Ergonomics Research Techniques

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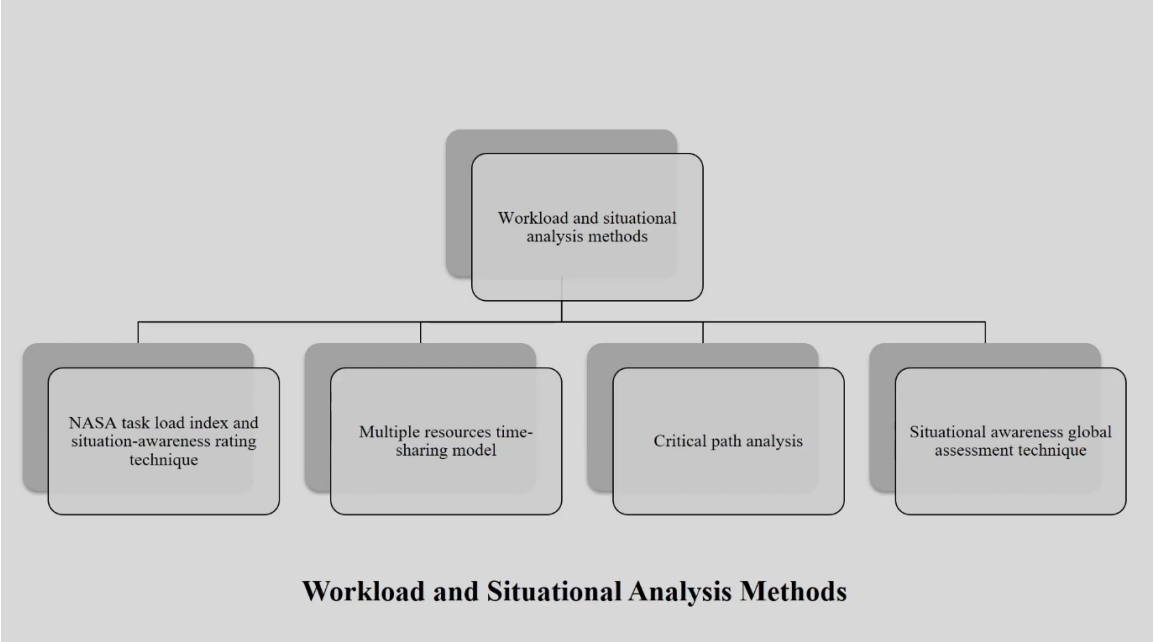
Week 10: Lec 32- Workload and situation analysis methods

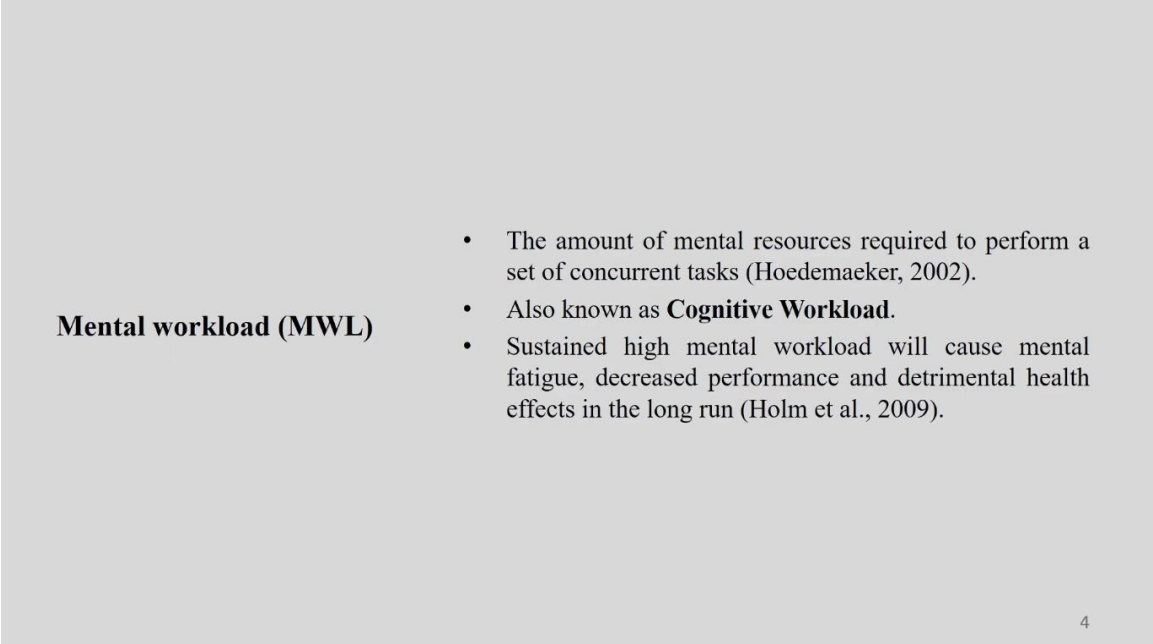
NASA Task Load Index (NASA-TLX)

Welcome back to this particular course and today we will be talking about Workload and Situational Analysis Method. So, there are several method for this particular topic. So, one by one we will be taking it. So, before we go into detail about varieties of method which is available for this particular section. First let us understand that what is workload and situational analysis and what we are going to cover under this particular topic.



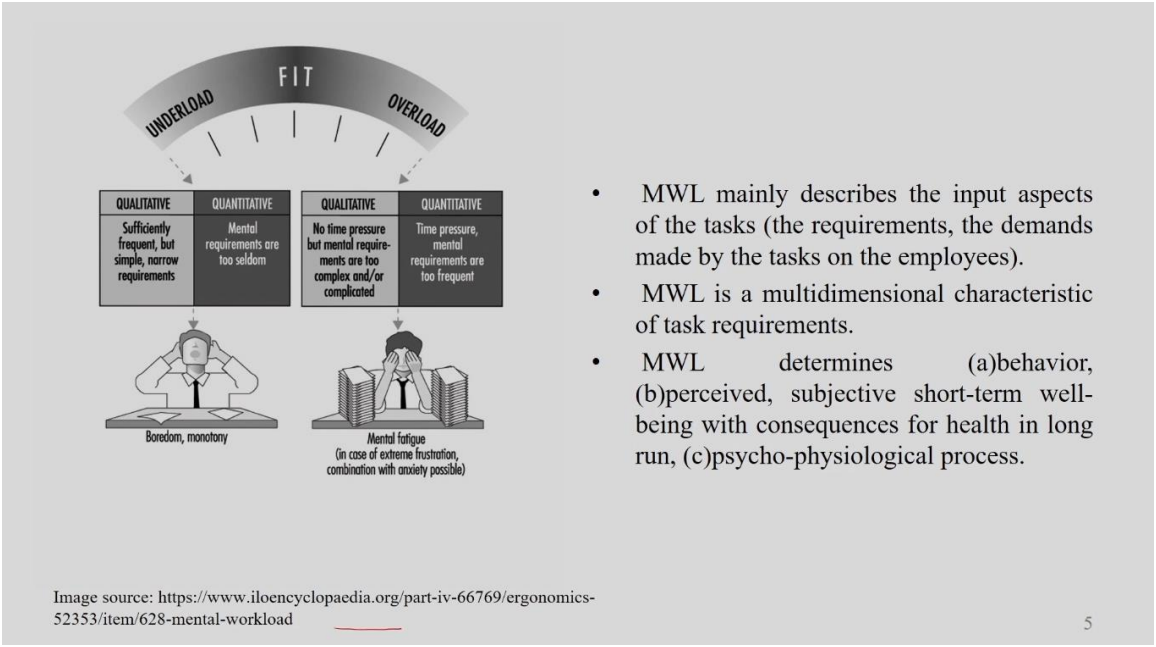
Workload and Situational Analysis Methods

So, for this we will be going for four major methodology or methods ok. So, first is NASA TLX, it is very commonly used tool to understand the mental workload. So, NASA task load index and the situation awareness rating technique ok. So, that we will be doing. Along with we will be doing multiple resource time sharing model. So, this model also we will be discussing critical path analysis and situational awareness global assessment technique. These four methods we will be discussing under this particular section ok. So, before we go into more detail of each individualmethods, first let us understand because this whole all these topic, all these methods basically related to the mental workload.



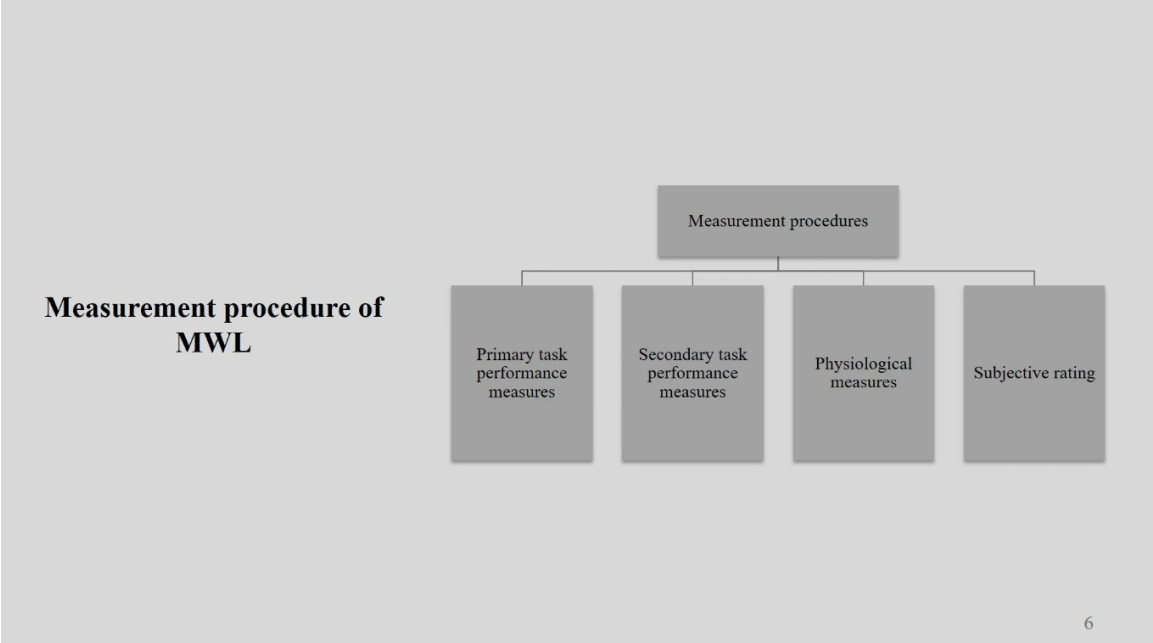
So, let us understand about what is mental workload and if we measure them what is the consequences and how it is useful to us ok. So, the amount of mental resources required to perform a set of concurrent task we will be calling it as mental workload ok. So, this particular definition specifically this part the concept exist from long back. However, this particular definition was given in 2002 by this particular fellow during one of his you know paper presentation. So, what it says- the amount of mental resources ok. So, maybe the memory, maybe the perception and all other information which is required. So, which those mental resources whatever is required to perform a set of concurrent tasks. So, if you have a task to finish. So, whatever mental requirements are if you are trying to analyze that that we will be taking that we will be calling it as mental workload or cognitive workload. So, sustained high mental workload will cause mental fatigue of course, it is very similar to our all the physical definitions right you know when a muscle is working for more than you know required time, what will happen the muscle will get fatigue. So, similarly for mental workload also if it persist for longer hours, longer duration or the intensity is very high in that case it will cause some kind of mental fatigue. And of course, if there is a fatigue it is expected that there will be the decrease in the performance because once there is a fatigue of course, the performance will get you know affected and it is in the deterioration. It it it actually declines ok and the detrimental health effects in long term. So, what happens in the physical fatigue, we realize that fatigue very easily, because it becomes prominent. However, in case of mental fatigue we may not understand or may not realize it on the spot. It is not definite on that particular point of time. However, it has bigger impact than than than the physical effect or physical fatigue. So, in comparison to the physical fatigue identifying the mental fatigue is difficult. However, the impact of mental fatigue is very very high

ok. So, Holm in 2009 they in his paper they claimed that if there is a sustained high mental workload it can cause mental fatigue, decreased performance and detrimental health effects in long run. Here again I am saying that physical fatigue identification is very easy, comparatively easy, not very easy. It comparatively easy as compared to you know mental workload and the effect the recovery is quite quick ok as compared to mental health. Whereas, if mental health or mental um workload you know sustained for longer hours definitely it has very detrimental health effect ok. So,before we go into the different methodology understanding the under load and overload is very important. If in a particular workstation or workplace somebody is overload feels overload due to different reason or due to different work demand, it can cause the mental fatigue. Whereas, in the opposite also if there is no load filled by the particular person or it cause the under load then also it can cause detrimental effect or it can cause mental fatigue. So, being an ergonomist our always like we always look for the optimization between the work demand and the capacity of the mental capacity ok. So, if we cannot do the optimization there will be either overload or under load and both under load and overload may cause mental fatigue.



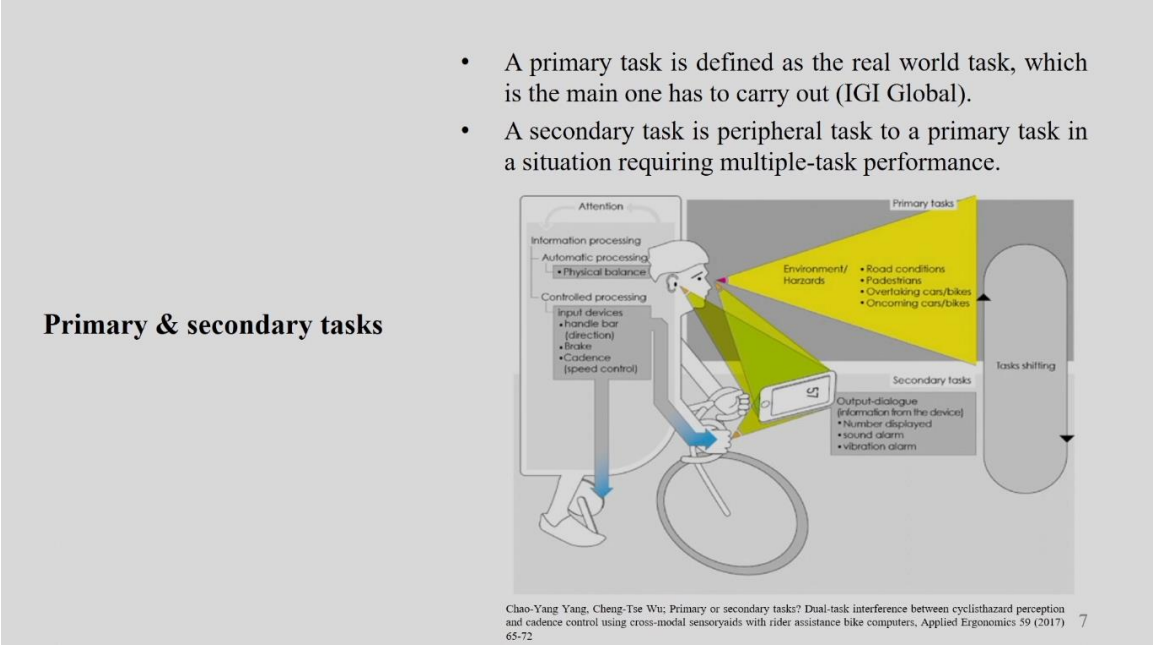
So, in this photograph you can see it is a image taken from this particular source. So, it is not claiming that you know we produced it, but this is very important to for us to understand this you know depiction ok. So, if it is overload then you know lot of you know problems happen ok. So, the person may feel lot of fatigue and you know the whole performance will deteriorate. Whereas, that opposite if it is under load then also similar kind of situation will occur. So, mental workload mainly describes the input aspects of the task, the requirements and the demands made by the task on the employee. And if it matches to the capacity or capability of that particular person it is optimized. If

it is not matching, if it is more than that then overload, if it is less than than, then under load. So, mental workload is a multi dimensional characteristics of a task requirement. So, mental workload determines the behaviorit perceives the subjective short term well being with you know consequences for health in long run and psychophysiological processes. So, all these three component behavior, perception of subjective short term well being with the consequences for health and the psychophysiological processes ok. So, it mental workload determines all these three factors and based on that consequences based on that feasibility only we can understand it is overload or under load. If it is overload we need to work on the reduction of the requirement whereas, if it is under load then we need to work on how to utilize that particular persons or operators capability or capacity in other task ok. So, understanding the mental workload in a particular situation in a particular workplace is very very important and that is why these tools are or methods are to identify them in the workplace ok.



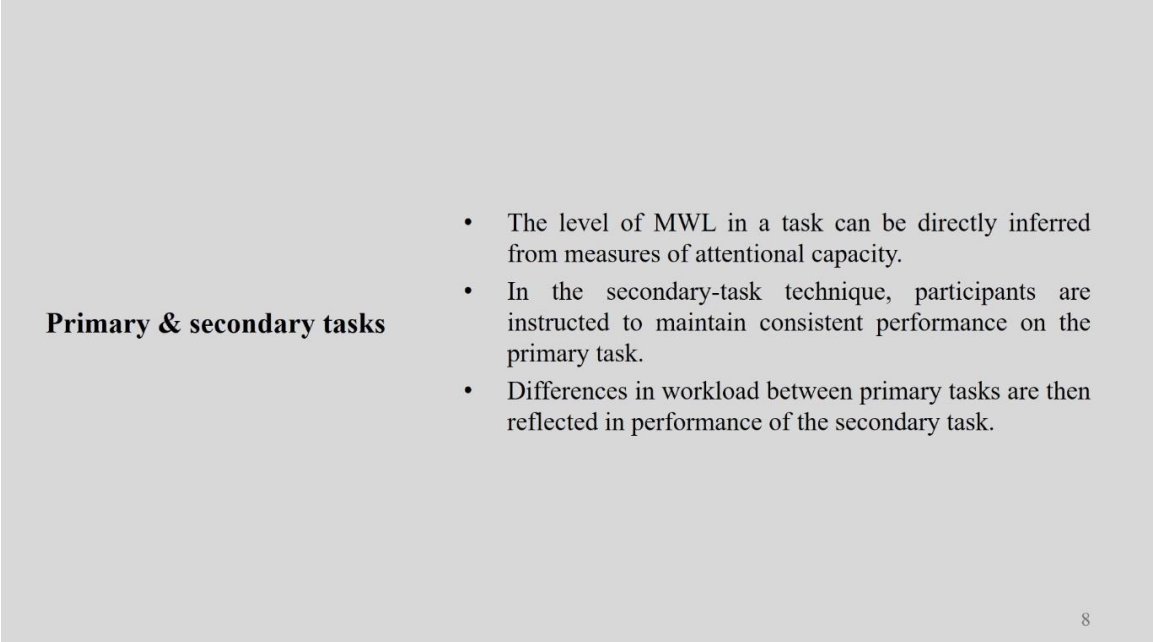
So, mental workload if we talk about this has major four what I can say structure. So, first is the identification of the primary task performance because when we are talking about a particular task there will be primary task and secondary task. So, identifying primary task performance and the secondary task performance are the major basic requirement and then the physiological measure because when you are doing a primary task or you are doing a secondary task you are connected with your the the physiological responses ok. So, that physiological measure. So, suppose you are tensed ok, you are doing some activity where you have a time pressure, ok within a stipulated time period you have to finish certain amount of job. So, you have a time pressure and then you are doing the job. So, that will get reflected on your varieties of physiological responses maybe breathing, maybe breathing pattern or maybe you know cardiovascular, cardio

respiratory parameters or maybe you know um fatigue ok. So, all these physiological responses can need to be checked or need to be measured when we are talking about mental health health as well as the subjective rating. Why subjective rating? Because perception of a particular work load is very subjective in nature. So, if I supposed to read a journal paper of 5 pages ok maybe within you know half an hour or 45 minutes I may not feel stress or I feel enjoyable because this particular subject is very much interesting to me. However, the person who is not to this particular field or this particular paper is not connected to his or her interest this 45 minutes is very much tiring for him or her right. So, subjective understand, the subjective rating is very very important when we are talking about this particular mental workload. So, when we are talking about mental workload measurement we have to understand what are the primary task performance measure, how do we actually measure the primary task performance, how do we measure the secondary task performance, primary task performance is like the performance which is directly connected to the goal of the system. Secondary will be surrounding ok which are subject you know near in the that particular environment. So, understanding the primary task performance and the secondary task performance and measuring that is very important for mental workload associated physiological measure and subjective ratings ok. These four components need to be measured when we are talking about mental workload measurement.

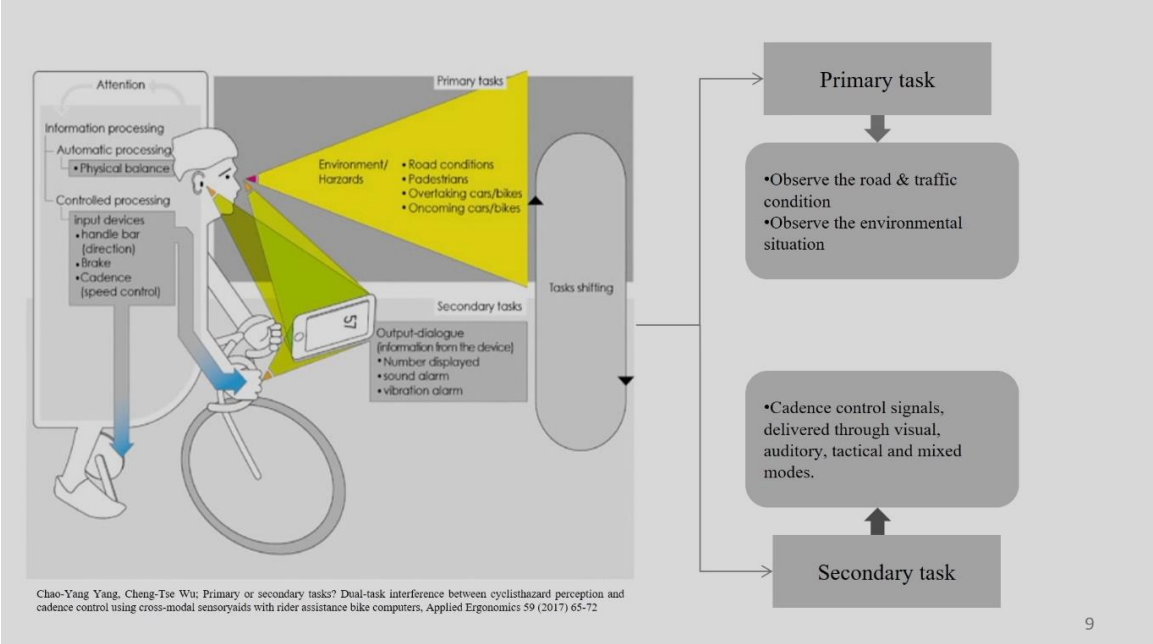


Now, let us understand in detail with an example for the primary and secondary task ok. So, what is the definition? A primary task is defined as the real world task which is the main one has to carry out by that particular person. So, if we talk about cycling, cycling you know using a cycle by cycle somebody has to go from one place to another. So, primary task is cycling. So, here you can understand how we have divided these things.

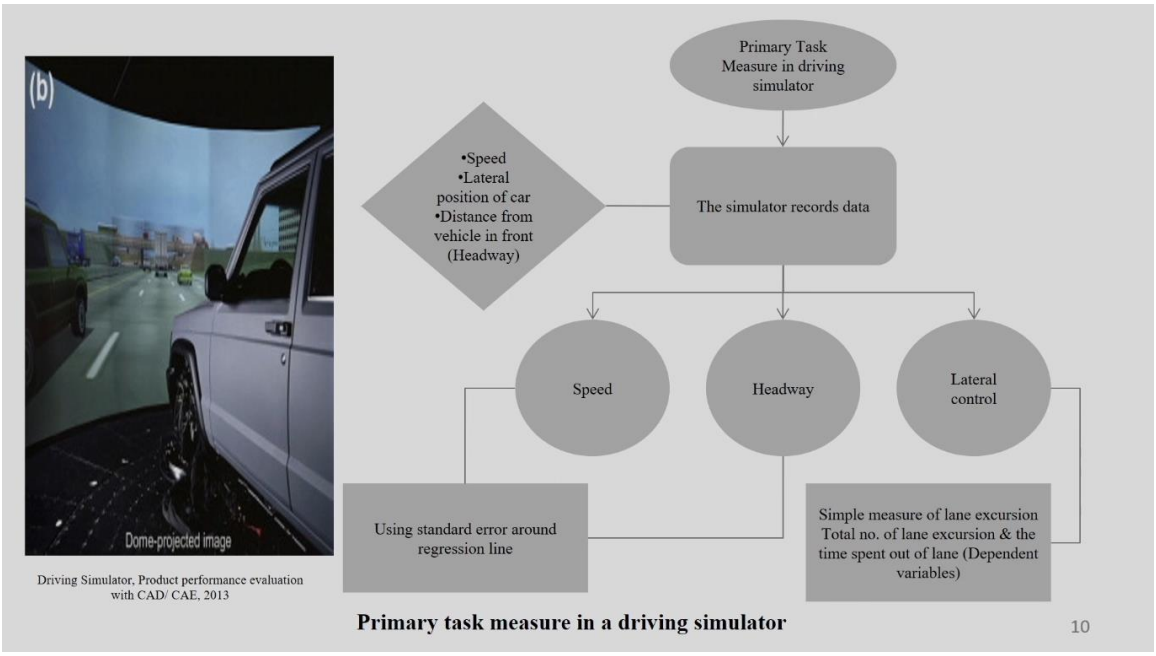
So, primary task what we are saying you need to understand the road condition, you need to understand the who are the pedestrian in that particular road, then overtaking the cars or bikes and over somebody is coming from the opposite side. So, these understanding is very much important when we are talking about the riding a bicycle. Whereas, secondary task will be what are the number of displays available in this if he or she has some different types of bikes. Then if there is some sound alarm, if some kind of vibration alarm. So, if some extra arrangements are there in that particular bicycle, how do we perceive it and respond towards that? So, that will be the secondary task. So, this particular example is given in this particular paper for more detail you can refer this particular paper. So, while doing this particular primary task and secondary task, what are the attentions required? So, information first the information will be processed through the automatic processing units. So, first is physical balance ok. So, when you are riding a bicycle you need to balance it physically and also you need to control the whole process like you know handle the particular bicycle bar and then brake and know when to paddle all these balancing and coordination propulsion, how it is moving, what is the road condition based on that how much force you need to apply. All these things are very much required when we are talking about primary task in the bicycle riding ok. So, so you you can understand from this particular thing that primary task and secondary task is in a circular mode. So, first you give more attention to the primary task and then you get also responses from the secondary task. Now, let us understand the definition of secondary task. A secondary task is the peripheral task ok. Primary task is the main task which they he or she need to perform ok. Without that the system will not function. Whereas, secondary task are the peripheral task to a primary task in a situation requiring multiple task performance ok. So, that is called secondary task. We will go for more example with driving simulator, then we can understand it more ok. So, this secondary task is very much connected to your reaction time ok. How quickly you are responding to a particular information ok.



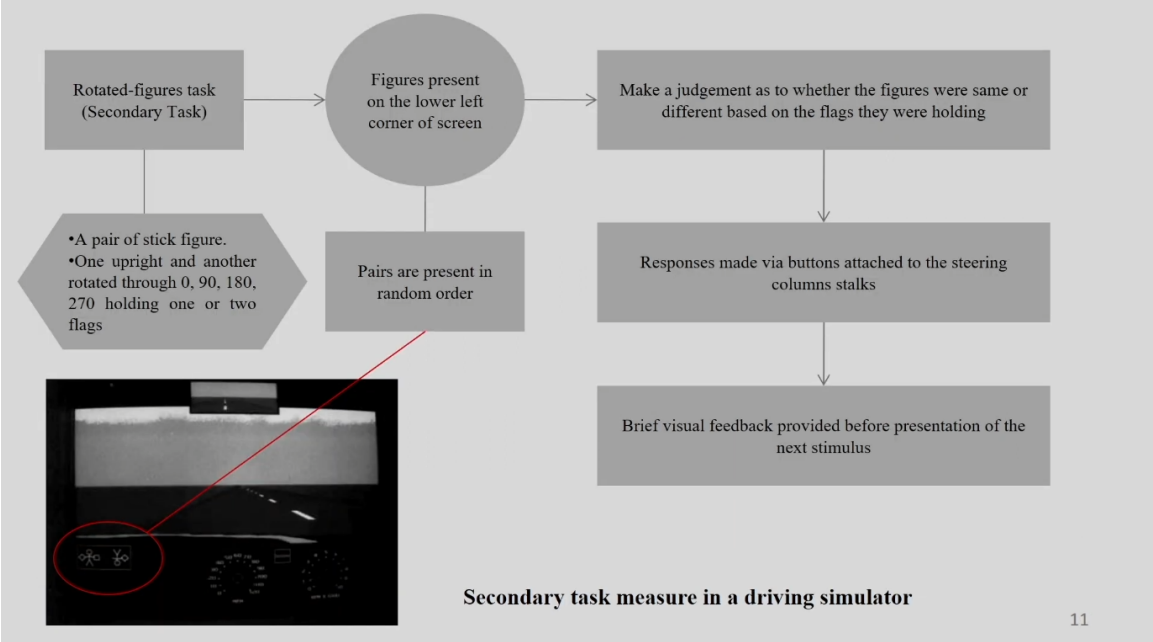
So, the level of mental workload in a task can be directly inferred from measures of attention capacity. In the secondary task technique participants are instructed to maintain consistent performance on the primary task. So, while performing the secondary task it is not desired that you are not maintaining the concentration or performance which is required to complete the primary task. So, primary task has to be fulfilled. Secondary task while doing the secondary task as well. So, you cannot compromise on the attention level of primary and secondary task. So, differences in workload between primary task are then reflected in the performance of the secondary task. So, if the primary task is very very crucial, very very critical in nature, then it is advised that in the whole design the secondary task or information related to secondary task should be minimal. If that is minimal then only the person will be able to give more attention to the primary task. However, if there is a diversion there is always a chance of accident or failure of the system. So, designing the designing the percentage contribution in a whole system of the primary task and secondary task is very very important and the decision has to be taken by the designer based on several you know experiments or experimental results ok. So, for each context primary and secondary tasks are different and the contribution need to be calculated beforehand. So, that there is less chance of accident. So, optimization of these two combinations are very important.



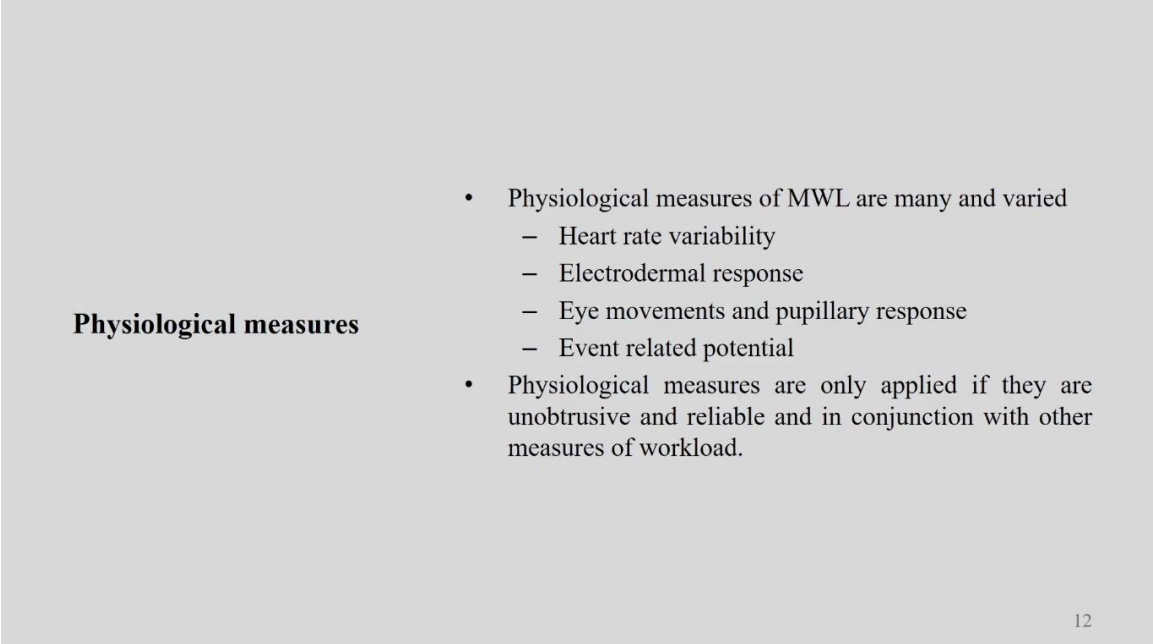
Now, if we go again we take this the earlier example. So, what it says that you know when there is a task shifting, first let us understand what how what are the primary and secondary task in this particular example. It says that observe in the primary task mainly the observe the road and traffic condition and observe the environmental situation ok. Whereas, in the second secondary task it says that you know condense the control signals delivered through visual auditory tactile or mixed mode ok. For these cases whenever these are you know going smoothly, the someone can pay attention over here definitely and this is vice versa it is you know it is in rotation. So, it keeps on getting the feedback ok. The same thing we mentioned from the same paper. So, you can refer the paper and you can get more detail about it ok.



Now, in a particular driving simulator for this particular example ok it is it is in 2013. So, what in this particular particular simulation technique or simulator what would they try to do when someone is driving or performing any task in the driving simulator, what are the major tasks or primary tasks available ok. So, here they understood first is speed, then is headway means what is the distance is there between the two car and the lateral control ok. So,the simulator records the data about all these three factors based on speed lateral position and distance from vehicle which is in front of that particular simulator ok. So, it is a simulator. So, they can and you can understand the speed and headway are connected you know it is a very complicated situation. If some car is you know about to stop ok you need to judge the speed of the car which is in front and accordingly you have to control the speed of your car also you have to take anaccount which is coming from behind. So, how so this this speed control and the headway understanding is very very important and this is the primary task whenever you are driving ok driving on a road and same thing can be measured in a driving simulator. And this can be you know using a standard error around the you know regression line you can understand this what is the connection between that what is the actual correlation between that ok.

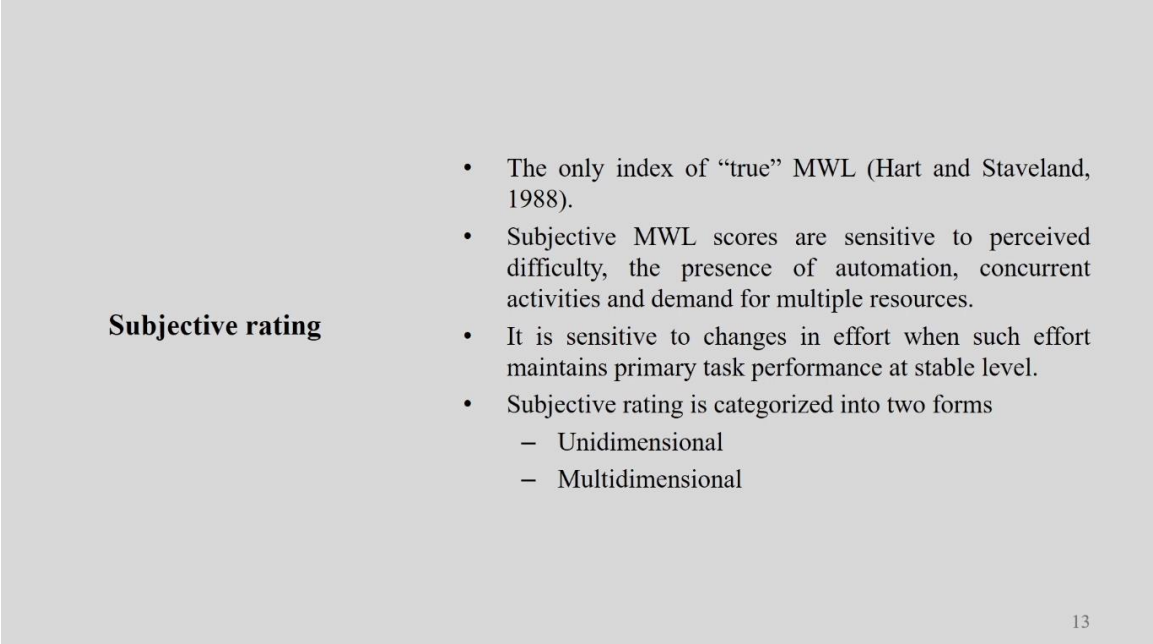


Now, for the secondary task in this particular driving simulator this particular experiment what they try to do while driving in a particular type of terrain, type of speed and the headways are you know varying continuously in the simulator. In that case if there is a secondary simulator stimulus ok stimulation then how quickly the driver is responding towards that. In this particular example you can see they mention there is two figures ok. So, what they have done they have you knowone vertical flag and another flag which is rotating from 0, then 90 degree, 180 degree and 270 degree. So, as soon as they are rotating at 90 degree you have to react to it, you have to give a response to it ok. So, using that particular data or using that particular reaction time data, the person can the the researcher can understand how quickly the responses can be grabbed and if the positions are this then how the perceptions will be ok. So, if you want to place you know maybe switch off your music system. So, if there is an error in that particular system how quickly you will be able to control it ok. So, if you want to understand that position, location and all those things maybe using this type of simulation you can do experiment and you can understand what is the impact of such secondary task on the primary task impact ok. So, that way it is possible.



Now, when we are talking about primary task and secondary task and the mental workload as I mentioned earlier, it is very much connected to your physiological variables ok. Because when there is a stress, when there is a demand from the work situation or if there is no demand in that particular work work place or work station then definitely there is an impact on the physiological variables. So, major variables are heart rate variability, electro dermal responses. So, you can get from the skin and then eye movement and pupillary response. So, gaze time, saccadic movement on all those things. So, these experiments maybe few of the experiments we can take it up in the laboratory and we may able tosee that how it is you need to collect data ok. So, through using eye tracking system we can have this type of small experiments ok. If there is an there is a you know simulation, there is a input primary responses ok, primary data then how your physiological changes are happening and the event related potential. So, all these are the varieties of physiological variables that you can measure. However, these are not only things you can have more physiological variable based on the type of objective you have in your research. So, physiological measures are only applied if they are unobtrusive ok. If it is unobtrusive then only they are applied and reliable and in conjunction with other measures of the workload. Individually these variables may not make any kind of sense. So,if you are doing the changes, the changes or intensity changes in the primary task how the physiological responses are changing. So, that impact you can see, but individually if you see in a particular you know single condition the physiological responses that may not interpret your data, it will not be possible to interpret the data ok. So, if the intensity is changing or frequency is changing or severity is changing of the primary task and secondary task and what is the impact is there on the responses physiological responses that you can measure. So, before after or you know 4-5 simulated

condition, what is acting best optimization those things you can identify using these physiological variables.



Subjective rating again as I mentioned as mental workload is very much subjective in nature, we really need to understand what is subjective rating. So, it is like you know the only index of true mental workload that is being identified by you know explained by Hart and Staveland in 1988. So, subjective mental workload scores are sensitive to perceived difficulty ok. So, that is why I am saying this is very much different from one person to another. The presence of automation, concurrent activities and the demand for multiple resources. So, how they are responding towards all these thing. It is sensitive to change the effect when each effort ok, if when each effort maintains primary task performance at stable level. Because if the primary task performance differ then there will be a difficulties to understand the subjective rating. So, keeping a primary task level constant, you can see what is the impact is happening from the perception level ok. So, for us typical set of primary task, how that particular primary task is being perceived by different group of people and how what is the differences are ok. So, that way the subjective rating will tell which group of people is suitable are you know are suitable for that particular task.

So, subjective rating is categorized into two major form unidimensional and multidimensional. So, here as as it you know in a schematic diagram. So, unidimensional means to be simpler to apply and analyze, but offer only general workload score whereas, multidimensional subjective rating provide some diagnostic for identifying the sources of mental workload ok. Here for the one-dimensional. It is a very much general workload score. So, it says yes there is an workload, mental workload. Whereas in the multidimensional there is a chance that you get a direction what is the sources of those mental workload ok. So, that is the difference. So, now, let us go into individual tool. Understood till here we try to understand what is mental workload, what are the you know dimensions are available for mental workload. Now, we will start with the single method.

NASA-task load index (TLX)

- It is a multi-dimensional subjective workload rating technique.
- It determines the MWL of a participant while they are performing a task.
- The subjective experience of workload is defined as an integration of weighted subjective responses (emotional, cognitive and physical) and weighted evaluation of behaviours.

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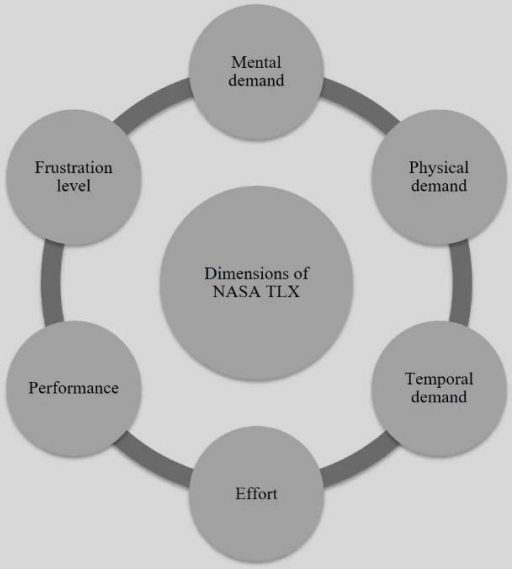
So, first I will start with the NASA TLX. So, it is a multidimensional subjective workload rating technique. It determines the mental workload of a participant while they are performing a particular task. The subjective experience of workload is defined as an integration of weighted subjective response. So, very important integrated weighted subjective response and the weighted evaluation of the behavior ok. So, this this will give you the indication what are the possible sources of mental workload for a particular situation.

NASA-task load index (TLX)



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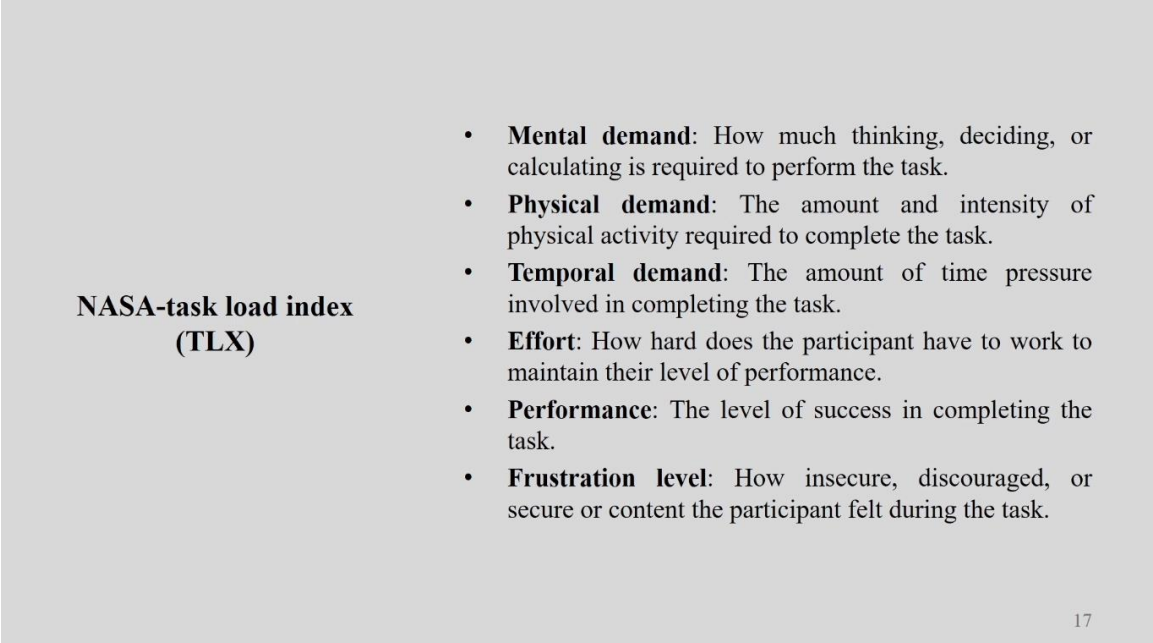
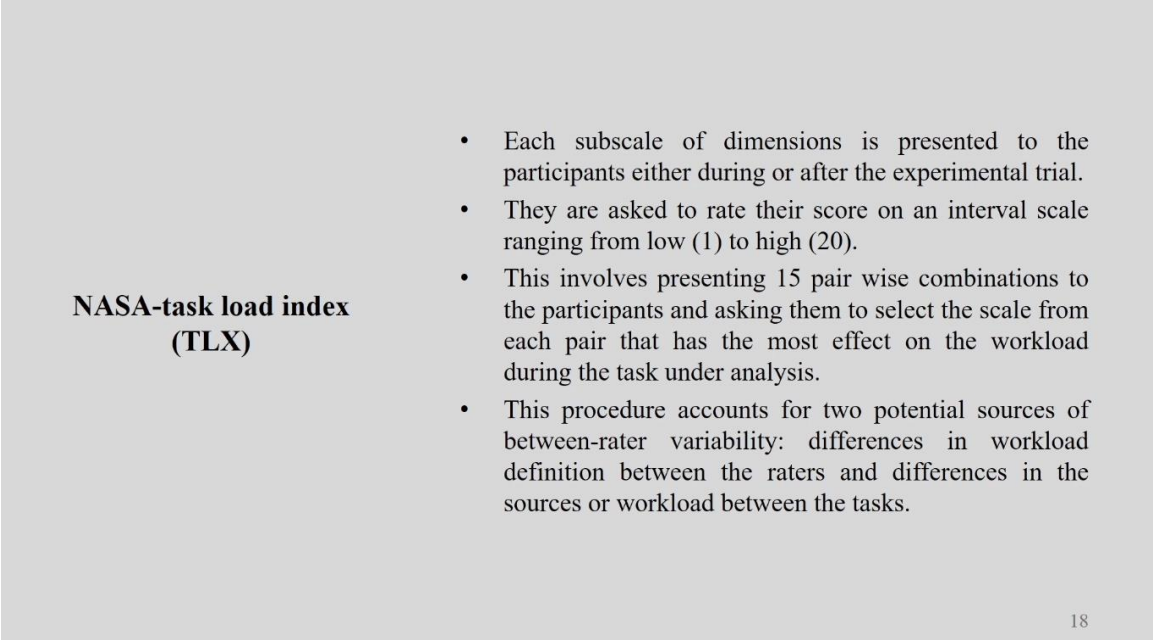
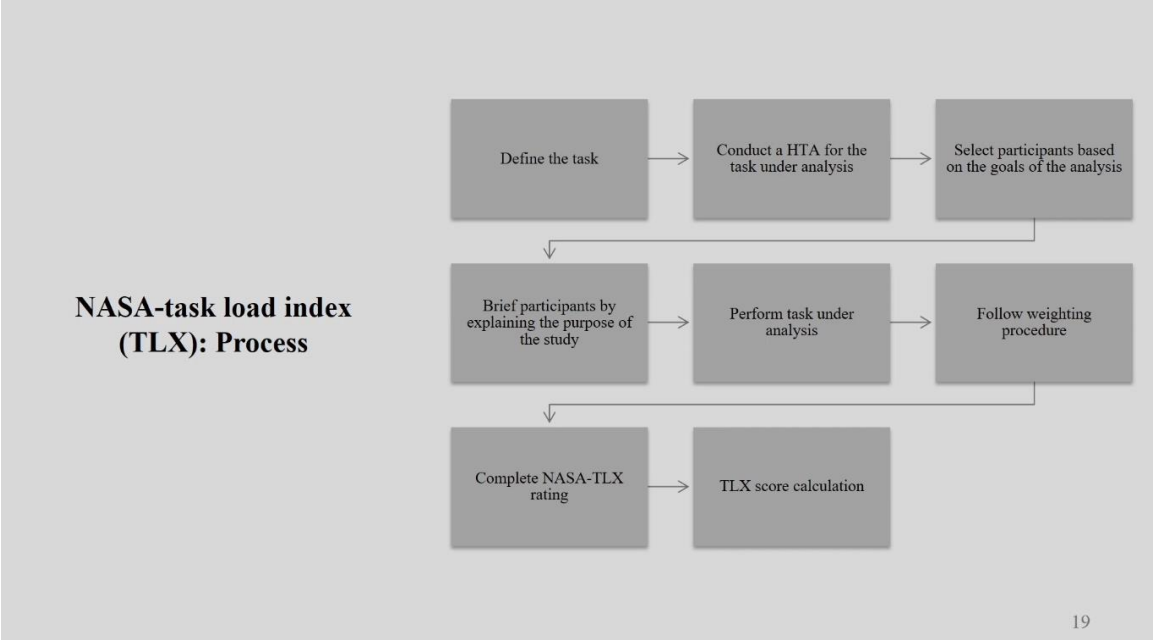
So, these are the main dimensions ok 6 major dimensions when we talk about NASA TLX. So, mental demand, physical demand because you know mental demand and physical demand they are both very much connected. If you are physically tired it may also cause you mentally tired. If you are mentally tired you may feel you are physically tired. So, this mental understanding the mental demand and physical demand at a single space is very very crucial and this NASA TLX because it is a multidimensional. So, it actually gives you an better understanding what are the kind of sources you have for the mental workload. Then temporal demand, effort, performance and frustration level these are the major 6 dimension that normally talked in the NASA TLX.



So, let us understand what are these factors. So, mental workload. So, mental workload says how much thinking or deciding or calculating is required to perform a particular task. So, when you are doing a particular task or when you are performing a particular task it says that how much thinking is required, how much decision making is there or how much calculation you need to do before you go for this particular task. That is mental demand. Whereas, in physical demand the amount and intensity of physical activity which is required to complete the task. So, force measurement and all those things ok. Temporal demand, the amount of time pressure involved in completing that particular task. Effort, how hard does the participant have to work to maintain their level of performance this is very important ok. So, again very very subjective in nature. So, how hard does the participant have to work to maintain their level of performance. Then performance, the level of success in completing that particular task and frustration level how insecure, discouraged or secure or content the participant felt during that particular task ok. So, job satisfaction it is very much connected to the job satisfaction.



So, each subscale ok. So, these all are what we can say the domains of NASA TLX and it has allscaling ok. So, each subscale of dimensions all these six dimension is presented to the participant either during or after the experimental task. So, depending on what type of experiment you are doing, depending on that you have to produce it. They are asked to rate their score on an interval scale ranging from 1 to 20, 1 represent low and 20 represent high. This involve presenting 15 pair wise combination to the participant and asking them to select the scale from each pair that has the most effect on the workload during the task under analysis. This particular procedure accounts for two potential sources of between rater variability, differences in the workload definition between the raters and the differences in the sources or workload between the task.



So, let us understand the procedure for NASA TLX. First you need to define the task, conduct of course, HTA we cannot deny HTA whenever we are talking about know any mental workload or cognitive behavior analysis. So, HTA for the task under analysis, then select participants based on the goals of the analysis. So, who are the you know sample, so sample selection, then what you need to do, you have to brief the participant by explaining the purpose of that particular study that perform that task under analysis. So, whatever task you have done the hierarchical task analysis and the same task to need to be performed by the by those group of people. Follow the wing procedure and then complete the NASA TLX rating and get the TLX score calculation.

Title	Endpoints	Descriptions
Mental demand	Low/ high	How much mental and perceptual activity was required? (e.g., thinking, deciding, calculating, remembering, looking, searching) Was the task easy or demanding, simple or complex, exacting or forgiving?
Physical demand	Low/ high	How much physical activity was required? (e.g., pushing, pulling, turning, controlling, activating) Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
Temporal demand	Low/ high	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
Performance	Good/ poor	How successful do you think you were in accomplishing the goals of the task set by the experimenter? How satisfied were you with your performance in accomplishing these goals?
Effort	Low/ high	How hard did you have to work (mentally and physically) to accomplish your level of performance?
Frustration level	Low/ high	How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed, and complacent did you feel during the task?

NASA-TLX rating scale definition

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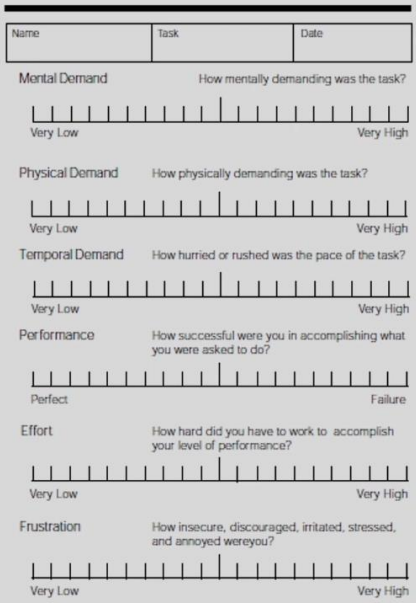
So, this is the rating scale identification, here you have all these dimension mentioned here and for all the cases starting point is low, low, low, here also low whereas, in the performance you have good from the left hand side it is good whereas, the right extreme right hand side it is poor. So, all the cases it is you know low on the left hand side, extreme right is high whereas, for performance extreme left is good and extreme right is poor. So, what it says? So, first the mental demand it says how much mental demand and perceptual activity was required. Again it is a perception right. So, how much mental and perceptual activity was required? For example, thinking, deciding, calculating, remembering, looking, searching etcetera was the task easy or demanding, simple or complex, no exacting or forgiving. So, these type of descriptions you have in the mental demand. Now, coming to physical demand, it talks about how much physical activity was required. So, was that particular task was easy or demanding, slow or very fast, slack or strenuous, restful or laborious. So, you need to understand for all these things you need to give a rating. For temporal how much time pressure did you feel due to the rate or pace at which the task or task elements need to be carried out or occurred. So, it is very much connected you know when there is a workflow somebody there is a you know something is coming and you have to do the work. So, those cases it is very much connected. So, was the pace was slow or okay leisurely or very rapid or you know it is very difficult to cope up. So, how do you rate them? Okay. Then performance, how successful do you think you were in accomplishing the goal of the task set by that particular experimenter. So, how satisfied were you with your performance in accomplishing those goals. So, these are the kind of questions you can you have to ask during the analysis of the you know data collection of your performance. Then effort, how hard did you have to work to accomplish your level of performance. So, you are trying to understand from a person how much effort they have they need to put for completing that particular task and the frustration level again low and maximum is high. So, how insecure, discouraged, irritated, stressed or annoyed versus secure you know gratified, content, relaxed and you know complimented. So, where it is? It is on the left side or right side you need to get the answer from the participant about the frustration level while doing that particular job or particular task okay. So, this is basic description.

NASA-task load index (TLX)



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Now this is how this particular scale looks like.

Advantages

- **Primary task**: Direct index of performance; effective in measuring long periods of workload and performance, overload and individual differences in resources competition.
- **Secondary task**: Can discriminate between tasks when no differences are observed in primary performance; useful for quantifying short periods of workload, spare attentional capacity, and even atomicity.
- **Physiological**: Continuous monitoring of data; increased sensitivity in measurement; does not interfere with primary task performance.
- **Subjective**: Easy to administer and analyze; provides an index of perceived strain; multidimensional measures can determine the source of MWL.

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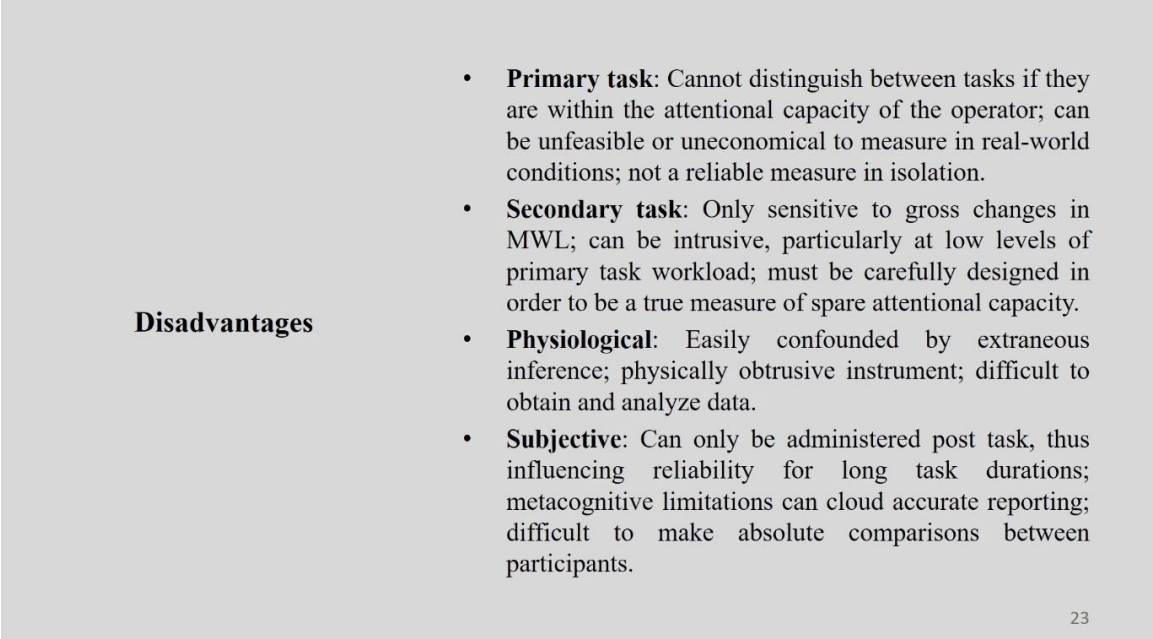
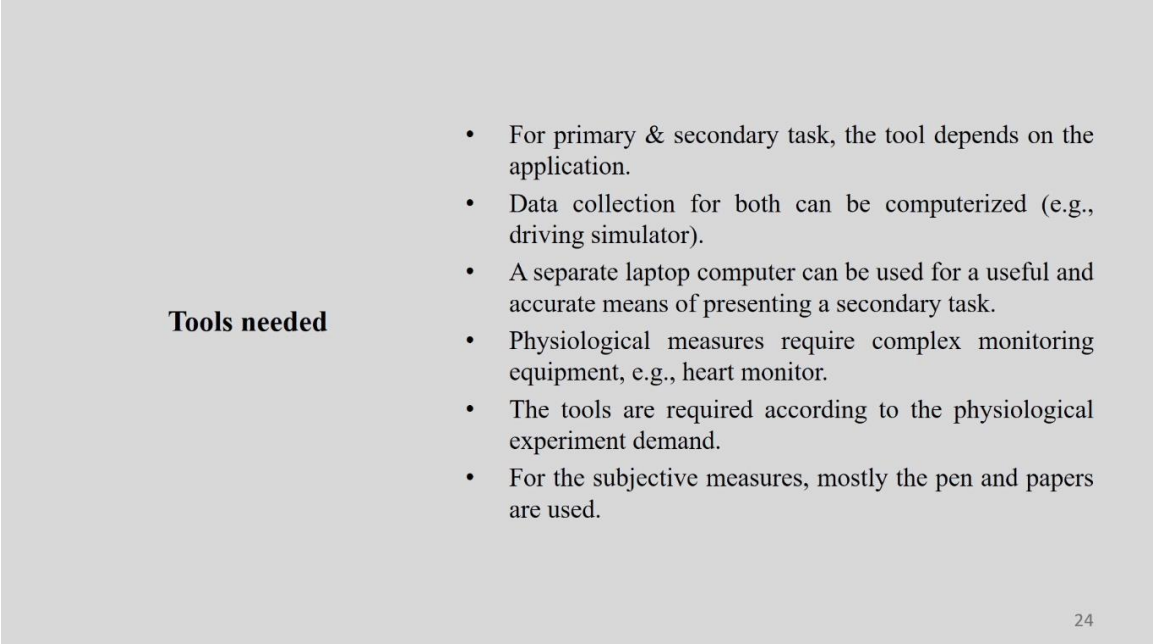
So, when we are talking about NASA TLX there are lot of advantages, also disadvantages okay. So, first let us understand when we are talking about primary task, secondary task, physiological and subjective responses okay. So, how what are the advantages are? When we are talking about primary task, so direct index of performance we are getting from NASA TLX. It is effective in measuring long periods of workload and performance, overload and individual differences in resources competition. Whereas in the secondary task it can discriminate between task when no differences are observed

in primary performance okay. So, when there is no differences in the primary performance also it is useful for quantifying short periods of workload, spare attention capacity and even automicity okay. So, from NASA TLX for primary task and secondary task these are the two major advantages. Now coming to physiological factors or physiological raters its continuous monitoring of a data and increased sensitivity in measurement does not interfere with primary task performance. Whereas when we talking about subjective rating, it is easy to administer and analyze it provides an index to a perceived strain multi-dimensional measures can be determined the sources of mental workload okay. So, these are the major advantages for NASA TLX.



However, again we have you know disadvantages as as well. So, let us understand what are those disadvantages. So, based on the context of your application you need to choose is NASA TLX is helpful or not helpful okay. So, let us go one by one primary task it cannot distinguish between the task if they are within the attentional capacity of the operator. It cannot discriminate okay and can be unfeasible or uneconomical to know measure in real world condition and not a reliable measure in isolation. So, that is for the primary task. For secondary task only sensitive to gross changes in mental workload of course, okay it cannot do the fine tuning okay. It can be intrusive particularly at low levels of primary task workload must be carefully designed in order to be a true measure of you know spare emotional attentional capacity. In case of physiological responses easily you know it is confounded by the extraneous interference because you know suppose heart rate variability. For any other involvement like you know something extra effort or personal factor actually affect the physiological variables. So, for those cases it is actually a disadvantage. So, physically obtrusive instrument difficult to obtain and analyze those data. So, when you are talking about mental workload you need to give the

same conditions very similar condition as actual or as real. However, for physiological data you really need to have lot of instrument connected. So, very difficult for you know actually getting such data. In case of subjective can only be administered post task okay. During task it is not possible thus influencing the reliability for a long task duration because if task is very long what happened in the initial stage and what happened in the last stage of the task. It is like very difficult to understand when the task is completed and you are getting the data okay. It is like metacognitive limitations can you know cloud accurate reporting and difficult to make absolute comparisons between the participants because absolute comparison is really not possible because it is very very subjective in nature okay. So, these are the disadvantages of NASA-TLX.



Now, let us understand what are the tools required to come you know to perform NASA-TLX. So, for primary and secondary task the tool dependent depends on the application. Data collection for both can be you know computerized you know for example, maybe driving simulator or any other simulator where you nearly need to understand okay primary and secondary. So, any simulation is possible you know some cases separate laptop or computer desktop can be used for a useful and accurate means of performing a secondary task. Physiological measures require complex monitoring equipment like heart rate monitor, maybe skin conducting you know monitor or many other physiology EMG or many other things okay, EEG sometimes okay. So, the tools are required according to the physiological experiment demand as I mentioned based on the objective of your research you need to introduce what are the physiological variables you are looking for. For the subjective measures mostly the pain and papers are normally being used because you ask them to rate it on the pen and paper. It can online also however, it is best that you have the data with you so, pain and paper method okay. So, that is all for

NASA-TLX. For next class we will be talking about the multi resource time sharing model okay. So, you all practice NASA-TLX for your context for your situation if you have any doubt we can discuss in the discussion session. Thank you. Thank you.