Is Statistical Learning Multisensory or Unisensory?

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Statistical Learning (henceforth SL) can be generally defined as the human ability to extract statistical regularities in how features and objects co occur in the world around us that allows us to learn about the environment. Although SL has been demonstrated in multiple different modalities (i.e. visual, auditory, tactile), it is currently debated the extent to which learning within these modalities is governed by shared or separate mechanisms. The first view is that SL is a "set of domain-general computational principles that operate in different modalities"[1] (Frost, 2015) that are located in different regions of the brain. It argues for the existence of multiple unisensory mechanisms, meaning that each type of stimuli (i.e. auditory, visual, or tactictile) are processed and learned in different regions within the brain. The second account suggests that SL occurs in one singular multimodal mechanism in our brains that processes SL cues from a number of different modalities. My proposed research with Professor Aaron Mitchel of the Psychology Department will attempt to adjudicate whether SL is a multisensory mechanism, or that the sensory mechanisms are integrated prior to learning, rather than after, as suggested by Frost[1] in his 2015 paper.

The processes of SL were first demonstrated in the domain of speech segmentation. Subsequent studies established that this also worked for other modalities (Saffran, Aslin, & Newport, 1996). These findings led to the assumption that even with streams of continuous auditory and visual stimuli, the participants were able to process the different modalities without error or confusion among modalities, thus providing empirical evidence of a modality general mechanism. This then led to numerous subsequent studies that demonstrated SL in a variety of different modalities, including non-speech auditory stimuli (Mitchel & Weiss 2011), visual stimuli (Mitchel, Christiansen, & Weiss 2014), and touch stimuli (Conway & Christiansen 2005), of which showed approximately equivalent performance, leading to it being interpreted as a modality-general, multisensory mechanism. However, Conway and Christiansen[4] used a different type of statistical learning task that allowed them to argue that multiple unisensory mechanisms exist. Listeners to the stimuli of this and other studies that suggest separate mechanisms have shown this may be the case through being able to successfully segment different streams of stimuli of different modalities (i.e. visual and auditory) only when the boundaries of said visual and auditory stimuli were in alignment, such that pauses in auditory and gaps in visual cues aligned (Mitchel & Weiss 2011).

Supported by Saffran's[1] findings, the empirical evidence found in Conway and Christiansen's[4] 2005 paper, and the discussion of individual differences in SL in Siegelman and Frost's[5] 2015 paper, the idea that SL is not a unified capacity and is thus individualized unisensory mechanisms arises and has been supported on numerous occasions. One such supporting factor is that SL appears to be independent of our general cognitive abilities that we use on a daily basis, such as working memory and general intelligence that is measurable using an IQ examination. This distinction between SL and working memory supports the claim that SL is modality specific because it provides a basis that many cognitive abilities are separate, making modality-specific SL mechanisms plausible. This widely dominating view was supported for many years by numerous studies and experts in the field, and suggests that the nature of learning

is different across modalities, such that the way in which an individual processes auditory stimuli is different from the way that a different individual processes the same stimuli, which are both different from the way the two individuals process a visual or tactile stimuli.

On the other hand, Mitchel and Weiss (2011) have suggested that within learning two different streams of stimuli, auditory and visual, learners are able to differentiate and segment between both streams of stimuli successfully. This was done assuming the boundaries between the stimuli were aligned, such that each stimuli was organized into triplets and there were pauses or breaks in the stimuli where the triplet ended. This suggests that to some degree there is some cross-modal SL, suggesting the existence of either a multi-modal mechanism or that learning occurs after the integration of the two distinct types of stimuli. Further, this is supported by the results of Mitchel, Christiansen and Weiss (2015), which found that statistical dependencies were calculated over an integrated percept arising from the McGurk illusion. The only way this could occur is if the two modalities of stimuli are learned and processed together, providing a cross-modal effect. This is where the modality specific debate currently stands, and is the side that I will be proposing research to test.

Understanding how a child learns language and pattern recognition through SL and transforms from a drooling, cooing and crying infant to an toddler with 10,000 words to an adult with over 50,000 is both fascinating and important in the neuro-linguistic and psychology fields. Not only will this proposed research provide additional information for the relatively new field, it could be an influential response to where the debate currently stands, and could alter the views many of the leading experts in the field hold on SL. Should this proposed research go as intended, Professor Mitchel and I will be able to suggest a singular multisensory SL mechanism, or that because of the individual differences seen in SL, that the separate types of stimuli are learned and processed together.

This proposed research will occur in three general stages that will carry through until the spring. Over the course of the summer, Professor Mitchel and I will read numerous different papers on SL, individual differences in SL, and on cognitive mechanisms and how they are separate from one another. Having only ever read a few, I will be catching up and learning quite a bit of material that will allow me a greater understanding, while together Professor Mitchel and I will be reading some of the newer papers that have been written in the past few years to learn more about the current stance of the debate. Following our readings, we will then proceed to designing an experiment, and mapping out exactly what the experiment and most importantly the stimuli will look like. This will likely be derived from a proposed experiment in Frost's[1] paper, where he goes into great detail about how he believes that different modalities of stimuli are processed and learned prior to being combined (see Figure 1 of his paper). From this proposed outline in the Frost paper, we can develop an experiment that may allow us to prove if what he hypothesized is true, or if it is indeed something else that may provide empirical evidence for a multisensory mechanism. From here, we can then spend the remainder of the summer developing the stimuli, which should hopefully be fully ready to use in the fall when students return to campus and we have subjects for our experiment. This will be the second stage, and will

theoretically be carried out prior to the end of the fall semester. From here, we will write up our experiment and discussion of our results, and then will finally present our findings in the spring.

I have always been intrigued by the way a child learns language, and what in our brains allows us to do so. Having only taken an introductory linguistics course in highschool, Introductory Psychology here at Bucknell, and being currently enrolled in Professor Mitchel's Introduction to Language Development course, I do not have a lot of knowledge or experience in language development and the field of SL. As Professor Mitchel knows with my millions of questions every class, and learned very early in my education at Bucknell at the first neuroscience meeting when I distracted him from the purpose of the meeting by asking about his research, I am very interested in expanding my knowledge through hands-on research with real subjects and stimuli that I have assisted in creating. This proposed research will allow me to find the answers to some of my questions, but more importantly will lead to more questions, and ways to answer my questions. I believe that being able to learn through research will be beneficial in helping me decide if this is what I want to pursue for the rest of my life, and will be vastly important in allowing me to get my foot in the door of the field. In doing so, I will be opening a world of possibilities of ways to not only ask and answer new questions, but to learn how to answer them using my own means and methods. Should I decide to pursue research rather than medicine or speech pathology in my graduate studies, this will be an important foundation for me to build. Being a first year, this proposal is something that I can not only set up during my time at Bucknell, but that I can actually see through to completion, and make further advancements on in later years, possibly through to my honors thesis my senior year. Not only will this allow me to witness and be a part of an entire research project, it will allow me to develop a new set of questions based on what we do or do not find with this proposal. In addition, never having conducted research of any type before, being able to be a part of this program will show me how conducting research in my potential field works, and will give me a set of very important skills that can be used no matter what field I end up choosing.

References:

[1] Domain generality versus modality specificity: the paradox of statistical learning, Ram Frost, Morten H. Christiansen, et al

[2] Learning Across Senses: Cross-Modal Effects in Multisensory Statistical Learning, Aaron D. Mitchel and Daniel J. Weiss

[3] Multimodal integration in statistical learning: evidence from the McGurk illusion, Aaron D. Mitchel, Morten H. Christiansen, and Daniel J. Weiss

[4] Modality-Constrained Statistical Learning of Tactile, Visual, and Auditory Sequences, Christopher M. Conway & Morten H. Christiansen

[5] Statistical learning as an individual ability: Theoretical perspectives and empirical evidence, Ram Frost et al.

[6] Statistical Language Learning: Mechanisms and Constraints, Jenny R. Saffran