1. Photopic & Scotopic Vision

https://www.wikilectures.eu/w/Photopic_and_scotopic_vision

Photopic vision

Photopic vision is the vision of the eye under well-lit conditions, normally usual daylight light intensity. It allows colour perception which is mediated by cone cells. Cone cells have a higher visual acuity as well as providing the eye's colour sensitivity. There are three types of cone cells to sense light for three bands of colour. Out of the six to seven million cone cells in the eye, 64% would be considered 'red' cones, 32% would be considered 'green' cones and 2% would be 'blue' cones. (Blue cones also have the highest sensitivity.

Scotopic vision

Scotopic vision is the vision of the eye under low light conditions. Cone cells do not function as well as rod cells in low level lighting so scotopic vision happens completely through rod cells, which are most sensitive to wavelengths of light on the electromagnetic spectrum of 498nm, which would be the blue-green bands of colour.

Mesopic vision

Mesopic vision is the type of visions that takes place in intermediate lighting conditions. It is basically a combination of photopic vision and scotopic vision, so both cone cells and rod cells are being used.

http://isle.hanover.edu/Ch03Eye/Ch03PhotopicScotopic_evt.html

The duplex theory of vision refers to the idea that there are functionally two distinct ways that our eyes work. The first system is called the photopic and the second is the scotopic system. The *photopic* system is associated with the cones, and the other, the *scotopic* system, is associated with the rods. The duplex theory is the idea that our visual system can operate in fundamentally different ways, depending upon the conditions in the environment. Daytime is the domain of photopic vision, but nighttime is when our scotopic vision comes to the forefront. These hypothesized differences in visual function derive from the following observations. First, rods are more sensitive to light overall than cones. Second, rods are most sensitive to different wavelengths than the cones are. That is, they have a different spectral sensitivity. Third, rods and cones have different spatial and summation properties, which we discuss shortly. And finally, cones support color vision but rods do not. In general, the photopic system is associated with daytime vision, and the scotopic system is our night vision system. However, there is a range of intermediate ambient light intensity in which both systems are working. This intermediate zone is said to be mesopic vision.

2. Saccade & Fixation

https://www.tobiipro.com/learn-and-support/learn/eye-tracking-essentials/types-of-eye-movements/

Fixations are the most common feature of looking that eye tracking researchers analyze to make inferences about cognitive processes or states that they are interested in probing.

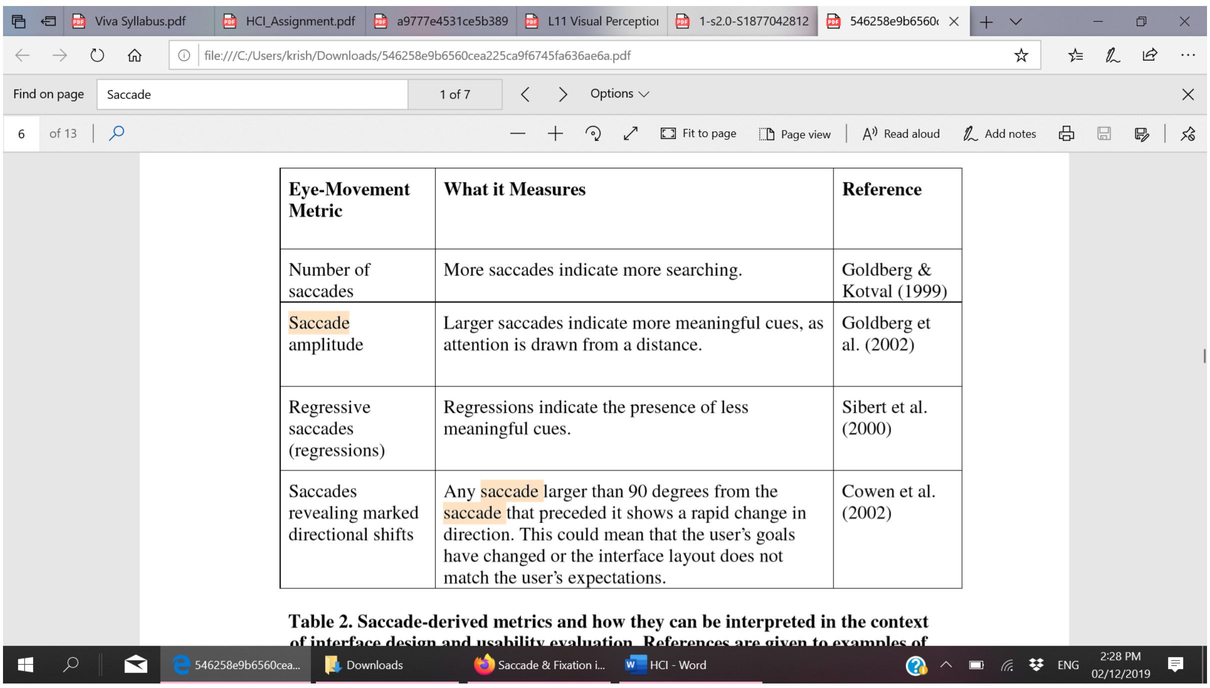
Fixations are those times when our eyes essentially stop scanning about the scene, holding the central foveal vision in place so that the visual system can take in detailed information about what is being looked at.Saccades are the type of eye movement used to move the fovea rapidly from one point of interest to another, while a fixation is the period of time where the eye is kept aligned with the target for a certain duration, allowing for the image details to be processed. Our perception is guided by alternating these sequences of fixations and saccades (see figure on the left). Due to the fast movement during a saccade, the image on the retina is of poor quality and information intake thus happens mostly during the fixation period.

Saccade facts:

- can be triggered voluntarily or involuntarily
- both eyes move in the same direction
- the time to "plan" a saccade (latency) is task dependent and varies between 100-1000 ms
- the average duration of a saccade is 20-40 ms
- the duration of a saccade and its amplitude are linearly correlated, i.e. larger jumps produce longer durations
- the end point of a saccade cannot be changed when the eye is moving
- Saccades do not always have simple linear trajectories

Fixation facts:

- a fixation is composed of slower and minute movements (microsaccades, tremor and drift) that help the eye align with the target and avoid perceptual fading (fixational eye movements)
- the duration varies between 50-600 ms (however longer fixations have been reported)
- the minimum duration required for information intake depends on the task and stimulus



Eye-Movement Metric	What it Measures	Reference
Number of saccades	More saccades indicate more searching.	Goldberg & Kotval (1999)
Saccade amplitude	Larger saccades indicate more meaningful cues, as attention is drawn from a distance.	Goldberg et al. (2002)
Regressive saccades (regressions)	Regressions indicate the presence of less meaningful cues.	Sibert et al. (2000)
Saccades revealing marked directional shifts	Any saccade larger than 90 degrees from the saccade that preceded it shows a rapid change in direction. This could mean that the user's goals have changed or the interface layout does not match the user's expectations.	Cowen et al. (2002)

Table 2. Saccade-derived metrics and how they can be interpreted in the context of interface design and usability evaluation. References are given to examples of

3. Peripheral Vision

https://www.webmd.com/eye-health/common-causes-peripheral-vision-loss#1

It's what allows you to see objects all around you without turning your head or moving your eyes. It helps you to sense motion and walk without crashing into things. It's what you use to see something "out of the corner of your eye."

Picture this: You look through a peephole and stare straight ahead. You see everything above, below, and to your sides. Suddenly, the peephole gets smaller and smaller. You see everything in front of you, but everything above, below, and around you goes black. It's like you're looking through a narrow tube or a tunnel.

This is how it feels to have "tunnel vision" -- a loss of your peripheral vision. Most often, it's a side effect of other medical conditions. Two of these, glaucoma and retinitis pigmentosa, are among the most common.

http://www.breck-mckye.com/blog/2012/08/human-vision-for-ui-designers/

Peripheral vision is motion sensitive, detail insensitive. It's not just the sight cells that are different in the periphery, but the nerve cells, too. Peripheral vision is dominated by so-called 'Y' cells, that are more responsive to rapid changes than sustained stimuli. The result is that peripheral vision is extremely motion sensitive – good for early humans when a rapid motion on the flank might be a hungry predator approaching. The tradeoff, however, is that peripheral vision can't resolve detail or shape as well as the fovea, whose 'X' cells are more sensitive to sustained signals, giving it more precision.

Peripheral vision is colour blind
You may know that vision cells are divided into those sensitive to brightness and those sensitive to colour – rods and cones respectively. What you may not know is that they are distributed unevenly across the retina, with colour cells focused in the fovea and sparse in the periphery. The result is that the further away from the fovea we go, the poorer peripheral vision is at resolving colour. At the outer edges of our vision, in fact, we're practically colour-blind.

4. Acoustic Shadow

https://en.wikipedia.org/wiki/Acoustic_shadow

An **acoustic shadow** or **sound shadow** is an area through which sound waves fail to propagate, due to topographical obstructions or disruption of the waves via phenomena such as wind currents, buildings, or sound barriers.

A short-distance acoustic shadow occurs behind a building or a sound barrier. The sound from a source is shielded by the obstruction. Due to diffraction around the object, it will not be completely silent in the sound shadow. The amplitude of the sound can be reduced considerably, however, depending on the additional distance the sound has to travel between source and receiver.

5. Sensory Thresholds

https://www.youtube.com/watch?time_continue=6&v=BRxAlnhxrSs&feature=emb_logo

https://www.chegg.com/homework-help/definitions/sensory-threshold-13

A sensory threshold is the level of strength a stimulus must reach to be detected. Psychologists study sensory thresholds to learn how humans and animals process sensory information. An absolute threshold is the lowest level of strength necessary for detection. For example, when sounds are just loud enough to hear (but no louder), they occur at the absolute threshold. Absolute thresholds vary according to sensory adaptation (diminished sensitivity to stimulus after prolonged exposure). Animals often have different absolute thresholds than people. The differential threshold is the point of lowest intensity at which one can tell that a stimulus has strengthened. A closely related topic is subliminal perception, the unconscious detection of a brief, subtle stimulus; whether this occurs is controversial.

6. Sensory Information Store

https://human-memory.net/sensory-memory/

Sensory memory is the shortest-term element of memory. It is the ability to retain impressions of sensory information after the original stimuli have ended. It acts as a kind of **buffer** for stimuli received through the **five senses of** sight, hearing, smell, taste and touch, which are retained accurately, but very briefly. For example, the ability to look at something and remember what it looked like with just a second of observation is an example of sensory memory.

The sensory memory for visual stimuli is sometimes known as the **iconic memory**, the memory for aural stimuli is known as the **echoic memory**, and that for touch as the **haptic memory**. Smell may actually be even more closely linked to memory than the other senses, possibly because the **olfactory bulb** and **olfactory cortex** (where smell sensations are processed) are physically very close – separated by just 2 or 3 synapses – to the **hippocampus** and **amygdala** (which are involved in memory processes). Thus, smells may be more quickly and more strongly associated with memories and their associated emotions than the other senses, and memories of smell may persist for longer, even without constant re-consolidation.

7. Visual Masking

7) Visual Masking
It is a phenomenon of visual perception. It occurs when the visibility of one image, called a target, is reduced by the presence of another image, called a mask.
The target might be invisible or appear to have reduced contrast or lightness.
3 diff. timing arrangements for masking:
→ forward masking : mask precedes the target
→ backward : mask follows target
→ simultaneous : mask & target are shown together
2 diff. spatial " " :
→ pattern masking : occurs when m & t overlap
→ metacontrast : do not overlap

http://www.scholarpedia.org/article/Visual_masking

Visual masking is the reduction or elimination of the visibility of one brief (≤ 50 ms) stimulus, called the "target", by the presentation of a second brief stimulus, called the "mask".

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2864989/

Masking is an important part of the study of perception and cognition. It is used both to investigate the properties of the visual system and as a tool to isolate many other aspects of cognition. Two applications of masking deserve special notice.

Consciousness research. Masking can systematically control the degree of conscious registration of a stimulus. Thus, masking provides an excellent paradigm to investigate the dynamics of conscious and unconscious processing Recent work also uses masking techniques to connect conscious awareness to neurophysiological properties. Importantly, while much research on consciousness involves the study of neurologically impaired patients , masking can be used to study the distinction between conscious and unconscious processing in normal observers. The special issue covers research concerning the impact of masked unconscious input on attention (Scharlau, this volume), semantic processing (Kiefer, this volume), and response activation Correspondingly, single cell recordings and brain imaging techniques combined with visual masking have provided new insights about which brain areas are involved in conscious and unconscious vision This and related work shows that even during the processing of unconscious inputs, large networks can be recruited. Thus, both psychological experiments and brain research on visual masking suggest that unconscious vision plays an important role in human cognition and can be studied in a rigorous way.

Visual processing. Masking has been used to study detailed properties of the visual system itself. The application of masking to visual processing encompasses a broad range of areas including the perception of contour (Francis, this volume), motion (Öğmen, this volume; Otto, this volume), colour, pattern (Herzog, this volume), stimulus brightness (Rudd, this volume), and spatial location (Breitmeyer, this volume).

8. Auditory Masking

https://www.sweetwater.com/sweetcare/articles/what-auditory-masking/

Auditory masking is when the perception of one sound is affected by the presence of another sound. Masking can be simultaneous or non simultaneous. For this discussion we will focus on simultaneous masking.

This is when a signal, the sound that is desired to be heard, is made inaudible by a masker, noise or unwanted sound that is present throughout the signal.
A not masked threshold is the quietest level of the signal which can be perceived in quiet. Masked thresholds are the quietest level of the signal perceived when presented in noise. The amount of masking is the difference between the masked and not masked thresholds. For example if the masked threshold is 20dB and the not masked threshold is 35dB the amount of masking would be 15dB.

The basic masking test involves the not masked thresholds being measured on a subject. Then the masking noise is introduced at a fixed sound level and the signal is presented at the same time. The level of the signal is varied until the new threshold is measured. This is the masked threshold.

The phenomenon of masking is often used to investigate the auditory system's ability to separate the components of a complex sound. For example if two sounds of two different frequencies (pitches) are played at the same time, two separate sounds can often be heard rather than a combination tone. This is otherwise known as frequency resolution or frequency selectivity. Frequency resolution is thought to occur due to filtering within the cochlea, the hearing organ in the inner ear. A complex sound is split into different frequency components and these components cause a peak in the pattern of vibration at a specific place on the basilar membrane within the cochlea. These components are then coded independently on the auditory nerve which transmits sound information to the brain. This individual coding only occurs if the frequency components are different enough in frequency, otherwise they are coded at the same place.

Masking illustrates the limits of frequency selectivity even in a normal hearing person. If a signal is masked by a masker with a different frequency to the signal then the auditory system was unable to distinguish between the two frequencies. Therefore by carrying out an experiment to see the conditions which are necessary for one sound to mask a previously heard signal, the frequency selectivity of the auditory system can be investigated.

9. Haptic & Tactile Perception

https://www.youtube.com/watch?v=6wJ9Aakddng

https://www.sciencedirect.com/science/article/pii/S2096579619300166

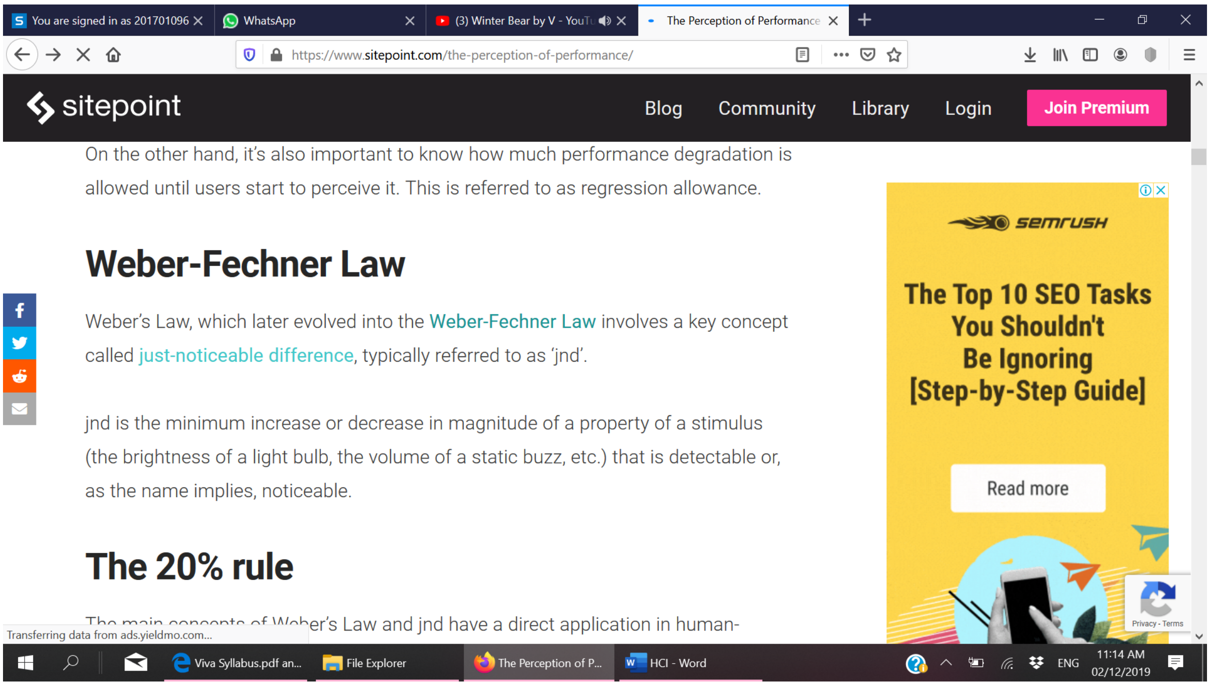
Perceptual organization is the process which converts the complex sensory information into coherent units, so that we can easily identify the objects in the environment2, 3. It was first proposed by Gestalt psychologists who suggested that perceptual organization was composed of two parts: grouping and segregation4, 5, 6, 7. Many factors have influenced our ability to organize information, such as time8, 9, 10, space11, 12 and featural relationships.

Studies of haptic / tactile perception are challenging, compared with the psychophysical studies in other sensory channels including visual and auditory modalities. Compared to visual and auditory channels, illusions in haptic domain were less than those in the former. Indeed, in everyday life we were exposed to a very few haptic illusions[24].

Recent research focused on the illusions in which we perceive the virtual environments or real world via haptic interfaces25, 26. One prominent reason is the complexity to design the suitable device / stimuli to accommodate and fulfill the research purposes by imposing the stimuli to different surfaces (such as finger, face and trunk/torso) of human body, in this direction, the compliances of the stimuli are critical and the rendering of appropriate stimuli are largely constrained by the materials and working mediums of the traditional haptic devices. With the burgeoning technique in virtual reality and marriage with the neuroimaging recording[27], the haptic devices that are compatible with the magnetic-free environment are hardly available. On the other hand, more interesting and sophisticated illusions have been observed in tactile modality, hence the investigating of the underpinning of neurocognitive mechanism poses a challenge to the academic circles. Among the illusions, three of them are conspicuous and have received wide attention. (*funneling* illusion, *Cutaneous rabbit* effect, *flash-lag* effect)

10.Weber-Fechner Law

https://www.sitepoint.com/the-perception-of-performance/



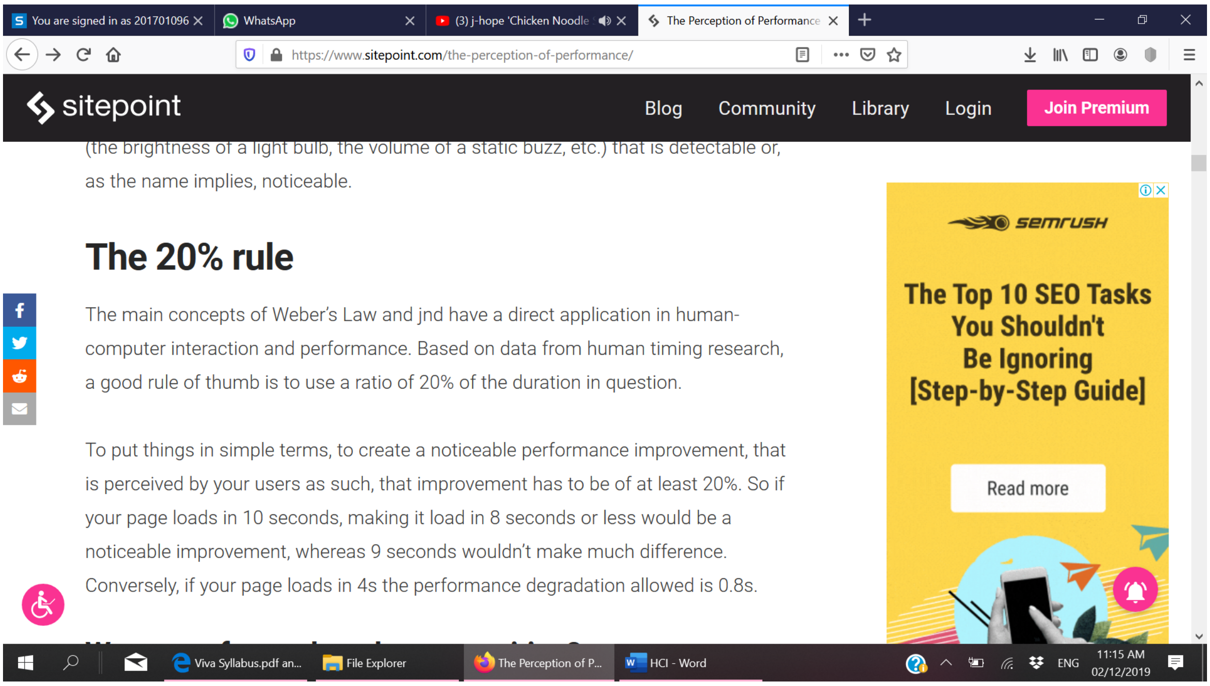
On the other hand, it's also important to know how much performance degradation is allowed until users start to perceive it. This is referred to as regression allowance.

Weber-Fechner Law

Weber's Law, which later evolved into the Weber-Fechner Law involves a key concept called just-noticeable difference, typically referred to as 'jnd'.

jnd is the minimum increase or decrease in magnitude of a property of a stimulus (the brightness of a light bulb, the volume of a static buzz, etc.) that is detectable or, as the name implies, noticeable.

The 20% rule



(the brightness of a light bulb, the volume of a static buzz, etc.) that is detectable or, as the name implies, noticeable.

The 20% rule

The main concepts of Weber's Law and jnd have a direct application in human-computer interaction and performance. Based on data from human timing research, a good rule of thumb is to use a ratio of 20% of the duration in question.

To put things in simple terms, to create a noticeable performance improvement, that is perceived by your users as such, that improvement has to be of at least 20%. So if your page loads in 10 seconds, making it load in 8 seconds or less would be a noticeable improvement, whereas 9 seconds wouldn't make much difference. Conversely, if your page loads in 4s the performance degradation allowed is 0.8s.

https://www.zorraquino.com/en/dictionary/digital-marketing/what-is-weber-fechner-law.html

Also known as the sensory-perception law, it states that sensory response to external stimuli (temperature, light, sound, etc.) is not proportional to the intensity of the stimulus. Where the intensity of the stimulus is very high, our senses self-adjust so as to only detect enormous differences, whereas when the intensity of the stimulus is very low, they adjust so as to amplify the smallest possible differences. In marketing, this implies that consumers do not always perceive variations in the pricing of a product or service. It depends on the size of the change. In user experience, this provides information, for example, on response times in interactions between the user and the systems.

11.Contrast Effect

Luminance contrast is a measure of the perceived lightness or brightness difference between two color stimuli. Psychophysical models of contrast coding typically include a nonlinear transformation from stimulus contrast to visual response. Early stages of contrast coding, whether measured psychophysically or neurophysiologically, provide a plausible basis for contrast limitations in reading. Moreover the scaling principle implies that the coding of contrast for reading is the same for characters of different sizes, and is the same for rendering by color contrast or luminance contrast, apart from any filtering stage that determines overall contrast sensitivity.

Measures of contrast must take into account adaptation effects According to Weber's law, greater luminance differences are required to be perceived for greater luminance levels of adaptation, and the ratio between luminance difference and the luminance of adaptation is constant:

$$\frac{\Delta Y}{Y} = const\,. \qquad (1)$$

The Weber definition can be used to measure the local contrast of a symbol against a uniform background, by considering [16]:

$$C = \frac{Y_{background} - Y_{symbol}}{Y_{background}}\,. \qquad (2)$$

12.Modality Effect

Computers utilize a wide range of technologies to communicate and send information to humans:

- Common modalities
  - Vision – computer graphics typically through a screen
  - Audition – various audio outputs
  - Taction – vibrations or other movement
- Uncommon modalities
  - Gustation (taste)
  - Olfaction (smell)
  - Thermoception (heat)
  - Nociception (pain)
  - Equilibrioception (balance)

Any human sense can be used as a computer to human modality. However, the modalities of seeing and hearing are the most commonly employed since they are capable of transmitting information at a higher speed than other modalities, 250 to 300[3] and 150 to 160[4] words per minute, respectively. Though not commonly implemented as computer-human modality, tactition can achieve an average of 125 wpm[5] through the use of a refreshable Braille display. Other more common forms of tactition are smartphone and game controller vibrations.

https://www.alleydog.com/glossary/definition.php?term=Modality+Effect

The modality effect refers primarily to how information is presented to a student. Used in experimental psychology, the term is used most often in areas dealing with memory and learning. In teaching, modality is used to describe the different ways that material can be presented to a learner: verbally, visually, kinetically, etc. The most successful teachers are able to present material using all of these modalities in the attempt to connect with the student's optimum learning style, which differs from person to person.

Modality can refer to a number of characteristics of the presented study material. However, this term is usually used to describe the improved recall of the final items of a list when that list is presented verbally in comparison with a visual representation. The effect is seen in free recall (recall of list items in any given order), serial recall (recall of list items in the order of study), short-term sentence recall (recall specific words from sentences with similar meanings) and paired associate recall (recall of a pair from presentation of one of its members).

13.Constructive & Direct Perception

https://www.revolvy.com/page/Constructive-perception?cr=1

Constructive perception, is the theory of perception in which the perceiver uses sensory information and other sources of information to construct a cognitive understanding of a stimulus. In contrast to this top-down approach, there is the bottom-up approach of direct perception.

Also known as intelligent perception, constructive perception shows the relationship between intelligence and perception. This comes from the importance of high-order thinking and learning in perception. During perception, hypotheses are formed and tested about percepts that are based on three things: sensory data, knowledge, and high-level cognitive processes. Visual sensations are usually correctly attributed because we unconsciously assimilate information from many sources and then unconsciously make judgments based on this information. The philosophy of Immanuel Kant explains that our perception of the world is reciprocal; it both is affected by and affects our experience of the world.

Examples

You are traveling down a road you never been on before, up ahead you see an octagonal red sign with white letters near an intersection. The sign has a vine growing on it, and all you can read is "ST_P." These letters alone are meaningless, however taken in its context and using knowledge from past experiences you infer that it is a stop sign. This is example of constructive perception because it required intelligence and thought to combine sensory information, a red octagonal sign with "ST_P" in white letters at an intersection, and knowledge from past experiences, stop signs are red octagonal signs with "STOP" in white letters placed at an intersection, to perceive it as a stop sign.

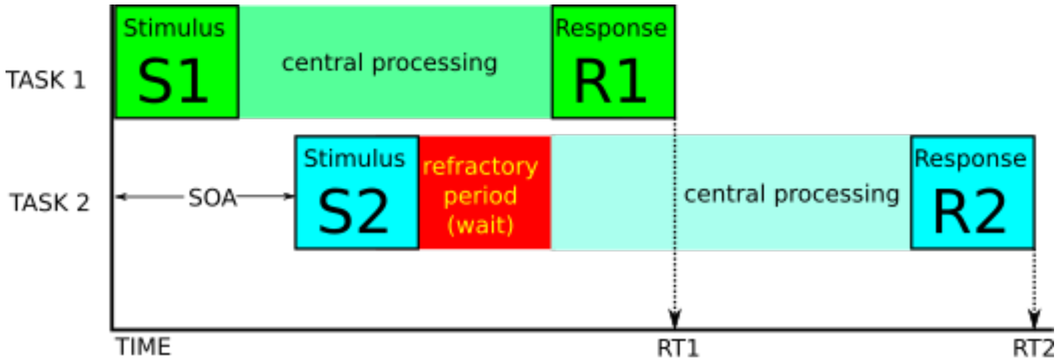
https://psycnet.apa.org/record/2003-00016-004

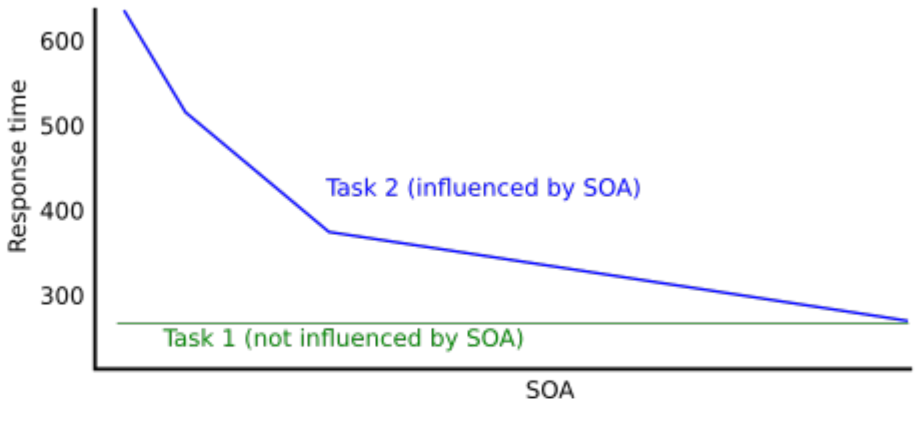
It is argued that the seeing of an environment by an observer existing in that environment is direct in that it is not mediated by visual sensations or sense data. The phenomenal visual world of surfaces, objects, and the ground under one's feet is quite different from the phenomenal visual field of color-patches. It is further asserted that the latter experience, the array of visual sensations, is not entailed in the former. Direct perception is not based on the having of sensations. The suggestion will be that it is based on the pickup of information.

14.Psychological Refractory Period

https://www.psytoolkit.org/experiment-library/prp.html

You do two tasks shortly after each other (task 1 and task 2). It turns out that the shorter the time interval between stimulus one and two (the SOA, see figure below, inspired by Pashler’s 1994 paper, p. 222, figure 1), the longer response time in task 2. One of the explanations for this is that the central processing of stimulus 2 has to wait (i.e., the refractory period) until the participant is done processing stimulus 1. The idea is that people can only handle the central processing of one task at the time. This is the central bottleneck.





The PRP paradigm has been used to distinguish between a single bottleneck model (e.g., McCann & Johnston, 1992) of information processing and a resource model.

This topic is related to multitasking. As explained in the experiment library entry under multitasking, there are different ways to measure multitasking, and this is one of them. In this case, the multitasking really focuses on the simultaneous processing of information.

15.Sound Localization & The Cone of Confusion

https://www.youtube.com/watch?v=jRBsLUdnjTQ

https://www.sciencedirect.com/topics/medicine-and-dentistry/sound-localization

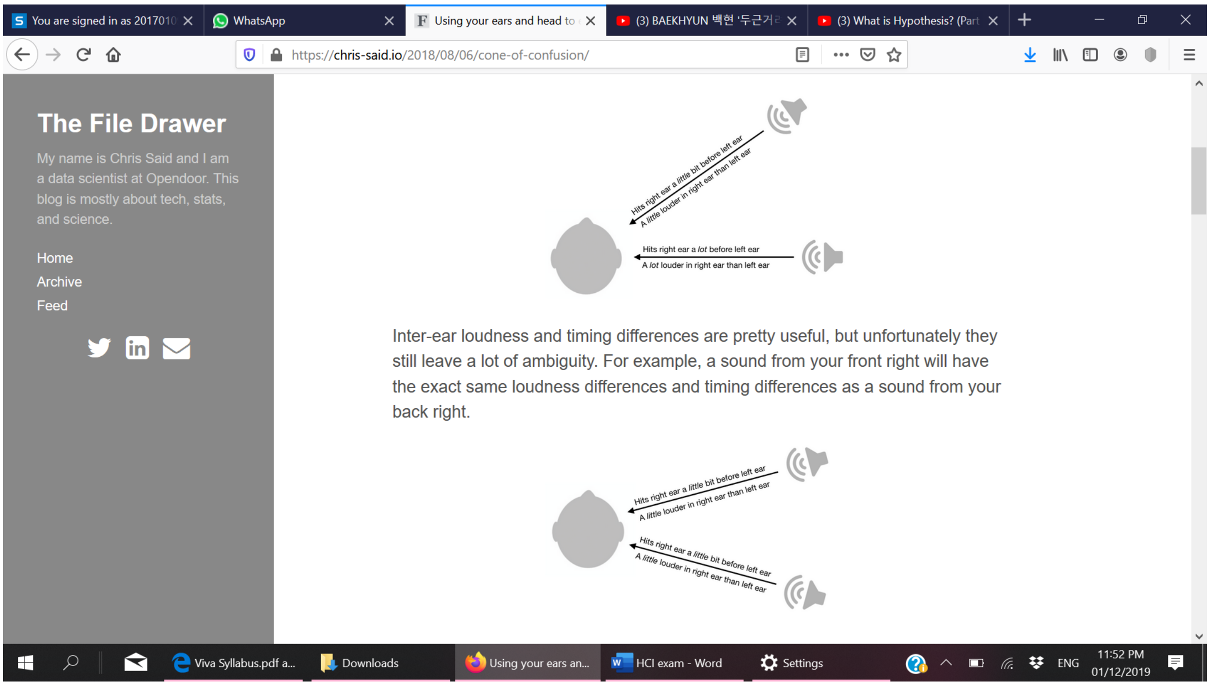
Sound localization refers to our ability to identify the direction of a sound source. There are two different aspects to sound localization. The first is known as absolute localization, or localization acuity, and refers to our ability to judge the absolute position of a sound source in three-dimensional space. In a typical adult experiment, listeners sit in an anechoic chamber with their heads fixed at the center of a spherically shaped grid of loudspeakers. A sound is played through one of the loudspeakers chosen at random and listeners are asked to point or gaze at the loudspeaker from which they think the sound originated. Acuity is measured as the difference between the actual and the judged angular positions of the loudspeaker relative to the listener's head. The second aspect is relative localization and refers to our ability to detect a shift in the absolute position of the sound source. Relative localization is quantified by the minimum audible angle (MAA), which is defined as the smallest detectable shift in angular location of the sound source.

In adults, localization accuracy depends on many factors, including the spectral content of the stimuli and the actual location of the sound source. Overall, adults are better at localizing noises than tones, both in absolute and relative localization tasks. They are also better at localizing sounds in the horizontal (left-right) than in the vertical (above-below) dimensions and better at localizing sounds placed in front than behind them (Middlebrooks and Green, 1991). Adults are comparatively better at relative than at absolute localization.

https://chris-said.io/2018/08/06/cone-of-confusion/

If the sound is louder in the right ear compared to the left ear, it's probably coming from the right side. The smaller that difference is, the closer the sound is to the midline (i.e the vertical plane going from your front to your back). Similarly, if the sound arrives at your right ear before the left ear, it's probably coming from the right. The smaller the timing difference, the closer it is to the midline. There's a fascinating literature on the neural mechanisms behind this.

Inter-ear loudness and timing diferences are pretty useful, but unfortunately they still leave a lot of ambiguity. For example, a sound from your front right will have the exact same loudness differences and timing differences as a sound from your back right.

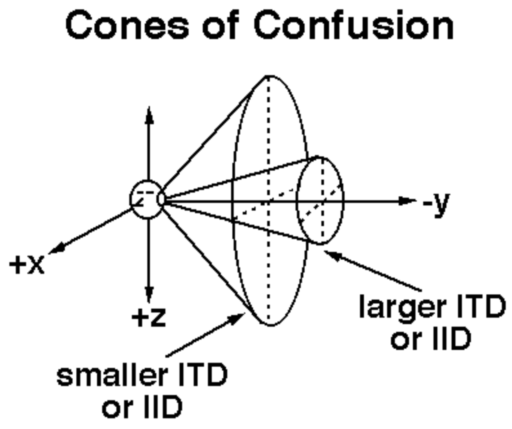


Not only does this system leave ambiguities between front and back, it also leaves ambiguities between top and down. In fact, there is an entire *cone of confusion* that cannot be disambiguated by this system. Sound from all points along the surface of the cone will have the same inter-ear loudness differences and timing differences.

While this system leaves a cone of confusion, humans are still able to determine the location of sounds from different points on the cone, at least to some extent. How are we able to do this?

Amazingly, we are able to do this because of the shape of our ears and heads. When sound passes through our ears and head, certain frequencies are attenuated more than others. Critically, the attenuation pattern is highly dependent on sound direction.

This location-dependent attenuation pattern is called a Head-related transfer function (HRTF) and in theory this could be used to disambiguate locations along the cone of confusion. An example of someone's HRTF is shown below, with frequency on the horizontal axis and polar angle on the vertical axis. Hotter colors represent less attenuation (i.e. more power). If your head and ears gave you this HRTF, you might decide a sound is coming from the front if it has more high frequency power than you'd expect.



16.Modality Appropriateness Hypothesis

Send me if you get it

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3306770/

According to Welch and Warren (1980), the Modality Appropriateness Hypothesis states that the influence of perception in each modality in multisensory integration depends on that modality's appropriateness for the given task. Thus, vision has a greater influence on integrated localization than hearing, and hearing and touch have a greater bearing on timing estimates than vision.

17.Cognitive Inhibition

https://www.youtube.com/watch?v=LAfk4M0nC3M (too cute)

https://study.com/academy/lesson/cognitive-inhibition-definition-example.html

Cognitive inhibition is the blocking out or tuning out of information that is irrelevant to the task or focus at hand. This mental process can be intentional or unintentional and can manifest itself in a variety of ways. A common way to measure cognitive inhibition in children is through something called a false-belief task. False-belief tasks are setups meant to measure **false belief**, or the idea that others may have beliefs and views about the world that are different from one's own.

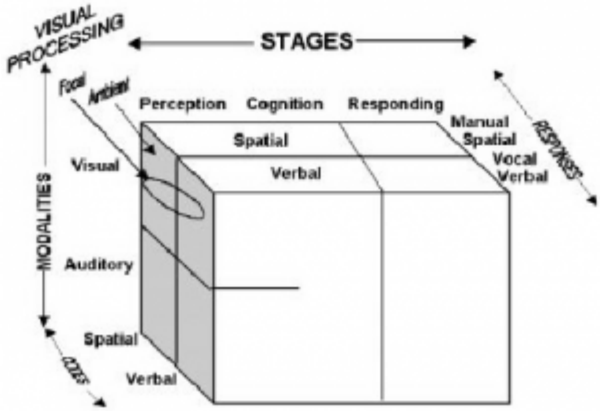
18.Multiple Resource Theory

https://blog.wuxiangyi.com/wickens-multiple-resource-theory/

Wickens' (1984) multiple resource theory (MRT) model[8] is illustrated in figure 1:
Wickens' MRT proposes that the human operator does not have one single information processing source that can be tapped, but several different pools of resources that can be tapped simultaneously. Each box in figure 1 indicates one cognitive resource. Depending on the nature of the task, these resources may have to process information sequentially if the different tasks require

the same pool of resources, or can be processed in parallel if the task requires different resources. Wickens' theory views performance decrement as a shortage of these different resources and describes humans as having limited capability for processing information. Cognitive resources are limited and a supply and demand problem occurs when the individual performs two or more tasks that require a single resource (as indicated by one box on the diagram). Excess workload caused by a task using the same resource can cause problems and result in errors or slower task performance.

The relationship between workload and performance is complex. It is not always the case that as workload increases performance decreases. Performance can be affected by workload being too high or too low (Nachreiner, 1995). Sustained low workload (underload) can lead to boredom, loss of situation awareness and reduced alertness. Also as workload increases performance may not decrease as the operator may have a strategy for handling task demands.
Wickens' theory allows system designers to predict when:
Tasks can be performed concurrently.
Tasks will interfere with each other.
Increases in the difficulty of one task will result in a loss of performance of another task.



19.Maintenance Rehearsal

https://www.alleydog.com/glossary/definition.php?term=Maintenance+Rehearsal

Maintenance Rehearsal is the process of repeatedly verbalizing or thinking about a piece of information. Your short term memory is able to hold information about about 20 seconds. However, this time can be increased to about 30 seconds by using Maintenance Rehearsal.

20.Elaborative Rehearsal

https://www.verywellhealth.com/elaborative-rehearsal-a-better-way-to-memorize-98694

Elaborative rehearsal is a method to more effectively encode information into your long-term memory by requiring the brain to process it in a more in-depth way. Elaborative rehearsal consists of making an association between the new information you're trying to learn and the information you already know.

Elaborative rehearsal can involve organizing the information, thinking of examples, creating an image in your head of the information and developing a way to remember the information through a mnemonic device. There are several mnemonic devices that can facilitate elaborative rehearsal, such as using the first letter of a list of words to make a new word.

Here are some examples of ways to use elaborative rehearsal in this task.

- **Translate information into your own words.** Rather than simply reading what your study guide says about which bone is connected to the next bone, try phrasing the information differently and then explaining it to someone else.
- **Compose study questions and answer them**. Come up with 10 questions about where specific bones are located in the body and which other bones they're connected to, and then answer your questions.
- **Use images to assist you.** Use paper and online images of the skeleton, as well as identify on your own body where each bone is located and what its name is. Rather than simply looking at the pictures on a study guide, use color to help you. For example, you could choose blue to color each bone of the leg once you've rehearsed its name several times. The color blue might remind you that blue jeans are worn over legs, which can help you recall the location of the bone.
- **Grouping of terms**. Outline different characteristics or categories of the bones and check off which ones fit into each group. You could identify all of the bones that are located in the foot and list them in that category, and then do the same for the other parts of the body.
- **Use a mnemonic strategy.** Mnemonic strategies can be very helpful in learning names or terms. For example, take the first letter of the list of bones in the arm and hand and create a new word where each letter stands for one of the bones you need to remember.
- **Space Out Your Learning**. Don't try to learn all of the bones in the body in one sitting. Your efficiency is likely to decrease if you spend too long cramming for a test. Research suggests that using the same amount of time (or less) spread out over the course of a few days can be more effective at placing the information you need to know in your memory.

21.Miller's Number

https://blog.prototypr.io/the-most-important-rule-in-ux-design-that-everyone-breaks-1c1cb188931

In 1956 there was a paper written that became one of the most highly cited papers in psychology. Titled, *The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information,* it was published in 1956 by the cognitive psychologist George A. Miller of Princeton University's Department of Psychology in *Psychological Review*. The crux of the paper suggests that the number of perceptual 'chunks' an average human can hold in working memory (a component of short-term memory) is 7 ± 2. This is frequently referred to as *Miller's law*. Here is a summary of the article, sourced from wikipedia:

In his article, Miller discussed a coincidence between the limits of one-dimensional absolute judgment and the limits of short-term memory. In a one-dimensional absolute-judgment task, a person is presented with a number of stimuli that vary on one dimension (e.g., 10 different tones varying only in pitch) and responds to each stimulus with a corresponding response (learned before). Performance is nearly perfect up to five or six different stimuli but declines as the number of different stimuli is increased. The task can be described as one of information transmission: The input consists of one out of n possible stimuli, and the output consists of one out of n responses. The information contained in the input can be determined by the number of binary decisions that need to be made to arrive at the selected stimulus, and the same holds for the response. Therefore, people's maximum performance on one-dimensional absolute judgement can be characterized as an information channel capacity with approximately 2 to 3 bits of information, which corresponds to the ability to distinguish between four and eight alternatives.

Moreover, the human mind can remember ~7 bits of information when completing a task that requires cognitive effort. This is critical, because humans are constantly performing tasks, and trying to juggle various stimuli in the mind when doing so. One of the key concepts behind Miller's Law is 'chunking', which basically means assembling various bits of information into a cohesive gestalt.

The Rule

Always organize elements of information in categories no larger than 9, but preferably ~5 chunks.

The more chunks of information you add to an 'interface', the more difficult it becomes to 'work', using the information at hand. This is **especially critical for first time users, because they haven't had the 'practice' needed to encode the interface into long term memory, or, for the behaviour to become habitual**.

22.Chunking

https://www.interaction-design.org/literature/book/the-glossary-of-human-computer-interaction/chunking

The term chunking was introduced in a 1956 paper by George A. Miller, The Magical Number Seven, Plus or Minus Two : Some Limits on our Capacity for Processing Information. Chunking breaks up long strings of information into units or chunks. The resulting chunks are easier to commit to working memory than a longer and uninterrupted string of information. Chunking appears to work across all mediums including but not limited to: text, sounds, pictures, and videos.

In his original paper, Miller proposed that the maximum number of items (one number in a phone number would be an item) that should be chunked is 7 +/- 2. In other words, chunking enhances working memory most effectively when a string of information is broken into chunks of five to nine items.

More recently, Miller's contemporaries such as Broadbent (1975) have suggested that the working memory capacity is actually 4-6 items and others like LeCompte (1999) have argued for as few as three. In practice, a range of three to six bits (4+/-1) appears ideal for interaction design.

The primary purpose of chunking is the enhancement of working memory. Chunking, therefore, should not be used when the information must be searched, scanned, or analyzed. Search engine results are an example of information that does not need to be memorized and therefore should not be chunked. If one where to constrain the number of results per page to five (4+/-1); then the end user could actually spend more time moving back and forth between pages (searching), comparing the various definitions (scanning), and deciding on the most appropriate definition (analyzing).

In short, Chunking should not be used as an argument for improved simplicity, legibility, or uncluttered page design.

Chunking, when applied in its proper context, is a subtle but powerful design principle that can help improve the overall usefulness of systems. The primary goal of chunking is to help in situations where the commitment of information to working memory is required. Chunking helps in this process by breaking long strings of information into bit size chunks that are easier to remember, especially when the memory is faced with competing stimuli.

23.Serial Position Effect

https://conversionxl.com/blog/serial-position-effect/

The serial position effect is the tendency of a person to remember the first and last items in a series best and the middle items worst. It's made of two parts:

- Primacy effect
- Recency effect

Primacy and Recency Explained

Primacy: Things that happen first are typically the most important because they influence what comes next.

The theory behind primacy effect is that there is a relatively small amount of processing effort expended in rehearsing the item by itself. So, basically, when you process the 9th item on a list, you're also processing the previous 8, where the first one is by itself. This results in greater cognitive fluency and therefore greater recall.

Recency: Things that just happened are relevant because they are the most accurate representation of "now."

The theory behind recency effect is that items at the end of a sequence are easier remember because of their preservation in our working memory (the part of our short-term memory that processes conscious and immediate perceptual information). Our working memory only holds ephemeral information. It acts as a buffer for new information while it processes it into other, longer-term memory systems.

All that stuff in the middle? That's likely to be forgotten. Even if people read everything, the stuff in the middle would be the most likely to be forgotten.

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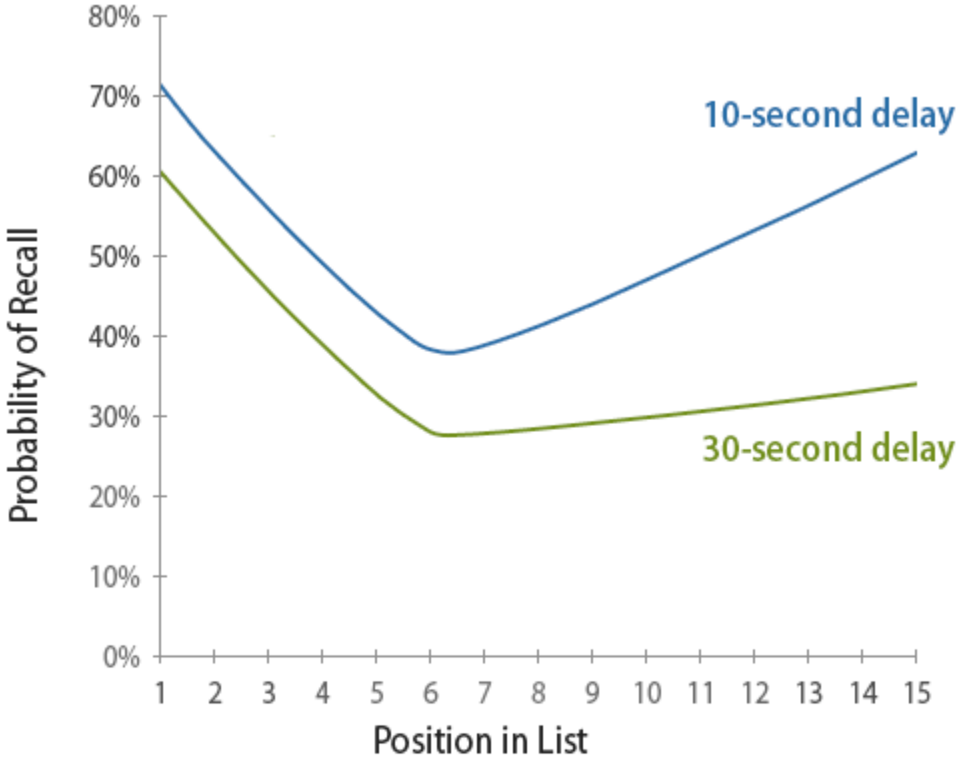


24.Hick-Hyman Law

https://www.interaction-design.org/literature/article/the-hick-hyman-law-an-argument-against-complexity-in-user-interface-design

The Hick-Hyman Law has been applied in human-computer interaction to highlight the importance of reducing the number of possible choices presented to users at any one time. It suggests there is a linear relationship between the number of options presented and subsequent choice reaction times. So selection speed would be slower with every extra item.

The applicability of Hick's law to UI design has been called into question, as users will often employ scanning strategies – when the user interface design supports them – that enable non-linear searching. For example, alphabetically ordered items allow users to focus on a specific portion of a list or to navigate directly to a point near to their target. Likewise, items in numerical order afford the same time-saving strategy.

Whether items are arranged in alphabetical or numerical order, distinguished by some pre-attentive attribute, such as colour, spatial location or size, it is essential to design the user interface to help the user make their selections as quickly as possible and this is progressively more important as the number of alternative options increases.

25.Confirmation Bias

https://www.interaction-design.org/literature/article/confirmation-bias-it-s-not-what-we-think-we-know-that-counts

Confirmation bias is our own tendency to choose evidence that supports our existing beliefs. It leads us to seek out confirmation whilst avoiding anything that detracts from our belief. This enables the religious to cite miracles that the non-believer refuses to see or for the pro-capital punishment lobby to see deterrent effects where none can be measured.

This bias comes out most often when we conduct research. Instead of testing a hypothesis (the scientific thing to do) we tend to try and prove it instead. Then we select data from our research which does just that. This devalues (and in some cases completely negates) the purpose of research – we want to find out what is really happening, not to support our own specific beliefs.

https://fs.blog/2017/05/confirmation-bias/

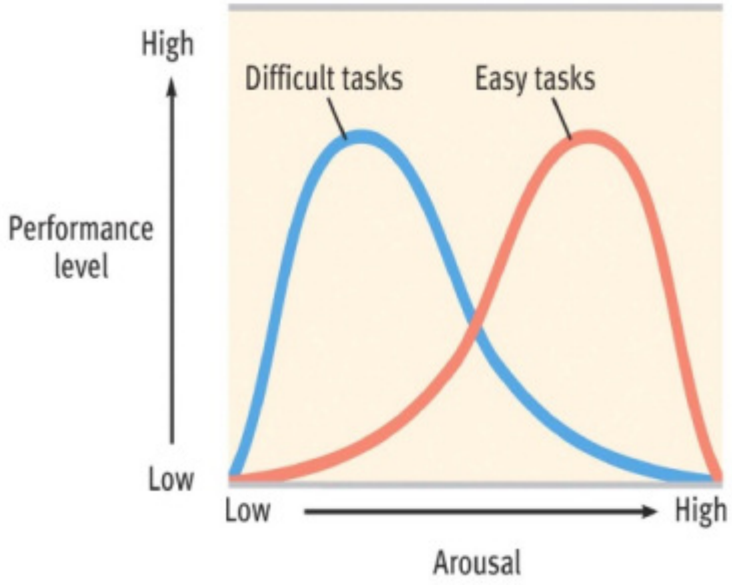
Confirmation bias is our tendency to cherry-pick information that confirms our existing beliefs or ideas. Confirmation bias explains why two people with opposing views on a topic can see the same evidence and come away feeling validated by it. This cognitive bias is most pronounced in the case of ingrained, ideological, or emotionally charged views.

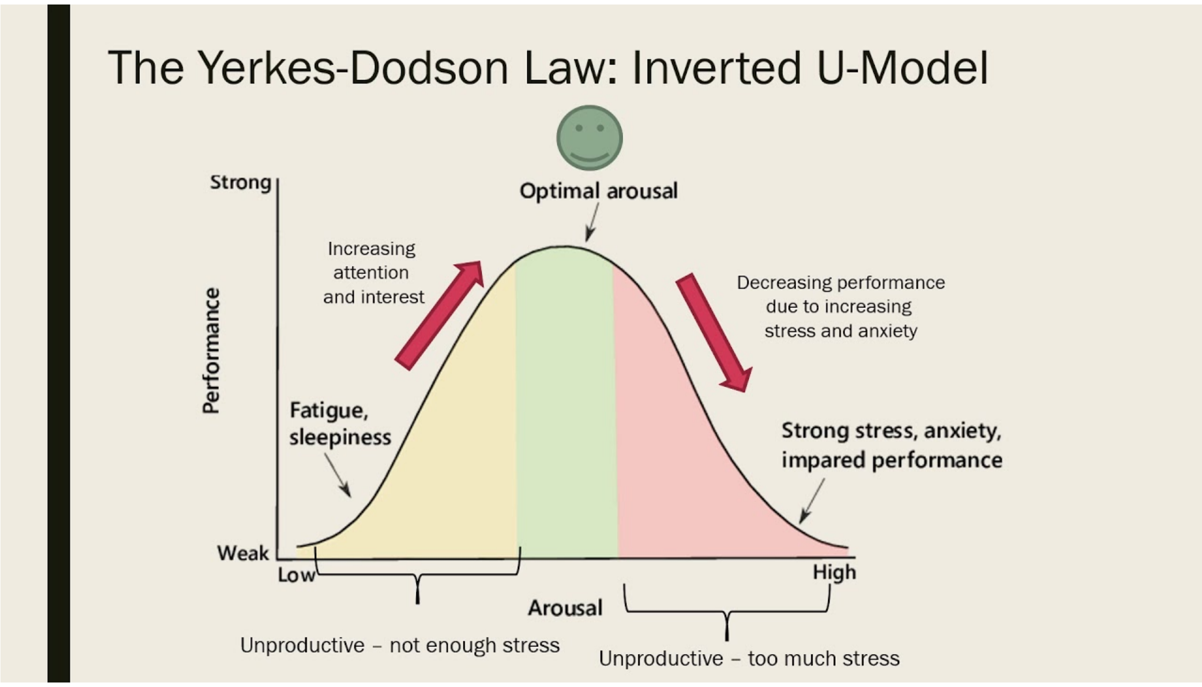
Failing to interpret information in an unbiased way can lead to serious misjudgments. By understanding this, we can learn to identify it in ourselves and others. We can be cautious of data that seems to immediately support our views.

26.Yerkes Dodson Law

https://www.verywellmind.com/what-is-the-yerkes-dodson-law-2796027

The Yerkes-Dodson Law suggests that there is a relationship between performance and arousal. Increased arousal can help improve performance, but only up to a certain point. At the point when arousal becomes excessive, performance diminishes.

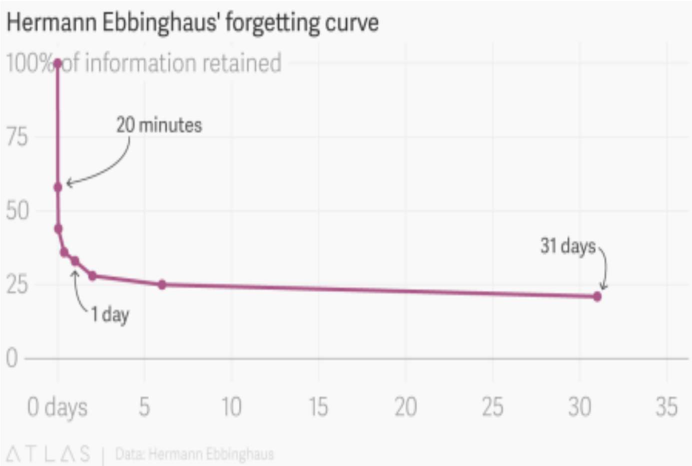


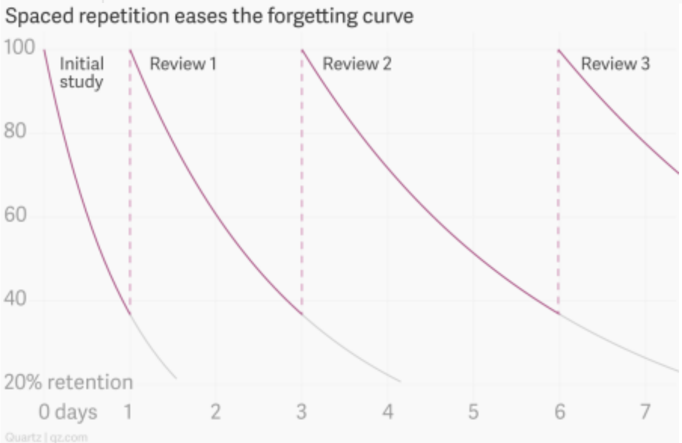


27.Ebbinghaus' Forgetting Curve

https://qz.com/1213768/the-forgetting-curve-explains-why-humans-struggle-to-memorize/

The forgetting curve is a mathematical formula that describes the rate at which something is forgotten after it is initially learned. The idea is over 100 years old. It originates in the late 19th century, with German psychologist Hermann Ebbinghaus, who was among the first scientists to perform experiments to understand how memory works.





28.Recall vs Recognition

https://www.nngroup.com/articles/recognition-and-recall/

The big difference between recognition and recall is the amount of cues that can help the memory retrieval; recall involves fewer cues than recognition.

Recognition is easier than recall because it involves more cues: all those cues spread activation to related information in memory, raise the answer's activation, and make you more likely to pick it. It's the reason for which multiple-choice questions are easier than open questions, where the respondent has to come up with an answer.

Search does require users to generate query terms from scratch — which most people are bad at — but from then on users are able to rely on recognition while using the search results. This is one of the reasons search engines have become such an essential tool for using the web. Search suggestions are a major advance in search usability because they partly transform the query generation task from one of recall to one of recognition.

Recall in User Interfaces

The classic example of recall in an interface is login. When you log in to a site, you have to remember both a username (or email) and a password. You receive very few cues to help you with that memory retrieval: usually, just the site itself. Some people make it easier for themselves by using the same credentials everywhere on the web. Others create a password that is related to the site (e.g., “amazonpassword” for Amazon.com or “buyshoes” on zappos.com) so that they can increase the ability of recall by making the site a stronger cue. And many others just keep their passwords somewhere on their computer or on a piece of paper.

Recognition in Interfaces

A menu system is the most classic example of a recognition-based user interface: the computer shows you the available commands, and you recognize the one you want. Say, for example, that you’re working with a word processor and want to draw a line through a sentence to indicate that it's no longer valid. Before the advent of graphical user interfaces you would have had to recall the name of this rarely used formatting feature. A difficult and error-prone task. Now, however, you look at the menu of formatting options and easily recognize the term *strikethrough* as being the one you want.

Promote Recognition in User Interfaces

How do you promote recognition? By making information and interface functions visible and easily accessible.

An application or a website usually has two components:

- The chrome or the interface: namely all the buttons, navigation, and other elements that are there to help the user reach his goal
- The content: the information that the user needs to achieve his goal

You can make both the content and the interface easy to remember; both can benefit from designing for recognition rather than recall. We’ll look at a few successful and less successful examples of supporting retrieval of information through recognition.

29.Flashbulb Memory

https://www.thoughtco.com/flashbulb-memory-4706544

Flashbulb memories are vivid, detailed memories of surprising, consequential, and emotionally arousing events like the terrorist attacks of September 11, 2001.

The term “flashbulb memory” was introduced in 1977 by Roger Brown and James Kulik, but the phenomenon was known to scholars well before then.

While flashbulb memories were initially believed to be accurate recollections of events, research has demonstrated that they decay over time just like regular memories. Instead, it’s our perception of such memories and our confidence in their accuracy that makes them different from other memories.

The researchers found that the two groups' descriptions of their memories of 9/11 varied. The group closer to the World Trade Center shared longer and more detailed descriptions of their experiences. They were also more confident about the accuracy of their memories. Meanwhile the group that was further away supplied recollections that were similar to those of their everyday memories.

The researchers scanned the participants' brains as they recalled these events and found that when participants who were close by recalled the attacks, it activated their amygdala, a part of the brain that deals with emotional response. This wasn't the case for participants who were further away or for any of the everyday memories. While the study didn't account for the accuracy of the participants' memories, the findings demonstrated that first-hand personal experience may be necessary to engage the neural mechanisms that result in flashbulb memories. In other words, flashbulb memories could be the result of being there rather than hearing about an event later

30.Orienting Response & Habituation

https://www.youtube.com/watch?v=UZO3vYrJlaY

https://link.springer.com/referenceworkentry/10.1007%2F978-0-387-79948-3_1317

The reflexive response to an environmental stimulus such that there is a transient orientation of the individual to the stimulus.

This phenomenon was first described by Sechenov in the 1850s and then developed by Pavlov as a critical element in conditioning theory. Pavlov referred to this response as the "what is it" reflex and identified it as necessary to the development of a conditioned response. The key criteria were that the stimulus was not so strong as to elicit an unconditioned response without conditioning, but also that the stimulus was strong enough to result in observable sensory awareness. A stimulus that fits into this circumscribed middle ground was considered to elicit an orienting response. Further, orienting responses were observed to decline in strength over time with repeated exposure to the stimuli, without reinforcement. This change in response over time is called habituation.

31.Simon Effect

https://www.psytoolkit.org/experiment-library/simon.html

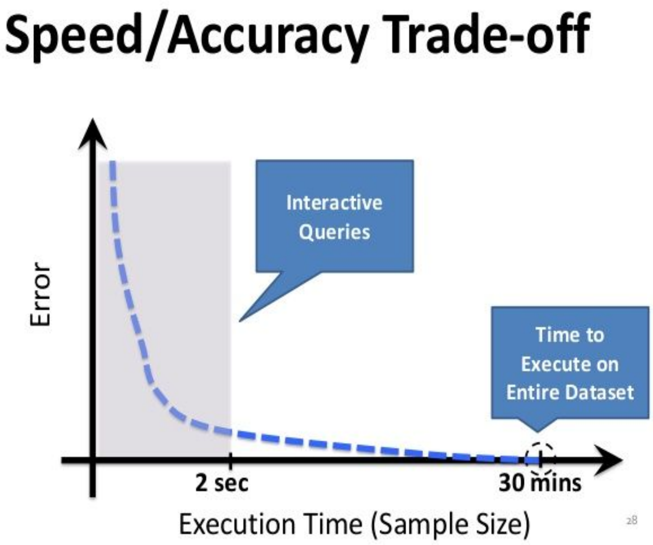
The Simon task and the Simon effect are named after J. R. Simon. Together with his colleague, he first described this effect in 1963. In essence, it shows that people respond faster and more accurately if there is a match between stimulus and response features (e.g., location, when for example stimulus and response are both located on the left side of one's body).

The effect is also known as a stimulus-response compatibility effect. There are many variants of the stimulus-response compatibility available. Like the Stroop effect, it is easy to notice consciously how difficult a mismatch between a stimulus and response can be.

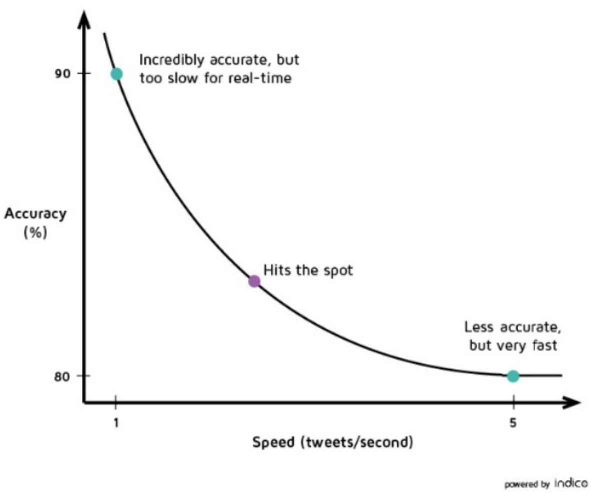
In this example, you need to respond to the words left and right with the `a` key (which is on the left side of the keyboard) and with the `l` key (which is on the right side of the keyboard). The Simon effect here simply means that you will respond more slowly to the word **LEFT** when it appears on the *right* side of the screen (i.e., **incompatible** condition) than when it appears on the *left* side (**compatible** condition) of the screen.

32.Speed-Accuracy Tradeoff

https://link.springer.com/referenceworkentry/10.1007/978-3-319-56782-2_1247-3



The Speed & Accuracy Trade-off in ML Models



The complex relationship between an individual's willingness to respond slowly and make relatively fewer errors compared to their willingness to respond quickly and make relatively more errors is described as the speed–accuracy tradeoff.

In experimental studies of human performance, both the speed at which an individual completes a task and the accuracy of their response rates are important considerations in methodological study design as well as in the interpretation of findings. Ideally, an individual attempts to maximize performance on both factors. In some situations, however, an individual may increase his or her response time at the cost of reducing the accuracy of his or her responses, while in other situations an individual may find it necessary to slow his or her response time in order to increase his or her overall accuracy level (Proctor and Vu 2003). In experimental research, illustrative schematics of speed-accuracy tradeoff data reveal consistent relationships across many different tasks. Following the basic principal that it takes time for an individual to process information accurately, consideration of the speed-accuracy tradeoff is often undertaken to determine the minimum amount of time that is required to produce a correct response on a given task

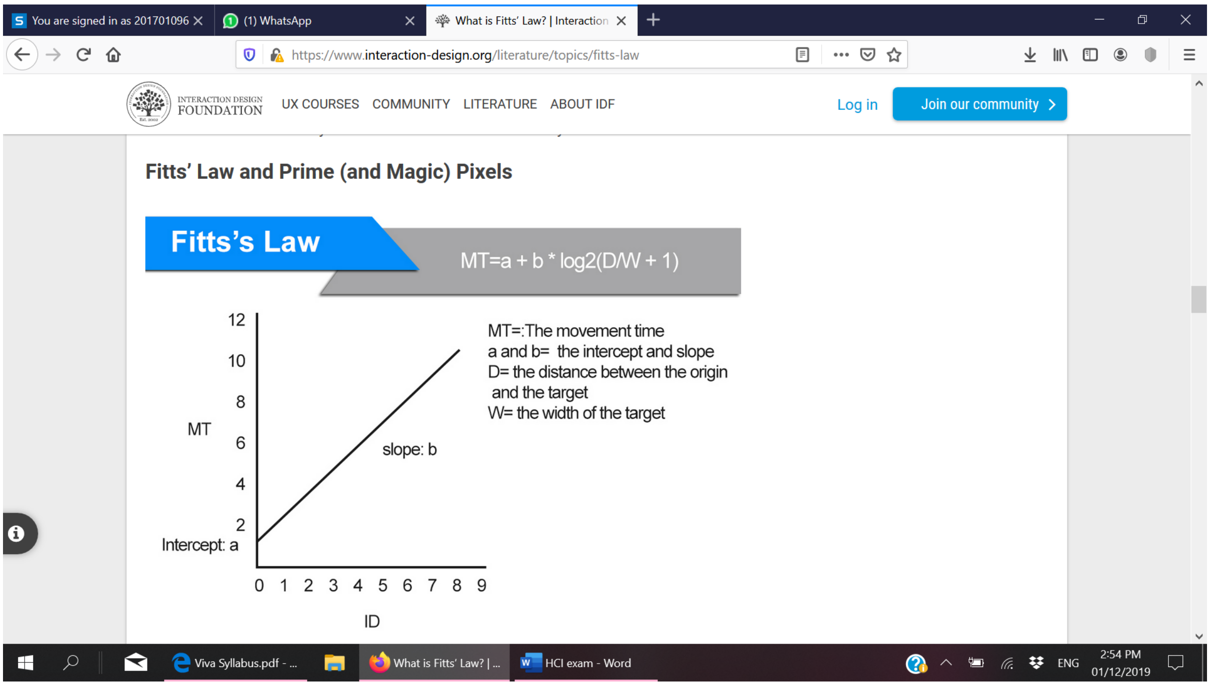
33.Fitts' Law

https://www.interaction-design.org/literature/book/the-glossary-of-human-computer-interaction/fitts-s-law (formulas)

https://www.interaction-design.org/literature/topics/fitts-law (better)

Fitts' law states that the amount of time required for a person to move a pointer (e.g., mouse cursor) to a target area is a function of the distance to the target divided by the size of the target. Thus, the longer the distance and the smaller the target's size, the longer it takes.

In 1954, psychologist Paul Fitts, examining the human motor system, showed that the time required to move to a target depends on the distance to it, yet relates inversely to its size. By his law, fast movements and small targets result in greater error rates, due to the speed-accuracy trade-off. Although multiple variants of Fitts' law exist, *all* encompass this idea.



the "**prime pixel**" – the point from which the user will carry out all of his or her actions while on your page.

There are four other pixels that matter to Fitts' Law in web design. We find these in each corner of the screen. They're called "**magic pixels**", and they provide a boundary that doesn't exist in the real world (where Fitts' Law is put in place for us to see more easily).

34.Aesthetic-Usability Effect

https://uxdesign.cc/design-principles-aesthetic-usability-effect-a9eb9903b326

The aesthetic-usability effect is defined as a user's bias to perceive an attractive product as more intuitive or usable, as opposed to a less aesthetically pleasing alternative. This bias presents itself regardless of whether or not the more pleasing product is actually easier to use.

There are two characteristics that we are analyzing in this case: **aesthetics** and **usability**, the two most important factors when assessing the overall user experience.

Positive comments in user research regarding aesthetics can unintentionally hide usability issues. It is up to the designer to identify when instances of the aesthetic-usability effect are taking place. This is done by comparing what a user **does** and how akin it is to what they **say**.