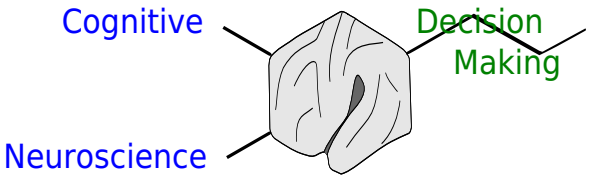


# Topic: Movement

Deciding when and how to move is a constant, but usually automatic, decision we make.

2019-02-28

# Article Discussed

Lhuillier, S., Gyselinck, V., Dutriaux, L., Grison, E., & Nicolas, S. (2018). “Like a ball and chain”: Altering locomotion effort perception distorts spatial representations. *Journal of Environmental Psychology*, *60*, 63–71. https://doi.org/10.1016/j.jenvp.2018.10.008

# Brief Summary

The article for this week was about how altering locomotion effort perception distorts spatial representation. Spatial representation is an image made up from a memory of a previously visited location. The article discusses how spatial representation changes around the immediate location in space. When participants wore ankle weights, they actually self-reported slower walking times and less distance traveled. This also affected the time it would take to walk a specified route and the participants' ability to have an accurate spatial representation of the area.

The main topic of this week's discussion was movement. In class, we specifically touched on the topic of cognitive strain, more so than cognitive ease. As a class, we discussed what triggers the use of System 2 and cognitive strain, how to avoid excessive cognitive strain on your system, and how extreme stress and PTSD can affect the ability to switch between System 1 and System 2. The class discussion was centered heavily on anxiety and depression, and the effects of these disorders on System 1 and System 2. Since anxiety and depression often manifest hand-in-hand, the effects of anxiety or depression, individually, is a bit harder to distinguish. It was concluded, however, that anxiety very severely impacts these systems. Influence of emotion on the distinction between System 1 and System 2 use, and success in performing tasks, as well as priming for affection, advertisements and the stresses associated with different jobs was also discussed.

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# Cognitive Process Neuroimaging Analysis

Neurosynth term: "spatial information"

## Top 5 Pubmed Articles

1: Fournier J, Müller CM, Schneider I, Laurent G. Spatial Information in a Non-retinotopic Visual Cortex. Neuron. 2018 Jan 3;97(1):164-180.e7. doi:10.1016/j.neuron.2017.11.017. Epub 2017 Dec 14. PubMed PMID: 29249282.

2: Connor CE, Knierim JJ. Integration of objects and space in perception and memory. Nat Neurosci. 2017 Oct 26;20(11):1493-1503. doi: 10.1038/nn.4657. [Epub ahead of print] Review. PubMed PMID: 29073645; PubMed Central PMCID: PMC5920781.

3: Lester AW, Moffat SD, Wiener JM, Barnes CA, Wolbers T. The Aging Navigational System. Neuron.

2017 Aug 30;95(5):1019-1035. doi: 10.1016/j.neuron.2017.06.037. Review. PubMed PMID: 28858613; PubMed Central PMCID: PMC5659315.

4: Rodo C, Sargolini F, Save E. Processing of spatial and non-spatial information in rats with lesions of the medial and lateral entorhinal cortex: Environmental complexity matters. Behav Brain Res. 2017 Mar 1;320:200-209. doi:10.1016/j.bbr.2016.12.009. Epub 2016 Dec 9. PubMed PMID: 27956211.

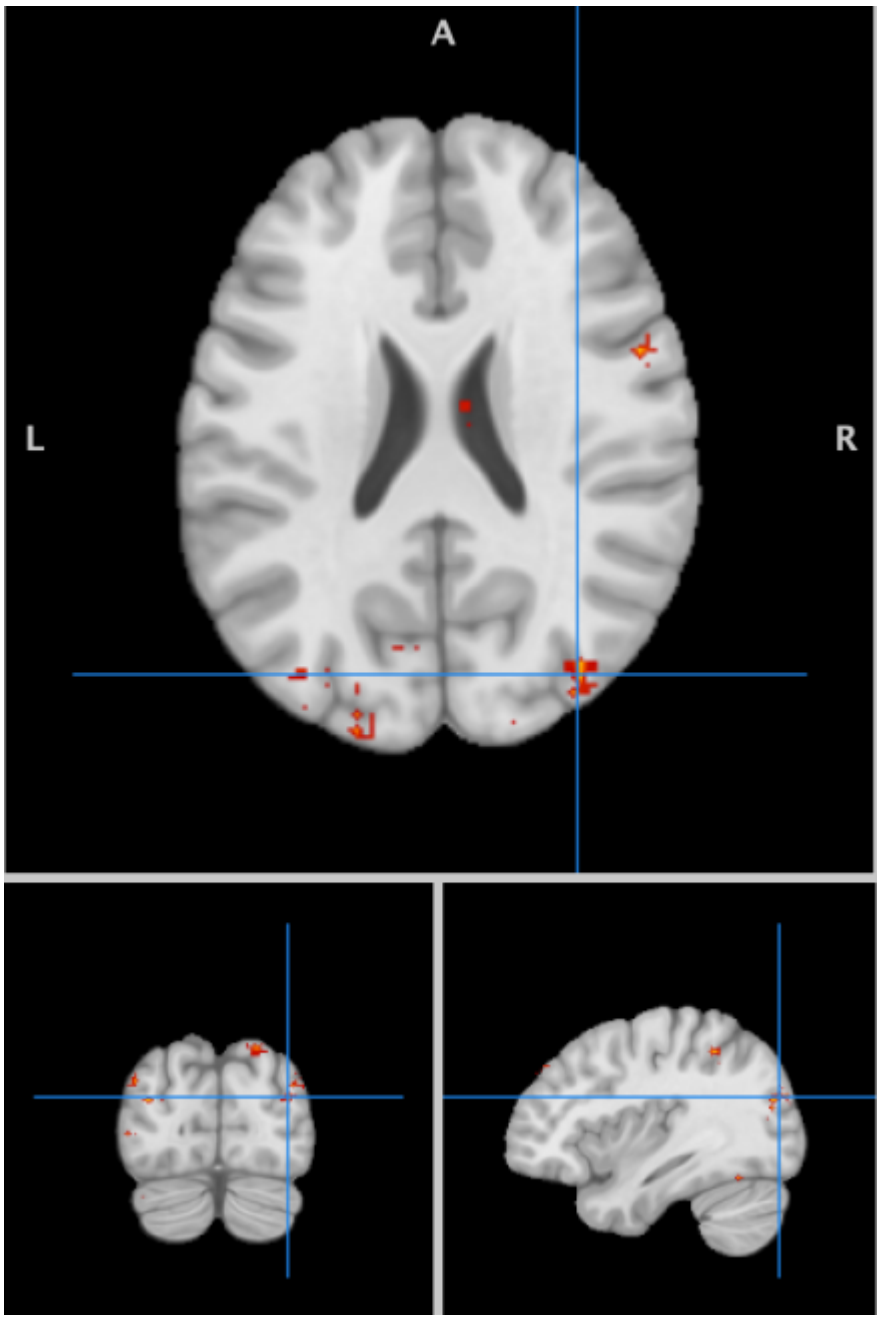
5: Hayakawa H, Samura T, Kamijo TC, Sakai Y, Aihara T. Spatial information enhanced by non-spatial information in hippocampal granule cells. Cogn Neurodyn. 2015 Feb;9(1):1-12. doi: 10.1007/s11571-014-9309-x. Epub 2014 Sep 11. PubMed PMID: 26052358; PubMed Central PMCID: PMC4454129.

## Top 5 Neurosynth Articles

| | | | |
|---|---|---|---|
| Time, space and emotion: fMRI reveals content-specific activation during text comprehension. | Ferstl EC, von Cramon DY | Neuroscience letters | 0.284 |
| Neural correlates of encoding space from route and survey perspectives. | Shelton AL, Gabrieli JD | The Journal of neuroscience : the official journal of the Society for Neuroscience | 0.232 |
| Load response functions in the human spatial working memory circuit during location memory updating. | Leung HC, Oh H, Ferri J, Yi Y | NeuroImage | 0.221 |
| Is there a role of visual cortex in spatial hearing? | Zimmer U, Lewald J, Erb M, Grodd W, Karnath HO | The European journal of neuroscience | 0.212 |
| Dissociable brain activations during the retrieval of different kinds of spatial context memory. | Suzuki M, Tsukiura T, Matsue Y, Yamadori A, Fujii T | NeuroImage | 0.209 |

## Brain region chosen for the term

Brain Region: V7 Visual Area




## Other Neurosynth terms associated with this brain region:

| Name | z-score | Posterior prob. | Func. conn. (r) | Meta-analytic coact. (r) |
|---|---|---|---|---|
| spatial | 5.83 | 0.69 | 0.38 | 0.42 |
| occipital | 5.56 | 0.68 | 0.51 | 0.44 |
| visual | 5.42 | 0.65 | 0.61 | 0.49 |
| symbolic | 4.46 | 0.82 | 0.08 | 0.06 |
| superior inferior | 4.28 | 0.81 | 0.12 | 0.11 |
| spatial information | 4.19 | 0.81 | 0.17 | 0.15 |
| parietal | 3.96 | 0.61 | 0.33 | 0.32 |
| occipito | 3.72 | 0.74 | 0.31 | 0.28 |
| abilities | 0 | 0.39 | -0.01 | -0.01 |
| ability | 0 | 0.49 | 0 | 0 |

# Questions posed by the class

## Background and vocabulary

### Q: What is spatial processing?

“Spatial processing is sensing and integrating information pertaining to a location in space”

“Spatial processing has been used broadly to encompass a number of different cognitive domains. Animal work has focused on the well-known hippocampal “place cells”, while topics such as spatial attention, spatial orientation, spatial construction, and spatial imagery have commanded ongoing debates in cognitive psychology and cognitive neuroscience”

Ruocco, Anthony C., and Farzin Irani. “Spatial Processing.” In Encyclopedia of Clinical Neuropsychology, edited by Jeffrey S. Kreutzer, John DeLuca, and Bruce Caplan, 2331–32. New York, NY: Springer New York, 2011. https://doi.org/10.1007/978-0-387-79948-3_1404.

## Q: What are Euclidean metrics?

“The Euclidean distance (Euclidean metric) between two points in either the plane or 3-dimensional space measures the length of a segment connecting the two points. It is the most obvious way of representing distance between two points.” Older works refer to this as the Pythagorean Metric. In simpler terms, Euclidean distance is used to define the length between two points and to find this the Pythagorean Theorem can be used. (ROSALIND | Glossary | Euclidean distance. (n.d.). Retrieved February 26, 2019, from http://rosalind.info/glossary/euclidean-distance/)

## Q: What is the Landmark Position Retrieval Task?

- Spatial memory
- Participants are asked to retrieve the spatial positions of previously encoded landmarks

> from their spatial re-presentation.

- Mental images incorporate metric information present in the world_movement. Adults and children

> show a ***linear time-distance relation***, that is, their mental scanning time is linearly
>
> related to the distances in the real space. (Wimmer, Robinson & Doherty, 2017)

## Q: What is proprioceptive feedback? (page 64 first paragraph)

Proprioception is “the unconscious perception of movement and spatial orientation arising from stimuli within the body itself.” Proprioceptive feedback, therefore, is the interpretation of the receptors within the body as stimuli change in a spatial setting. People alter their voluntary motor functions based off of proprioceptive feedback, through negative feedback loops and other cues.

Grey, MJ(Oct 2010) Proprioceptive Sensory Feedback. In: eLS. John Wiley & Sons Ltd, Chichester. http://www.els.net [doi: 10.1002/9780470015902.a0000071.pub2]

Proprioception is the body’s sense of position or motion. When you move a part of your body, propriceptive feedback is the mechanism by which the body “calculates error signals between the movement predicted by the brain’s internal model of the body and the actual movement”.

Dean, J. (2013). Proprioceptive feedback and preferred patterns of human movement. *Exerc Sport Sci Rev., 41*(1), 36-43.

### Q: What are some examples of cognitive collages (Tversky)?

Cognitive collages consist of the following factors, “hierarchical representations, cognitive

perspectives, cognitive reference points, alignment to other locations, rotation to a

frame of reference, and regularization of geographic features.” These factors essentially distort memory and judgements of the environment. These distortions often can often go in opposite directions as well. Therefore, trying to make an accurate mental map becomes challenging. However, the brain has an almost self-correcting system. When people are asked information on the environment people acknowledge there are inconsistencies and to then counteract this people retrieve additional information that corrects the inconsistency in the correct direction. Therefore, figures often emerge from the collages in order to be corrective.

Tversky, B. (1993). Cognitive maps, cognitive collages, and spatial mental models. Lecture Notes in Computer Science Spatial Information Theory A Theoretical Basis for GIS, 14-24. doi:10.1007/3-540-57207-4_2

### Q: What is the definition of “amodal representations” as stated in the beginning of the article?

Amodal Representations/perception is when you perceive a whole of a physical structure when only parts of it affect sensory receptors. An example would be if someone was standing in front of the TV while you were watching. You’d still be able to tell it was the TV behind the person, and could probably piece together what the person was covering up.

> Breckon, T., & Fisher, R. (2005). Amodal volume completion: 3D visual completion. *Computer Vision and Image Understanding*, *99*(3), 499–526.

https://doi.org/10.1016/j.cviu.2005.05.002

## Cognitive representations

### Q: Are enhanced supramodel representations what lead some to have a “picture-perfect memory?”

It's still controversial as to if photographic memory actually exists considering there's little research to back it up. On a related topic however, there is a condition called hyperthymesia that results in people being able to recall an abnormally large amount of their life experiences in vivid detail. Interestingly, people with this condition do not show exceptional memory in other domains besides autobiographical memory. In a study done on those with hyperthymesia, it was found that there were some significant differences in brain structures compared to the control participants. Those with hyperthymesia had amplified white matter tracts which may suggest that the transfer of information is enhanced in those participants with the condition. Future research needs to be done on whether or not participants were in fact born with these brain differences or if these are a result of unique experiences during development.

Parker, E. S., Cahill, L., & McGaugh, J. L. (2006). A case of unusual autobiographical remembering. *Neurocase, 12*(1), 35-49. doi:10.1080/13554790500473680

## Q: Could someone explain what podokinetic information is and provide some examples?

**ExactTulip: "**Podokinetic after-rotation (PKAR) is a phenomenon in which subjects inadvertently rotate when instructed to step in place after a period of walking on a rotating treadmill (Scott, Lohnes, Horak, & Earhart, 2011)."

Scott, J. T., Lohnes, C. A., Horak, F. B., & Earhart, G. M. (2011). Podokinetic Stimulation

Causes Shifts in Perception of Straight Ahead. Experimental Brain Research.

Experimentelle Hirnforschung. Experimentation Cerebrale, 208(3), 313–321.

https://doi.org/10.1007/s00221-010-2480-3

This journal article analyzes the phenomenon called podokinetic after-rotation, another way of describing how when someone is blindfolded after walking on a rotating treadmill and afterwards asked to stand still for a period of time, tend to rotate their body unknowingly as if they were still on the treadmill. A similar example of this type of locomotive behavior includes someone being on a boat for a period of time, then after returning to land, still experiencing the feeling and movements that occurred while being on the boat.

## Q: What is podokinetic information and how does it relate to motor stimulation?

This sort of information involves the relationship with the sensation of touch in the body, and specifically on the feet, and with the floor. This phenomenon is called a somatosensory-motor system. Podokinetic information influences directional control, and this in turn, allows people to walk smoothly and with purpose. Motor units are recruited and the muscles in these units help carry out the commands of the nerves in the brain.

> Weber, K. D., W. A. Fletcher, C. R. Gordon, G. Melvill Jones, and E. W. Block. "Motor Learning in the

> ‘Podokinetic’ System and Its Role in Spatial Orientation during Locomotion.” *Experimental Brain Research* 120, no. 3 (June 1998): 377–85.

### Q: In what part of the brain is the podokinetic motor sensory system active?

The podokinetic system is part of the somatosensory-motor system that is in postcentral gyrus of the parietal lobe.

> Motor learning in the ’podokinetic’ system and its role in spatial orientation during locomotion | Request PDF. (n.d.). http://dx.doi.org/10.1007/s002210050411

The article I read stated that the podokinetic sensory motor system senses and controls spatial orientation during movement, by referencing body orientation to the space-stable stance foot.

> Jones, G. M., Galiana, H. L., Weber, K. D., Fletcher, W. A., & Block, E. W. (2000). Complex podokinetic (PK) response to post-rotational vestibular stimulation. *Archives Italiennes De Biologie*, *138*(1), 99–105.

## Experimental results

### Q: Why did ankle weights negatively affect landmark position retrieval on a map?

It says that the researchers third hypothesis was that “individuals tend to simulate their walk during recall of spatial representations. The increase in perceived walking effort (and therefore also decrease in walking speed) should then negatively affect the parameters or motor simulation during a spatial recall task, resulting in lower scores in a spatial retrieval task.”

This spatial retrieval task was the landmark position retrieval. The hypothesis was confirmed because the ankle weighted participants had a harder time with landmark position retrieval. (all from the article)

### Q: What does the inferior parietal lobe do? And does it interact with the temporal lobe when semantic memory is occuring

Inferior parietal lobe has been involved in the perception of emotions in facial stimuli, and interpretation of sensory information. The inferior parietal lobule is concerned with language, mathematical operations, and body image, particularly the supramarginal [1)]gyrus and the angular gyrus_movement.

> Keren, G., Y. Epstein, A. Magazanik, and E. Sohar. “The Energy Cost of Walking and Running with and

without a Backpack Load." *European Journal of Applied Physiology and Occupational Physiology* 46, no. 3 (June 1, 1981): 317–24. https://doi.org/10.1007/BF00423407.

Lhuillier, Simon, Valérie Gyselinck, Léo Dutriaux, Elise Grison, and Serge Nicolas. "'Like a Ball and Chain': Altering Locomotion Effort Perception Distorts Spatial Representations." *Journal of Environmental Psychology* 60 (December 1, 2018): 63–71. https://doi.org/10.1016/j.jenvp.2018.10.008.

The inferior parietal lobe has been found to impact visuospatial cognition and processing ("Inferior Parietal Lobule - an overview | ScienceDirect Topics"). There is also evidence to suggest a role in integrating sensory information ("Inferior Parietal Lobule - an overview | ScienceDirect Topics"). Unfortunately, the specific functions of this area are more so understood in monkeys than in humans as of now.

Inferior Parietal Lobule - an overview | ScienceDirect Topics. (n.d.). Retrieved February 26, 2019, from

https://www.sciencedirect.com/topics/neuroscience/inferior-parietal-lobule

# Cognitive Processes

### Q: Can someone explain how does recalibration works? If there is damage to the area that controls recalibration would we be able to locomotion?

Changes in the sensory input to the perceptual motor system results in a rescalling of the motor system that is recalibration. For example in this study the participants walking pace was re-adjusted due to the perceptual recalibration. When you are walking with a backpack you adjust and walk at the same speed, but imaginary walking is slowed down by a backpack.

Brand, M. T., & de Oliveira, R. F. (2017). Recalibration in functional perceptual-motor tasks: A systematic review. *Human Movement Science*, *56*(Pt B), 54–70. https://doi.org/10.1016/j.humov.2017.10.020

There have not been specific studies on perceptual recalibration, however it is known that damage to the parietal lobe impact the somatosensory system and motor control. "Imaging studies underscore the prominent role of the parietal cortex as a sensorimotor interface and provide complementary information about the interrelationship between perception and action."

Freund, H.-J. (2003). Somatosensory and motor disturbances in patients with parietal lobe lesions. *Advances in Neurology*, *93*, 179–193.

### Q: If you know the start location and the end location, can you find a route through spatial surveying? Can you use assumptions? For example on long road trips you may not know the exact way, but you know generally and could give directions?

This is not from an article but personally I think that when giving directions across longer distances it is possible to give a basic level of direction, however not specifics. You can assume that the person receiving directions will double check them on Maps anyways so you don't have to be as specific, assuming they have access to that information. Also when you are at home and you are driving to a place you have never been (a place within the area of your home) you can generally imagine a way to get there by using landmarks. If you are going to a restaurant to meet a friend you might think " oh it is near my elementary school" then go off that and find your way, leaving with enough time it would generally take to get to said landmark.

## Methodological issues

### Q: Do you think that there is sampling bias present since the sample was just from undergraduates in the psychology department?

Yes, students are required in a lot of cases to participate in research. This study states that up to 25% of students felt coerced into doing the study. While there are alternative assignments, the students feel they are much more complicated than just doing the research. The problem with forcing students as opposed to student volunteers (which would have their own sociocultural biases compared to the general population based off of education and wealth and lifestyle) is the student often times feels they cannot give the processor their true feelings since they rely on them for their education and grades. It's not voluntary.

(Leentjens & Levenson, 2013)

### Q: Do you think if the age group in this study was increased that it would change results significantly?

Every study on the relationship between proprioception and age has, predictably, found that proprioceptive functions decrease with age. There is a positive correlation between motor skills and proprioception in regard to change over time due to aging. This means that yes, if the age group was increased, results would change significantly.

Liutsko L, Muiños R, Tous-Ral JM. Age-related differences in proprioceptive and visuo-proprioceptive

function in relation to fine motor behaviour. *Eur J Ageing*. 2014;11(3):221-232. Published 2014 Jan 18. doi:10.1007/s10433-013-0304-6

# Implications of the study

## Q: Does walking around campus with a backpack always feel shorter than walking with nothing? If you think so, why?

I think that it feels longer when you have a heavy backpack. The weight makes the walking less bearable. I think that one can easily link this to the article read. Although those with ankle weights didn't actually differ in their walking speeds, they guessed that it took longer to walk to various points[2)]. I think that it could be argued that due to the additional weight they felt slower and that the trip was longer. - VideoSport

DivideSegment: I think it also depends on the weight of the backpack. On a typical day my backpack isn't too heavy and I barely notice it due to the frequency on having it on, but on day's when it is particularly heavy I notice the extra weight and definitely feel as if I am going slower.

## Q: The article references a different study stating, "it has been shown that individuals tend to estimate slopes in front of them as steeper if they wear a heavy backpack (Bhalla & Proffitt, 1999)." What are the evolutionary benefits of this error in perception?

When you wear a backpack or have a heavy weight attached to you it is going to take more energy to climb a slope or perform physical tasks[3)]. By overestimating the steepness of the slope, people are evaluating a greater amount of difficulty for the climb, which is accurate. Evolutionarily, I'm assuming that this would allow people to make more accurate assessments of their capabilities while carrying something and thus allow them to not overestimate their abilities and harm themselves in the process. It may be particularly important that people view the slopes as steeper rather than simply acknowledge that the task is more difficult due to the weight because people have a tendency to take risks and overestimate their capabilities [4)].

## Q: The article made me think about our increasing dependence on technology to guide us to and from a destination instead of planning the route ourselves.

## Has society’s reliance on GPSs weakened our spatial skills?

There is significantly less active engagement with the environment when people use GPS navigation instead of planning a route with a map or based on previous knowledge of an area. This lack of engagement can certainly contribute to people mindlessly travelling and therefore can affect our spatial skills due to a lack of experience. Based on the research I found, there is not a huge effect from GPS itself, but it is society’s reliance that can cause these weakened skills.

Leshed, G., Velden, T., Rieger, O., Kot, B., & Sengers, P. (2008). In-car Gps Navigation:

> Engagement with and Disengagement from the Environment. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1675–1684). New York, NY, USA: ACM.

https://doi.org/10.1145/1357054.1357316

The increasing use of GPS navigation changes the way drivers interact with their environment which effects how/ where they apply their spatial cognitive skills. Following simple turn by turn instructions allows us to focus our spatial resources less on the environment and more on other things in the car such as the radio, cell phone and conversations within the vehicle. This ultimately de-skills our spatial cognitive skills. However there are navigation assistance systems that can help overcome spatial deskilling. Studies have shown that North-up GPS is better for spatial knowledge acquisition vs Track-up GPS. Example, driving south on I-81 on a North-up map would show the arrow pointing south. A Track-up GPS (more common, seen on ways and Google maps) would show you driving straight north all the time. Several studies have also shown that landmarks on GPS can help improve spatial skills. “Landmarks are external reference points that can serve as key navigation cues which are easily remembered and recognized.”

Gramann, K., Hoepner, P., & Karrer-Gauss, K. (2017). Modified Navigation Instructions for

Spatial Navigation Assistance Systems Lead to Incidental Spatial Learning. *Frontiers*

*in Psychology*, *8*. https://doi.org/10.3389/fpsyg.2017.00193

## Q: How could this research be used to help amputees or those with prosthetic limbs?

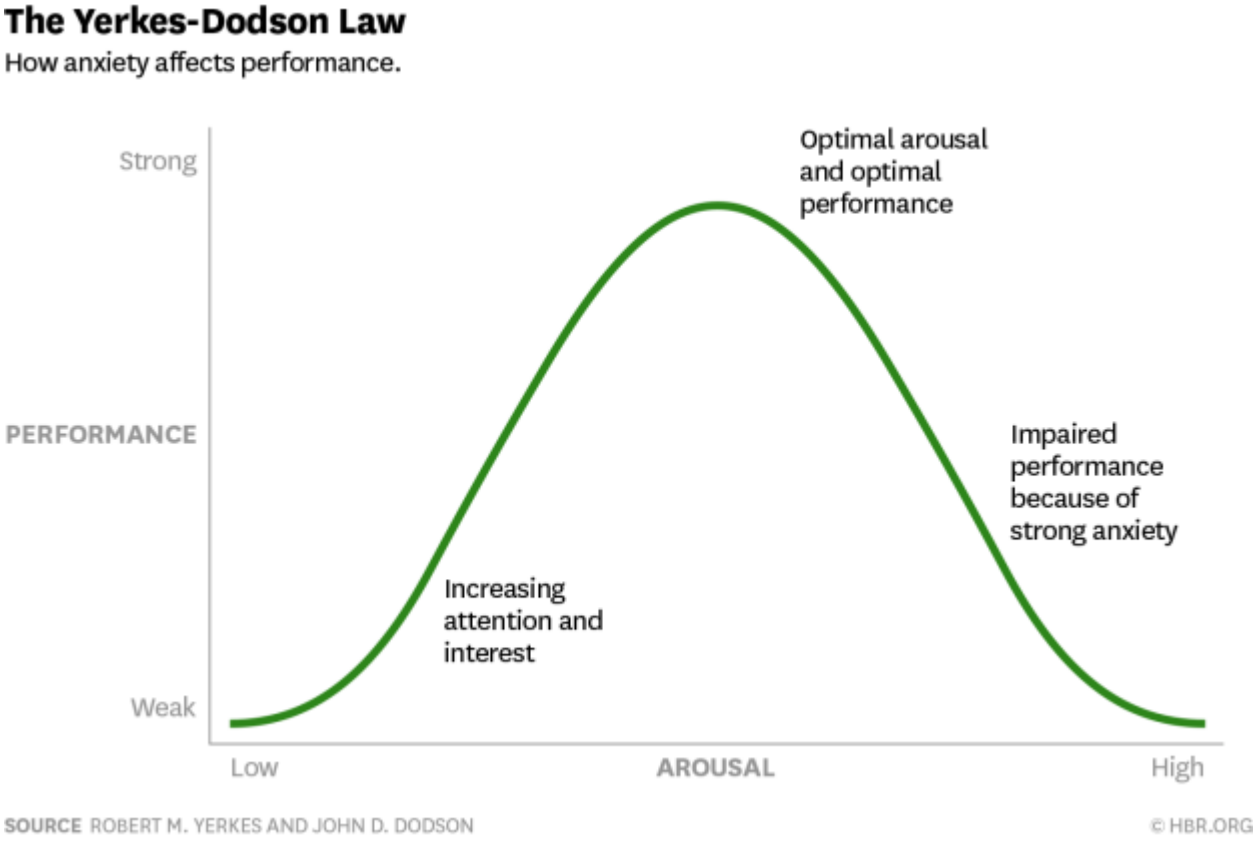
RavioliJaguar: Currently I am taking a class called the Artificial Brain. We discuss how we can brain computer interfaces (BCIs) and prosthetics can be developed and used by those who are disabled. The f`indings from this article discuss a lot of the sensorimotor planning that needs to be done to be able to spatially execute movement and understanding the cognition that helps us with it. In one study, they explore using auditory cues in order to help individuals understand their spatial awareness based on the auditory pattern. They combine that those two functions in order to heighten one where those who might be disabled struggle to process now because of amputation. Possible areas involved are the primary auditory cortex, hippocampus, posterior parietal cortex, and primary motor cortex.

Huang, M., Daly, I., Jin, J., Zhang, Y., Wang, X., & Cichocki, A. (2016). An exploration of spatial auditory

BCI paradigms with different sounds: music notes versus beeps. Cognitive Neurodynamics, 10(3), 201–209. //https://doi.org/10.1007/s11571-016-9377-1//

Mokienko, O. A., Chervyakov, A. V., Kulikova, S. N., Bobrov, P. D., Chernikova, L. A., Frolov, A. A., & Piradov, M. A. (2013). Increased motor cortex excitability during motor imagery in brain-computer interface trained subjects_movement. Frontiers in Computational Neuroscience, 7. https://doi.org/10.3389/fncom.2013.00168

## Q: : Related: The chapter mentions that familiarity tends to put us in a better mood and leads us to “let down our guard.” Where in everyday life can this cause problems? What are some applicable solutions?




If we are too relaxed and “let our guards down,” we will have a lack of arousal that can lead to poor performance. The optimal arousal for something we are good at is higher than the optimal arousal for something we are bad at or uncomfortable with.

## Q: Related: Can holding a pencil between your teeth (forcing you to smile) be useful in some types of therapy to cure depression?

https://journals.sagepub.com/doi/pdf/10.2466/pr0.2002.91.3f.1079

This article shows that the effects of smiling and laughing do have a significant impact on mood. Because of this, forcing smiles can be useful for depression but there are underlying causes of depression that would not be changed just from forcing a smile.

## Q: What are some examples of the new techniques for information representation and manipulation mentioned in the article?

We were not able to find a conclusive answer for this question. However, we found that age has a significant effect on an individual's ability to represent a memory of spatial information. This could be in part due to the fact that older adults have a harder time with retaining information while simultaneously processing new information. This could have an effect on the performance of individuals on tasks such as the one discussed in the article.

Salthouse, Timothy A, Deborah Mitchell, and Roni Reiter-Palmon. "Memory and Age Differences in Spatial Manipulation Ability," n.d., 17.

Creating a spatial representation from memory draws on the resources for spatial working memory. These tasks are therefore difficult to perform at the same time and can affect the performance of tasks such as the one in the document where you have to constantly create a spatial representation while walking a route and adjusting based on what you run into.

Pearson, David G., Robert H. Logie, and Ken J. Gilhooly. "Verbal Representations and Spatial Manipulation During Mental Synthesis." *European Journal of Cognitive Psychology* 11, no. 3 (September 1, 1999): 295–314.

https://doi.org/10.1080/713752317.

This study tested the spatial processing abilities of both males and females. Using passive and active spatial tasks involving mentally following through a set path, this study concluded that while there's little difference in male and female performance for passive tasks, men performed better on active tasks. The act of recalling previously studied and memorized points in space is a difficult task, and it still differs greatly than more active tasks; these more active tasks are a different sort of stressor than passive ones and are received by men and women differently, as a result.

Vecchi, Tomaso, and Luisa Girelli. "Gender Differences in Visuo-Spatial Processing: The Importance of Distinguishing between Passive Storage and Active Manipulation." *Acta Psychologica* 99, no. 1 (June 1, 1998): 1–16. https://doi.org/10.1016/S0001-6918(97)00052-8.

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Pearson, David G., Robert H. Logie, and Ken J. Gilhooly. “Verbal Representations and Spatial Manipulation During Mental Synthesis.” *European Journal of Cognitive Psychology* 11, no. 3 (September 1, 1999): 295–314. https://doi.org/10.1080/713752317.

Salthouse, Timothy A, Deborah Mitchell, and Roni Reiter-Palmon. “Memory and Age Differences in Spatial Manipulation Ability,” n.d., 17.

Vecchi, Tomaso, and Luisa Girelli. “Gender Differences in Visuo-Spatial Processing: The Importance of Distinguishing between Passive Storage and Active Manipulation.” *Acta Psychologica* 99, no. 1 (June 1, 1998): 1–16. https://doi.org/10.1016/S0001-6918(97)00052-8.

1)

2)

Lhuillier et al., “‘Like a Ball and Chain.’”

3)

Keren et al., “The Energy Cost of Walking and Running with and without a Backpack Load.”

4)

Sandseter and Kennair, 2011