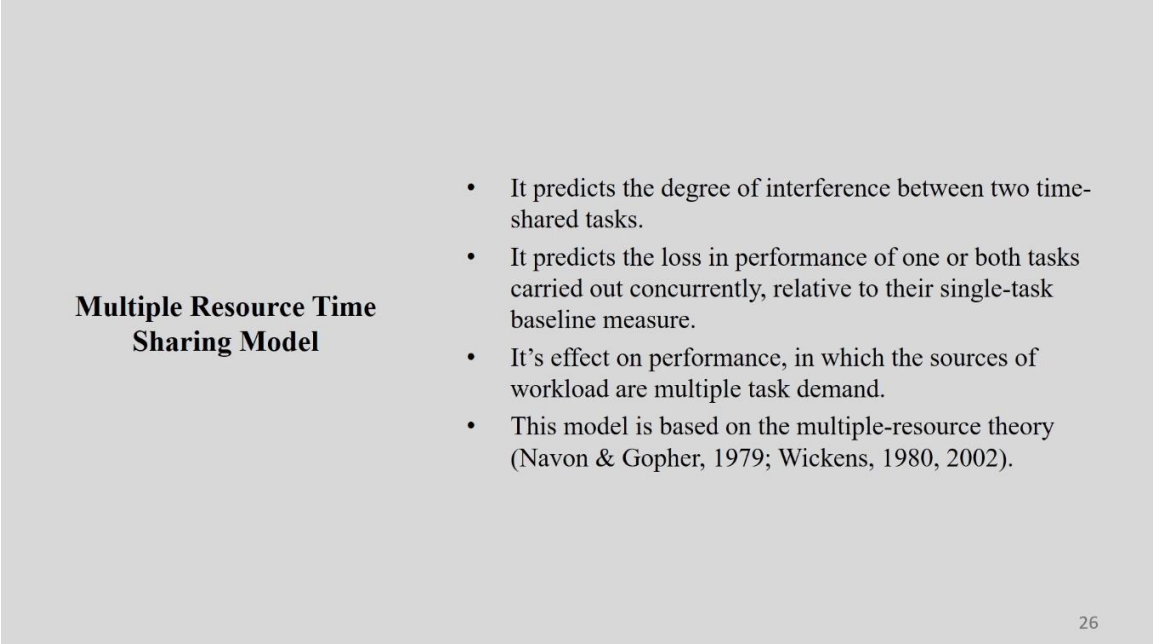
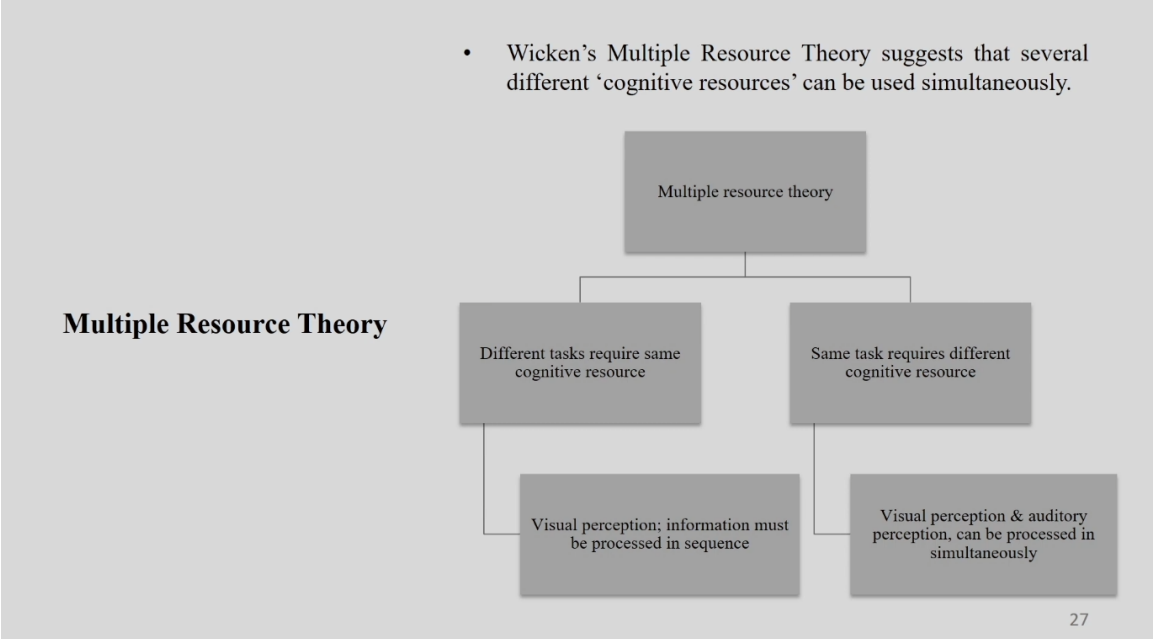
Week 10: Lec 33- Workload and situation analysis methods

Multiple Resource Time Sharing Model

Hello everyone, we are back to the particular class where we were talking about the analysis of mental workload and human behaviour right ok. Now, today we will be discussing a very specific tool, we call it as multiple resource time sharing model ok. So, multiple resource time sharing model from the this particular name we understand where there will be a single resource where multiple task will share that particular resource or there are multiple task where one single resource will be giving the input towards that ok. So, multiple combination of tasks. So, here the lot of interactions will be there with the human, with the machineries and the resources in a particular system. So, I always suggest all of you to please remember the understanding of complex system, complex ergo system because in if you go to the industry you we will come to know that every system is very very complex in nature. So, it is not one man, one like one operator, one machine and one's know in a single environment. It is always multiple in nature, it is interacting with each other in different domain and different dimensions right. So, this particular analysis or this particular method actually help us that how we can improvise on our or how we can optimize our system. So, that the productivity is good and our productivity help us to get more performance ok. So, whenever we are talking about implementation of ergonomics principle or ergonomics theory in a particular system, our always goal is to enhance the productivity whereas, we want to save or we want to enhance the well being of the operator right. So, this particular theory or this particular model actually make us understand that how we are sharing the information or the sources in a particular system to complete a whole job. So, it is multiple resource time sharing model ok.



So, let us begin with the detail of the this particular method. So, what it says? It predicts the degree of interference ok. It help us to understand the degree of interference between two time shared tasks. So, if there is a single two task where within a single time that do both the tasks need to be completed, what are the varieties of interference are there. So, that once we understand that what are the interference, how we can change it or how we can monitor it or how we can do the improvisation on that, so that our final productivity is good ok. So, it predicts the degree of interference between two time shared task. It predicts the loss of performance, actually it predicts the loss of performance of one or both tasks carried out concurrently relative to their single task baseline measure ok. So, when there is there are two, three tasks going simultaneously of course, we can have an understanding if this task 1 we do at a time, there is no task what is the kind of time taken. For task 2 also we have some kind of measurement, task 3 also, task 4 also. Now, that is the individual baseline. Now, with this particular model or particular method, we do understand if these three or four tasks are being carried out simultaneously what are the time interference and what is the loss of performance in the whole process. So, that we will come to know. So, if the loss is too high then we really need to understand where the intervention need to be need to be given or where we can start the design changes, so that the performance is not being hampered. So, its effect on the performance in which the sources of workload are multiple task demand and this particular model is based on the multiple resource theory. This particular model that multiple resource time sharing model is based on the multiple resource theory which was first you know introduced in 1979 and over the period of time, it has a lot of modifications. So, first let us understand or let us take some input from that particular theory.



So, in Wickens like whatever Professor Wickens said in 1980 and in modified version in 2002, he said that multiple resource theory suggest that several different cognitive resources can be used simultaneously. So, different cognitive resources can be used simultaneously. So, it has a typical structure of this particular theory. It says it can be majorly two types. One that is different task require the same cognitive resources, different task requires same cognitive resources. Another says same task require different cognitive resources. So, I am going to give an example. So, different task, you are writing and you are speaking. In these two task you need one specific cognitive resources to support it. So, that is one thing. Whereas, the same task you are writing only, however, you need two cognitive support or cognitive resource to write that. So, this is the two different varieties of example. So, multiple resource theory says it can be two different way. In one case, different task require same cognitive, one single cognitive resources. Whereas, a single task may require two varieties of cognitive resources. In the first case, that visual perception information must be processed in a sequence. If two task requires single multiple cognitive resources, in that case visual perception information those things must be processed in a sequence. Because you cannot have, you cannot do it simultaneously like. So, for each task you have to have a sequence. Here comes the interference ok. In the second case, visual perception, auditory perception both the things can be processed in simultaneously ok. So, if you need suppose I am talking about writing. In writing if you need visual as well as auditory you need to process it simultaneously. This is just an example ok. So, when we are talking about in industry there are no sets of big system where a lot of you know informations are processed by a single person or single operator or multiple operators at a same time all these scenarios can happen and we need to analyze it and using this particular method or particular model we can realize or we can understand where are those interference and

where the interference are difficult to handle we need intervention over there ok. So, this is the importance of this particular theory.

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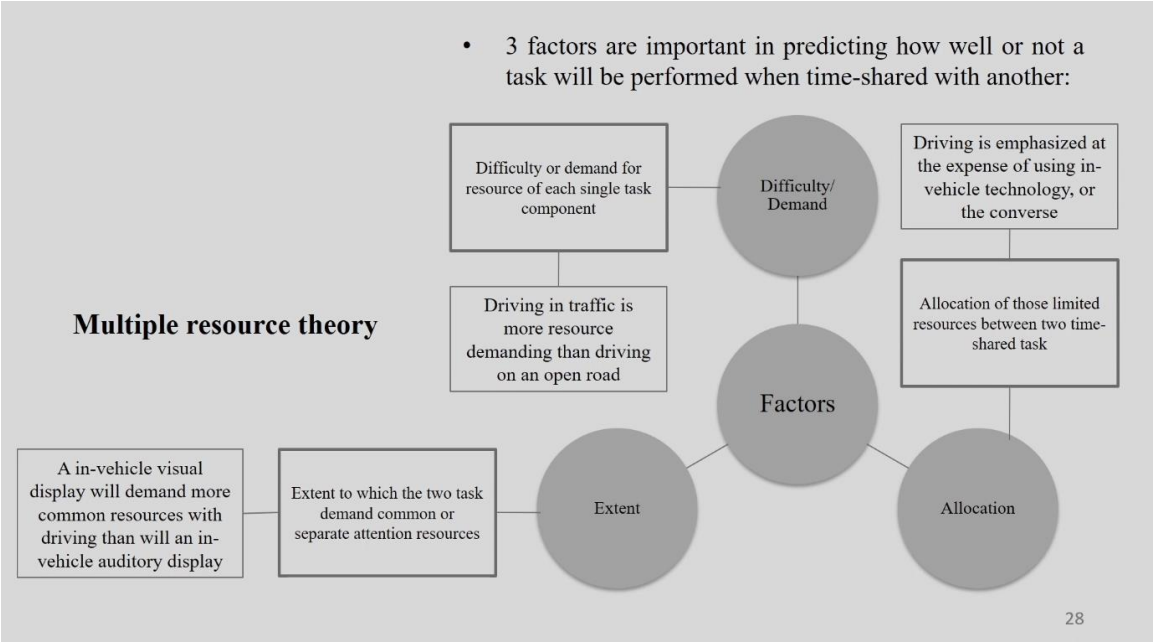


Now, when we are talking about these things. let us understand into detail about the factors ok. Here it says multiple resource theory says three different factors are more are important in predicting- how well or not a task will be performed when time shared with another ok. So, when I am talking about multiple resource theory, it says there are major three factors. One factor is difficulty or demand job demand, then is extent and the third is allocation. So, these three factors are important in predicting how well or not a task will be performed when time shared with one another ok. Let us understand more into detail when I am talking about difficulty or demand it says difficulty or demand for resources of each single task component, each single task component it is not simultaneously all the tasks each single task we have to identify. So, driving in a traffic example is more resource demanding than driving on an open area correct. So, you need lot of resources because you need visual, you need your skill, you need your auditory you know resources all these information some background understanding everything is required right. So, this is when we are talking about driving in a traffic. So, understanding the speed so all these perceptions are understanding the signal everything whereas, when we are talking about in a open road of course, it has less demand just an example. Now, when I am talking about extent. What it says extent to which the two work task demand common or separate attention resources are required ok. So, for example, in in any vehicle visual display will demand more common resources with driving than will an in vehicle auditory display of course. In vehicle visual displays are more informative more required than the in vehicle auditory responses. Now, coming to

the allocation. It says allocation of those limited resources between two time shared tasks, if there are two or three time shared tasks how you are actually allocating them. So, driving is emphasized at the expense of using in vehicle technology or the converse ok. So, these three factors we are going to consider in this multiple resource theory and these particular method or particular concept we are going to use in this particular what we can say the multiple resource time sharing model ok.

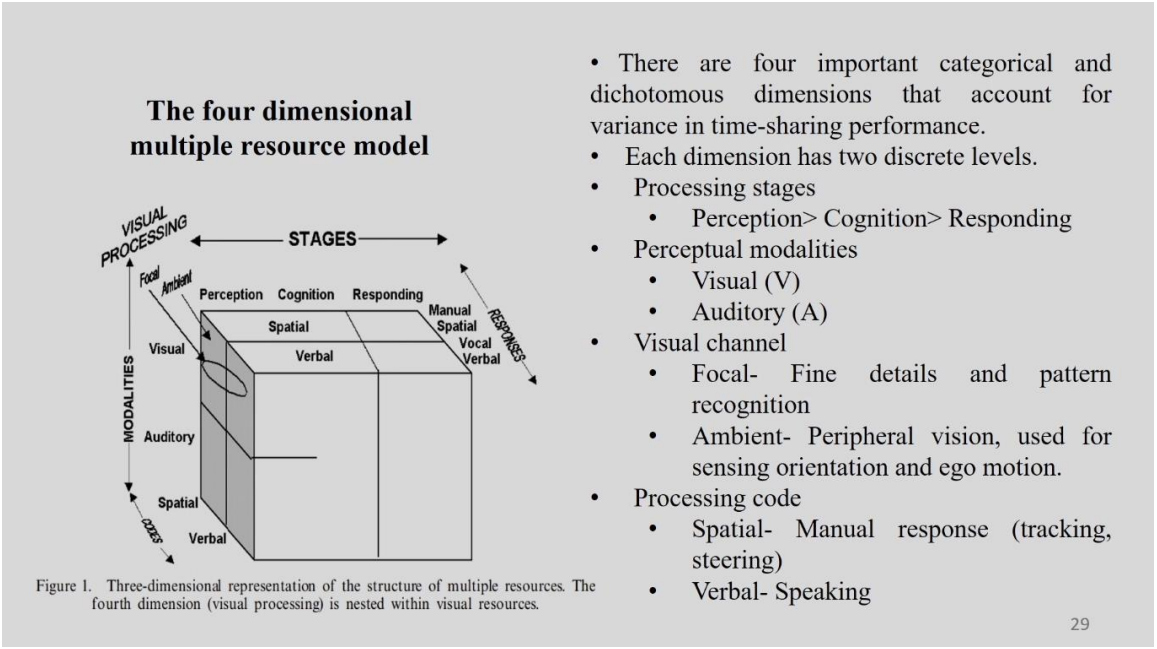
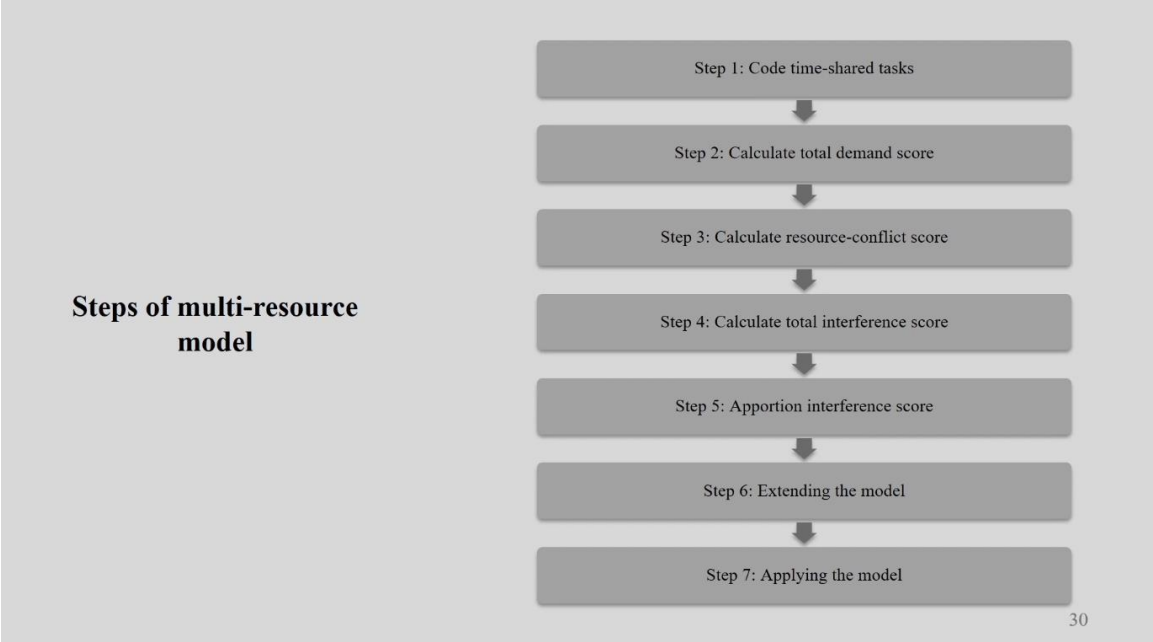


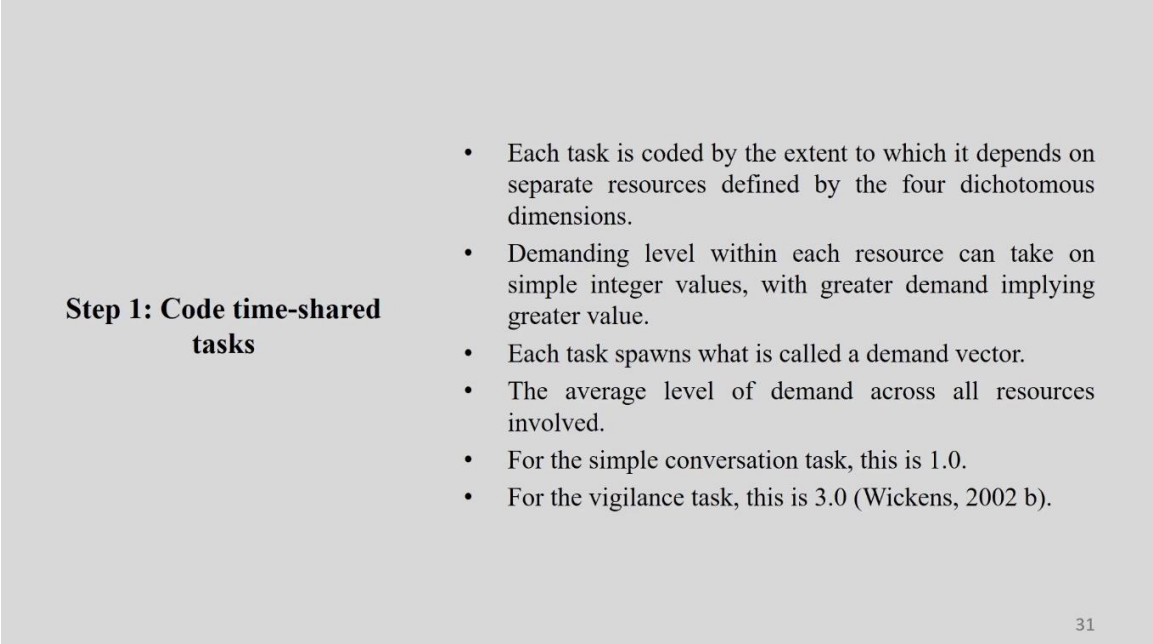
Figure 1. Three-dimensional representation of the structure of multiple resources. The fourth dimension (visual processing) is nested within visual resources.

Now, let us go further. Now, when I am talking about these three factors, let us understand these three dimensional what I can say model, four dimensional model ok. So, one is processing stages, another is perceptual modalities, then visual channel and the processing code. Here it says there are four important categorical and dichotomous dimension. Four important categorical and dichotomous dimensions that account for variance in time shared performance ok. Now, let us understand each of them. First is processing stages. Now, in processing stage when we are we have some kind of information or some kind of yes some kind of information, then what we need to do? We have to first perceive it and then respond it right. Here we say perception, then recognition or cognition and then responding. Now, here in this particular particular figure you can see that perception and cognition are together and then responding right. So, it is dichotomous ok. These two are perception and cognition and then responding this is. Now, when I am talking about the perceptual modalities. When I am talking about perceptual modalities, one can be visual, another can be auditory. So, here it is visual this particular thing and then auditory. Now, when I am talking about the visual channel, one can be focal, another is ambient. Here you can see that focal this portion and then ambient right. Now, when I am talking about focal what it says fine details and pattern recognition. Focal means very much detail right. So, fine details and pattern

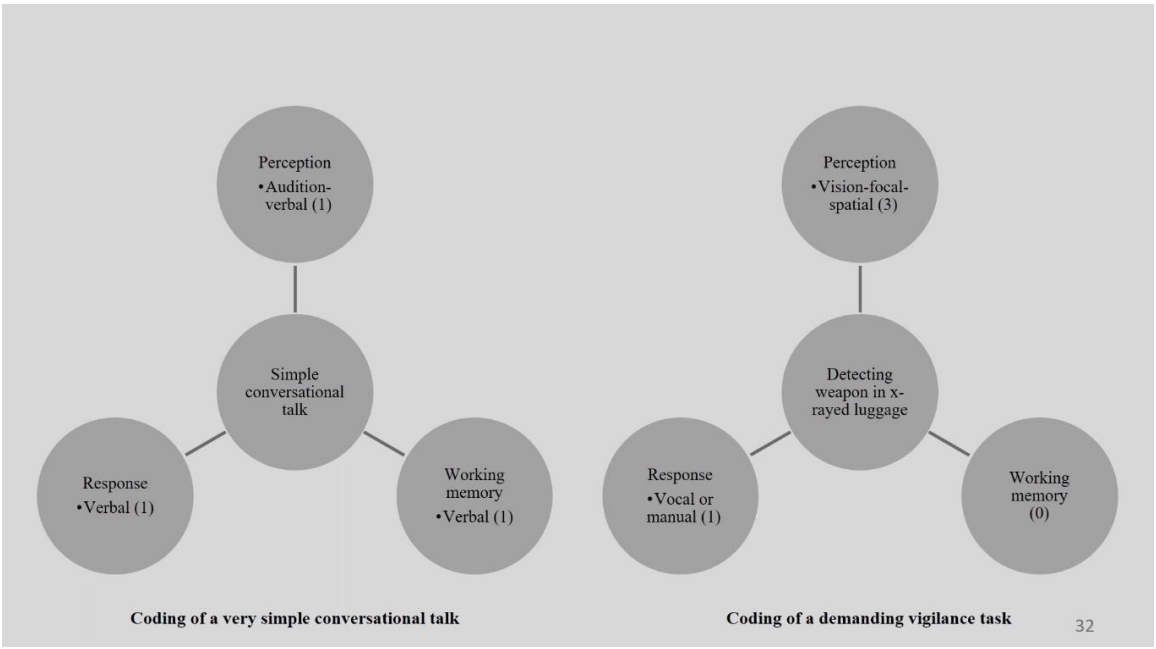
recognition whereas, in ambient you are actually looking at the periphery. Peripheral visions used for the sensing the orientation and ego motion fine. The next is processing the code. One can be spatial, another can be verbal. In spatial it says manual responses like tracking, sharing, steering and all those thing, another is verbal responses. So, in this particular way we can actually represent all these four dimensions ok. So, this is the four dimensional multiple resource model this is the actual model.



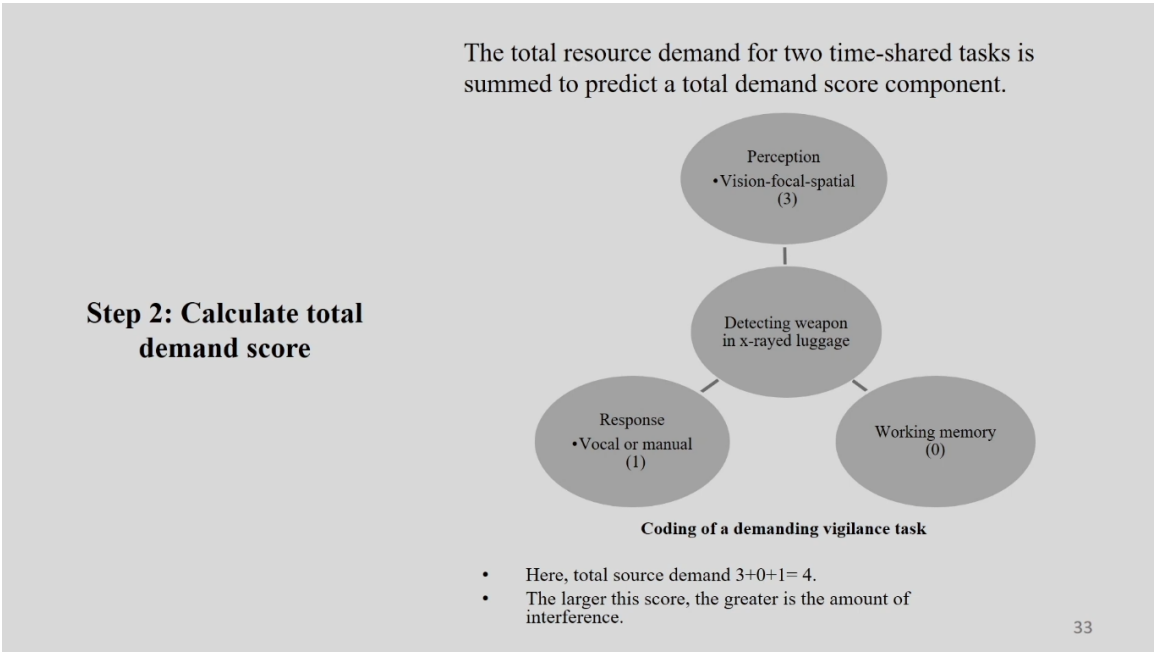
Now, let us go further with the multiple resource model that particular steps that we are going to follow. So, first step is coding the time shared task. When we start, we start with the coding of the time shared task. Once that coding is done then what we do calculate the total demand score. Now, this is very much important for us to understand over here that it is very much skill based you know, it is from lot of learning you will be able to code them. There are always it is possible that there are difference in opinion in some cases you know when we are actually coding that we will come to know in the next slides ok. Once we calculate the total demand score we actually calculate the resource conflict score. So, we have total demand score and then we are trying to understand where are the those conflicts. Then to calculate the interference score once we understand the conflict, we understand the interference and from there we actually apportion the interference score, then extend that particular model and apply that model in that particular situation. So, let us take all these steps in more detail.



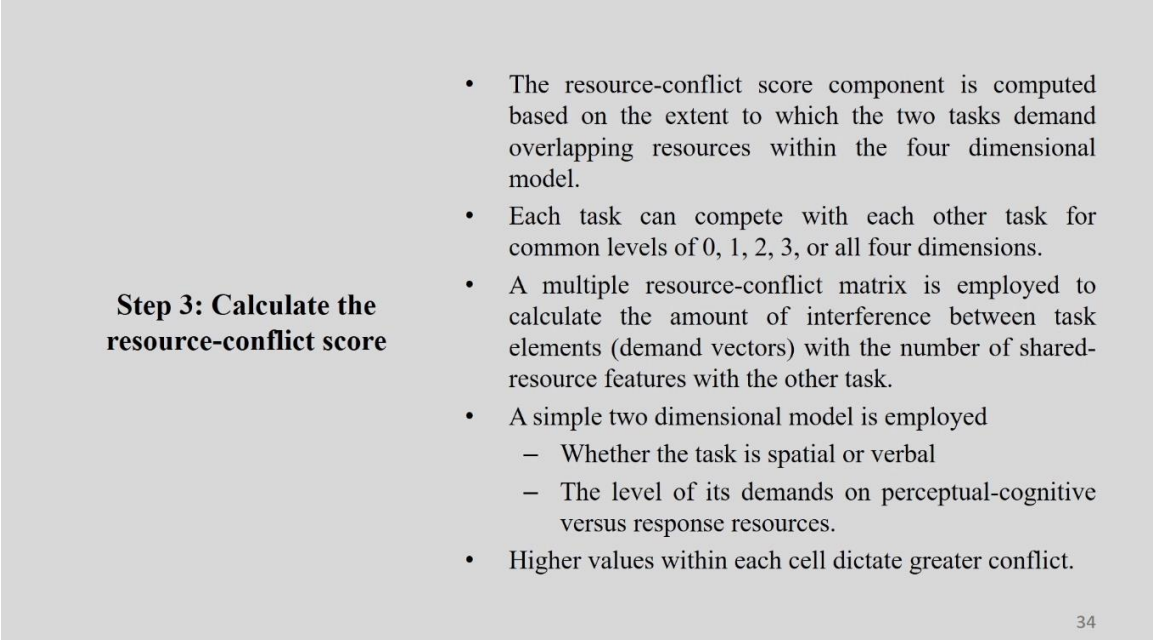
So, coding the time shared task. Each task is coded by the extent to which it depends on separate resources defined by the four dichotomous dimension. Whatever dimensions we have understood from that particular model, this particular model is very important. So, you know perception processing stage, perceptual modalities, visual channel and the processing code. Under that all these dichotomous factors you need to understand very critically from that particular system and then you have to establish that. So, then only you will be able to code them. Visual, then auditory for visual channel you have focal and ambient, in processing you have spatial and verbal ok. So, what it says that each task is coded by the extent to which it depends on the separate resources defined by the four dichotomous dimensions. Then demanding level within each resources can be on simple integer values 1, 2, 3 something like that with greater demand implying the greater value, greater demand greater value. Each task spawns with what is called the demand vector ok. The average level of demand across all resources are involved. For example, if it is simple conversion task it is 1, if it is visual sorry simple conversation task it is 1, if it is a vigilance task it is 3. Now, this particular 1 and 3 assigning this 1 and 3 this example has taken from this particular paper, this particular reference ok. So, if it is simple conversation task we take it as 1 and if it is vigilant task because you have lot of resources involved for that then it is 3.



Now, let us go into more detail. So, again that you know factorial understanding. So, coding a very simple conversational task here it says perception auditory. So, 1 working with a memory that is verbal that is 1 and the responses is 1 ok. So, all are 1, 1, 1 whereas, when I am talking about the coding of a demanding visual task like you know detecting the weapon in x red you know luggage then then what we are going to do? Perception visual in focal and spatial both vision focal and spatial. So, in that case we are giving a number assigning it as 3 whereas, responses we have vocal or maybe some manual activity. So, it is 1, maybe working memory we may not need so it is 0.

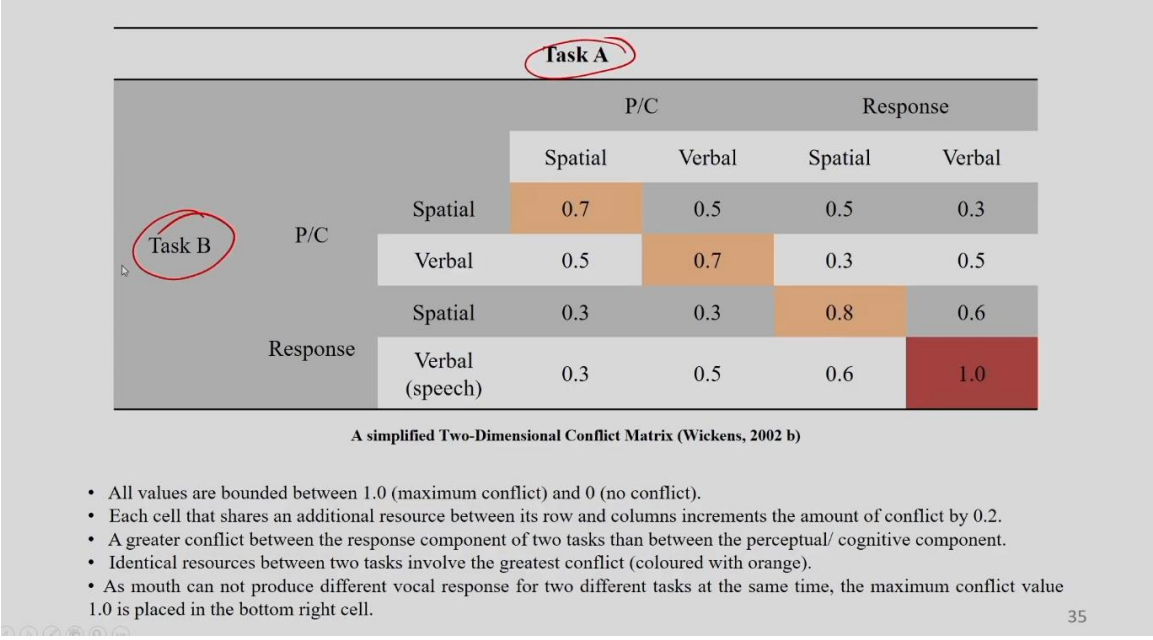


So, now, if we try to code them so that is the next step which is calculate the total demand score for the visual vigilance demanding task, it says the total resource demand is 3 because 3 this is 3 plus 1 plus 0 ok. So, it is 4 ok. So, the total resource demand for 2 timed shared task is some to predict the total demand score component and for this particular example it is 4. 4 the larger the score is the greater is the amount of interference. So, from this particular score we can understand that if there is an requirement of the intervention or not. From the next steps we will understand where the intervention is required. So, here we understand the intervention is required or not in the next phases the results we will see interventions are required at which direction and which step ok.



Now, next step of this particular method is calculating the resource conflict score. What it says? The resource conflict score component is computed based on the extent to which the 2 task demand overlapping resources within the 4 dimensional model. So, overlapping ok, because that is the main agenda of this particular method that we are trying to understand where the those overlappings are and how they are actually interfering in the whole performance ok, individual task performance. So, the resource conflict score component is computed based on the extent to which the 2 task demand overlapping resources within the 4 dimensional model. Each task can compete with each other with each other each task can compete with each other task for common levels like 0, 1, 2, 3 like that ok. A multiple resource complex conflict matrix is employed to calculate the amount of interference between task element. So, we need to really draw a resource conflict matrix that we are going to show in the next slides. So, with the number of shared resource feature with the other task. Now, a 2 simple dimensional model need to be employed to understand whether task is spatial or verbal and the level of its

demand on perceptual cognitive versus perceptual or cognitive perceptual cognitive versus the response resources. 2 things, one is whether the task is spatial or verbal and the level of this particular demand level of this particular demand on perceptual cognitive or the response resources that we need to understand. Higher the values within each cell indicate the greater conflict understood.



			Task A: P/C Spatial	Task A: P/C Verbal	Task A: Response Spatial	Task A: Response Verbal
Task B	P/C	Spatial	0.7	0.5	0.5	0.3
		Verbal	0.5	0.7	0.3	0.5
	Response	Spatial	0.3	0.3	0.8	0.6
		Verbal (speech)	0.3	0.5	0.6	1.0

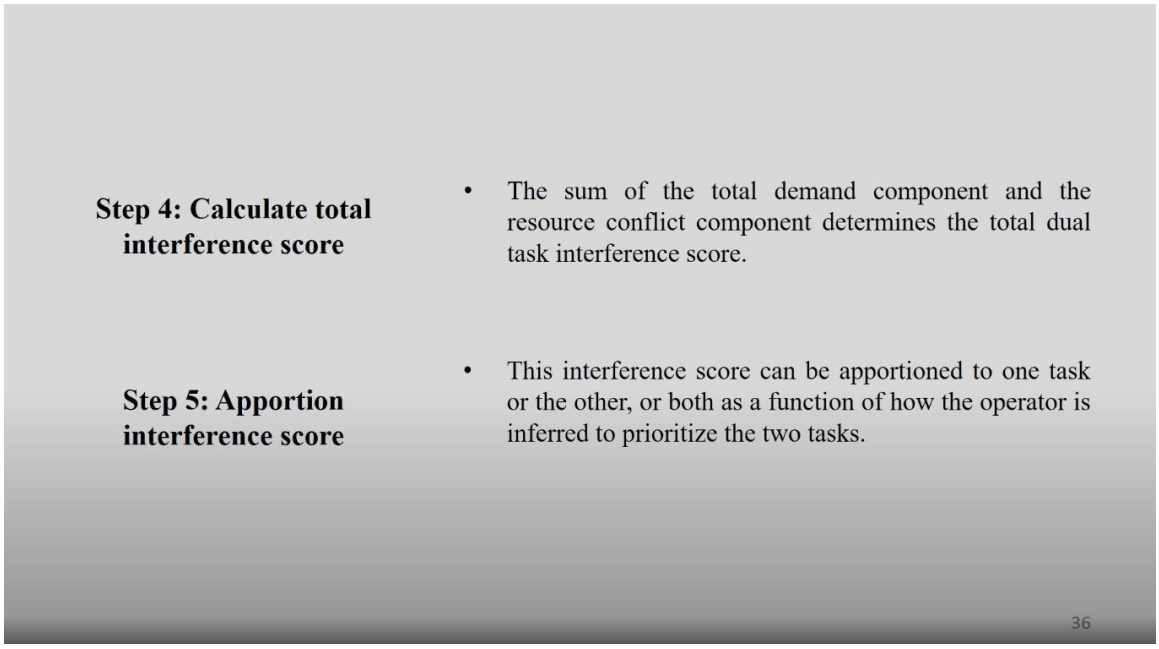
A simplified Two-Dimensional Conflict Matrix (Wickens, 2002 b)

- All values are bounded between 1.0 (maximum conflict) and 0 (no conflict).
- Each cell that shares an additional resource between its row and columns increments the amount of conflict by 0.2.
- A greater conflict between the response component of two tasks than between the perceptual/ cognitive component.
- Identical resources between two tasks involve the greatest conflict (coloured with orange).
- As mouth can not produce different vocal response for two different tasks at the same time, the maximum conflict value 1.0 is placed in the bottom right cell.

35

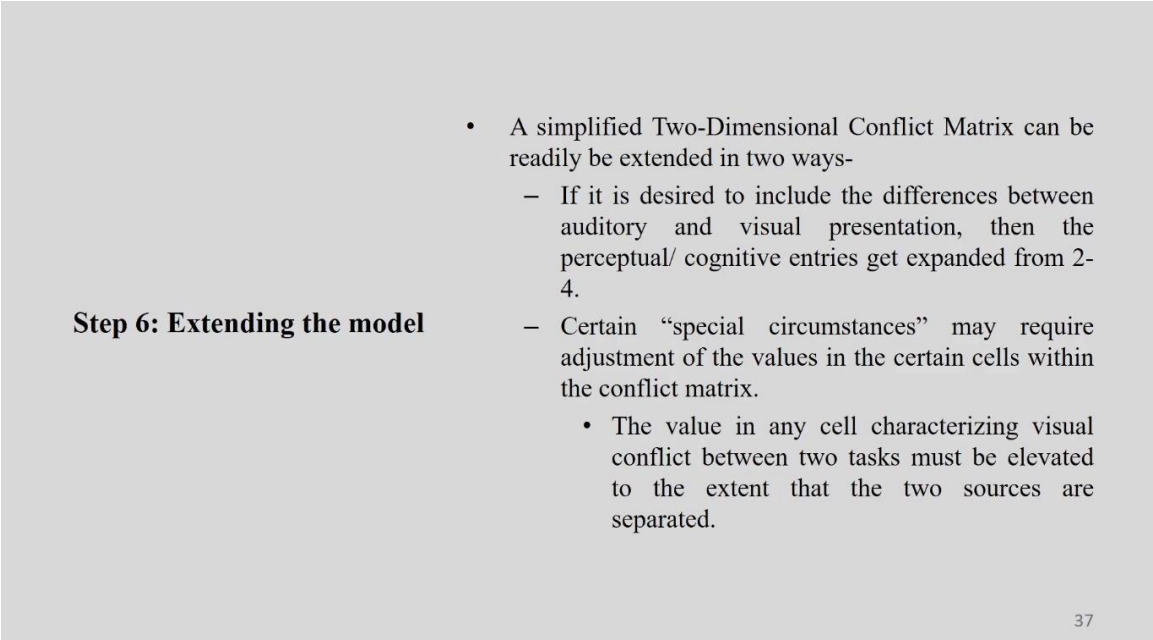
So, now, let us understand how do we write that particular matrix. Now, here is task A and task B. Now, first understand these ok. So, all values are bounded within 1 to 0. 1 means maximum possible conflict whereas, 0 means no conflict. This is again the example is taken from this particular reference and it is a simplified 2 dimensional conflict matrix. It can be more ok. So, right now we are talking about for our learning we are talking about 2 dimensional conflict matrix. So, all values are bounded between 1 to 0. 1 means maximum conflict, 0 means no conflict. Each cell like these cells, these cells, these cells ok. So, these cells that shares an additional resources between its row and column increments the amount of conflict by 0. 2. A greater conflict between the response component of 2 task than between the perceptual and cognitive component. Identical resources between 2 tasks involve the greatest conflict. So, colored with these oranges right, these cells, these cells and these cells. As mouth cannot produce different vocal responses for 2 different tasks at the same time. It is not possible right. For 2 separate tasks you cannot speak simultaneously together. It is not possible. So, the maximum conflict value is 1 is placed in the bottom right cell because it is not possible. If you are talking about Varbal and both the cases you need Varbal it is really not possible to produce it right. So, it is maximum possible conflict. So, it is not possible. So, if you have to give a command to both the task Varbal you cannot do it at one time. You have to say give the command for first and then second ok depending on the priority.

So, you cannot do it. So, that is why it is maximum conflict and that is why it is 1 fine. So, you understood this particular matrix. This matrix is very easy. Now you have given this spatial and Varbal and then spatial and Varbal for the you know perception and cognition cognitive and then responses. For here also you have written this and then you mapped this particular model and you created this particular matrix for task A and task B. Now here it is 2 tasks. It may have 3 tasks or 4 tasks ok. So, according to the number of tasks, number of tasks involved for this analysis the matrix will be more complex in nature.

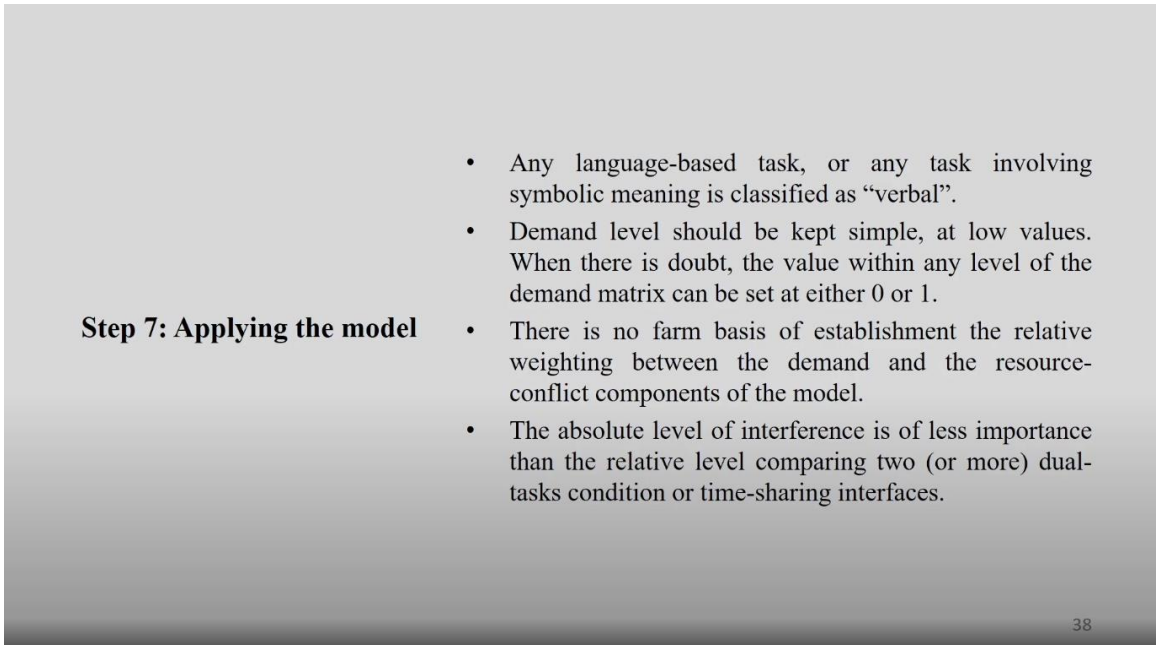


The fourth step is calculating the total interference score. What it says? The sum of total demand component and the resource conflict resource conflict component determines the total dual task interference score. Total dual task interference score. So, if you have 2 tasks doing so, what you it says that total task interference score. Now fifth step is apportion the interference score. It says this interference score can be apportioned or allocate to one task or the other or both as a function of how the operator is interfered to prioritize the 2 task. Here I said suppose for 2 task you have to give vocal command ok, Varbal command. You cannot do it simultaneously so, the operator need to prioritize it. So, how these interference can be eliminated using the system design so, that prioritization becomes more easy for the operator. So, here the decision makings come right. So, if it depends on the operators decision, then there is always a chance of error, there is always a chance of an accident. However, if system defines yes this should be the process then there will be less chance of error, less chance of accident. So, here is the this apportion actually help us take the decision for the designer it helps the designer to take the decision where how to design it so, that there is this particular conflict can be overcome you can overcome ok. So, this is very very important and crucial step in the

system design, because if we cannot design it correctly then there will be always a chance that we are depending on the operator, operators decision ok. So, if that is so, then there will be always a chance to misread that particular situation and there will be a chance where we can have some kind of accidents ok.



Now, next step is extending this particular model. So, a simple simplified 2 dimensional conflict matrix can be readily you can extend in 2 ways majorly 2 ways. First is if it is desired to include differences between auditory and visual presentation, then the perceptual cognitive entries get expanded from 2 to 4 ok. So, perceptual cognitive entries get extended from 2 to 4, this is one way and the second way is the certain spatial circumstances may require adjustment of the values in certain cells within the conflict matrix. So, it is it is depending on how do you want you can do this kind of extension. So, in this particular case it says the value in any cell characterizing the visual conflict between 2 tasks must be elevated to the extent that the 2 sources are separated out. Because if it is separated out then it becomes very easy for the operator to go ahead with the system. Otherwise if it is connected with each other these resources are same, then become then it is again a decision making again there is a chance of error ok. So, this actually help us to give a direction where the intervention can be. So, we can understand from these core we can say the intervention is required or not from all these steps we can understand where the intervention is required ok. So, first says that it is required or not, the next all these steps help us to understand where we should start, where we should take the decision ok being a designer or being the you know system controller ok.



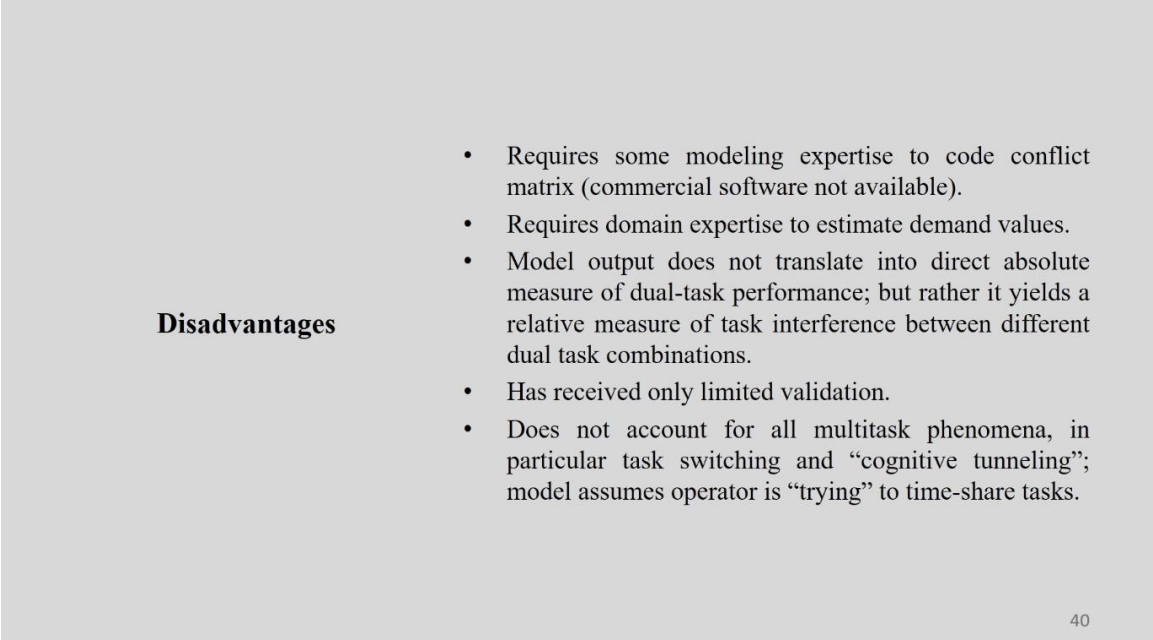
Last step is the applying this particular model. So, any language based task or any task involving symbolic meaning is classified as verbal. Demand level should be kept simple because if it is more complex, then it becomes very difficult for someone to analyze it. So, demand level should be kept in simple at low values where there is doubt the values within any level of the demand matrix can be set at either 0 or 1. There is no firm basis of establishment the relative weighting like weightage between the demand and the resource conflict components of this particular model. So, here the experience matters, skill matters as as you know if you keep on working you will understand how to assign them. The absolute level of interference is of less importance than the relative level comparing to dual task condition or time sharing interference.

Advantages

- Captures known empirical phenomena that influence dual-task performance in many multitask environments (vehicle control).
- Based upon theory.
- Simple (arithmetic) in its computations.
- Relatively robust to simplifications (equal-demand coding).
- Flexible in its applications (number of resources, qualitatively different tasks).

39

Now, let us understand the advantages of this particular method. So, it captures known empirical phenomena that influence the dual task performance in many multiple multitask environment ok. So, what it does? It captures known empirical phenomena, it is very known to us. However, it help us to understand those influences in the dual task performance in multiple multitask environment. It is based upon a particular theory. So, theory is already established. So, multiple resource theory that is very established theory. So, this particular tool is very very beneficial because it is already tested. So, simple in its computation relatively robust to simplification because you can do very simplified thing we will take it in the next slide. So, flexible in its adaptation because you can have lot of flexibility to do lot of changes or lot of permutation combination in this particular tool or method. So, these are the advantages.



However, there are lot of disadvantages every tool has every method has advantages and disadvantages. So, it requires some modeling experience because if you do not have, then you will not be able to code them that conflict matrix you will not be able to create. So, requires domain expertise to estimate the demand value that was my very take that you know if you are not experienced enough you will not be able to give the right code, right value to those activity. Model output does not translate into direct absolute measure of dual task performance, but rather it yields a relative measure of task interference between the different dual task combination. It has received only limited validation and does not account for all multitask phenomena. In particular tasks switching and the cognitive tunneling model assumes operator is trying to time shared task. It is it says that it operator is trying to however it is not completely true. So, these are the advantages.

A simplified Two-Resource Conflict Matrix

		Task A: P/C	Task A: R
Task B	P/C	0.8	0.6
	R	0.6	1.0

P/C= perceptual/cognitive; R= response

- The matrix shows greater conflict in the negative diagonal (indicating red blocks) than the positive diagonal (indicating green blocks).
- It portrays the inability to respond to two tasks at once (bottom of the right, 1.0).
- The greater capacity to time share the perceptual-cognitive aspects of a pair of tasks (top of the left, 0.8).

Now, take more example for this simplified to resource conflict. You can say from this table we have simplified this particular table like you know we simplified here for more understanding. So, task A and task B perception and cognition and the responses. So, this red zone are difficult and green zones are less difficult. So, this particular matrix shows the greater conflict in the negative diagonal than the positive diagonal because if you have less conflict you can go ahead whereas if you have more conflict you need to really look into like if you talk about one it is really not possible. It portraits the inability to respond of towards two tasks at one time like one and the greater capacity to time share the perceptual cognitive aspects of a paired task.

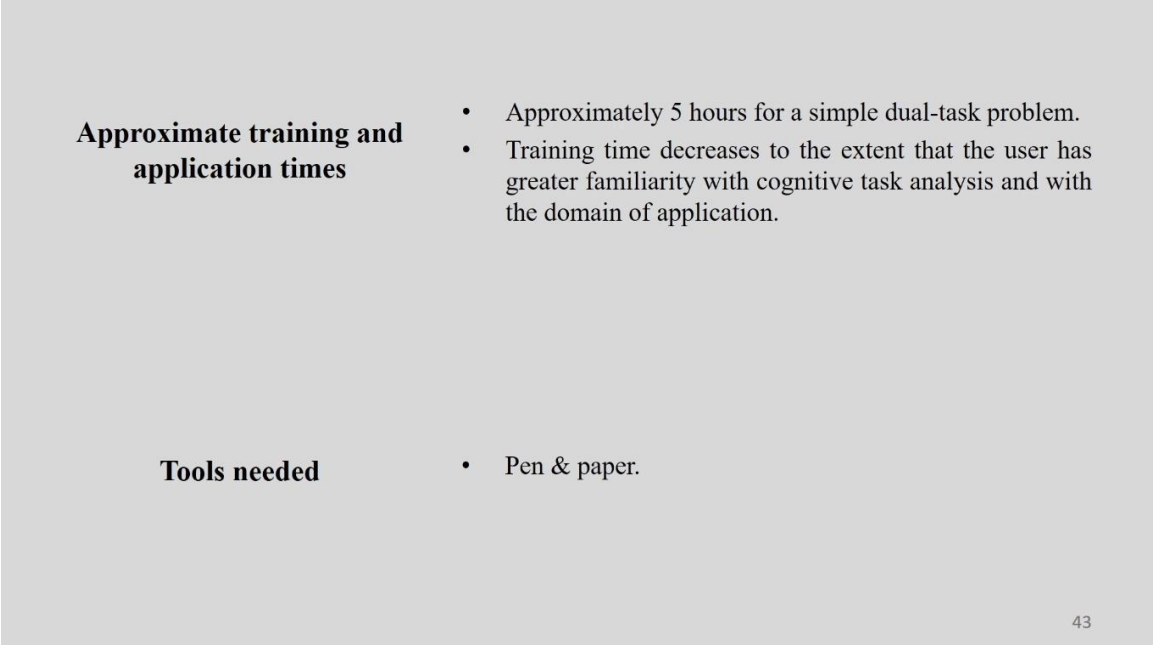
Predicted total interference values resulting from six tasks combinations

Tasks	Demand component	Conflict component	Total interference
AA	1 + 1 = 2	0.8 + 0 + 0 + 0 = 0.8	2.8
BB	1 + 1 = 2	0.8 + 1 + 0.6 + 0.6 = 3.0	5.0
CC	1.5 + 1.5 = 3	0.8 + 1 + 0.6 + 0.6 = 3.0	6.0
AB	1 + 1 = 2	0.8 + 0 + 0.6 + 0 = 1.4	3.4
AC	1 + 1.5 = 2.5	0.8 + 0 + 0.6 + 0 = 1.4	3.9
BC	1 + 1.5 = 2.5	0.8 + 1 + 0.6 + 0.6 = 3.0	5.5

Demand component represents tasks difficulty, conflict component represents source conflicts

- *Task A*- pure, demanding, monitoring; so its vector of demands across the two resources is [2,0].
- *Task B*- standard information transmission involves perception and response [1,1].
- *Task C*- Also a tracking task, but has an incompatible control, so demands are [1,2].
- The demand components are computed by summing the average demand across all resources within a task (negative diagonal), across both task (positive diagonal).
- The conflict components are computed by summing the conflict matrix components of all cells that are demanded by both tasks.

And this is the you know what it says that this is like combination, permutation combination AA, BB, CC, AB, AC, BC. So, how you can you can do the permutation and combination. So, from these conflicts from the same table we referred it and then we calculated this in this again this is from the that particular reference. So, task A it says that pure demanding and monitoring. So, its vector of demand across the two resources is two. Task B says the standard information transmission involve perception and responses and task C is a tracking task. It is a tracking task but has an incompatible control. So, demands are one and two. So, this way we have defined it, not we, from the example it is defined and the demand components are computed by summing the average demand across all the resources within that particular task, negative diagonal and across both task if it is positive diagonal. We understand this is negative, this is positive. So, the conflict components are computed by summing the conflict matrix components of all cells that are demanded by the both task. This is how we can implement it or use it.



Now, let us understand what is the approximate time for if you want to use it what is the kind of approximate time you require. So, it says that approximately 5 hours for a simple dual task problem approximately. So, you can have break also in between and training time decreases to the extent that the user has greater familiarity with the cognitive task analysis with the domain of application. It is very true for all the methods and you need only pen and paper to compute this. So, you do not need any kind of software or all you can use simple pen and paper to use this for using this particular tool. So, this is very very useful method. However, it is not very complex. If you have good understanding about the perception, about the cognitive task and about the domain knowledge of this particular method, then definitely you can have good data and you can take better decision that where the interference are and how you can give the solution towards it.

That is all for today. So, I suggest again as I do for all the methods, you take up a task and do the analysis, you create the matrix and try to understand if the interferences are there or not, if interferences are there, how do you go for the more detailing and how do you go for the intervention to avoid these interference. Because as long there are more interference, there are more chances of accidents, more chances of error and mental workload. If interferences are more, mental workload will increase. Right now we are talking about mental workload. So, this is how we can do this analysis and we can take advantage of it and we can implement to enhancing the whole system performance in terms of human operator, in terms of the whole system. So, that we can do. So, that is all for today. Let us take the last topic of this particular cognitive like mental workload in the next class. Thank you. Thank you.