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Beyond the Stimulus: A Neurohumanities Approach to Language, Music, and Emotion

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The brain basis of language, music, and emotion can be studied from the perspective of the psychological and cognitive sciences. Does this approach link to concerns of the humanities meaningfully? We outline prospects of developing a genuine neurohumanities research program.

Some experiences are quintessentially human—and are sometimes considered the defining features of being human: the faculty of language, the capability to make or enjoy music, and the experience of emotion. These ubiquitous aspects of human nature are especially tough challenges for artificial systems to capture and simulate, their computational power notwithstanding. (It will be a long, long time before an artificial system "listens" to Kool and the Gang and Messiaen and outputs "wow, both of those pieces gave me goosebumps.") For more than 2000 years, questions about these domains have been at the core of humanistic inquiry. Many theories (from the eminently plausible to the certifiably insane) have been proposed to account for the origin and nature of these fundamental experiences. With the emergence of neurobiological research in the late 19th century, and the explosion of new approaches in the last 50 years, these topics have been studied with the range of methodologies now available to human neuroscience. But with few exceptions, humanities and neuroscience research have proceeded in parallel, with few points of connection that have yielded major insights. In part the reasons are sociological (scholars in the different intellectual traditions are deeply suspicious of one another), in part methodological (say a close reading of a text versus a high-resolution scan of a synapse), and in part logical (what could the relationship between the relevant concepts from humanities and sciences actually be?). The different cultures and intellectual traditions continue their work in isolation, but the yearning to find accounts of how these fundamental aspects of human experience arise from neural processes is present and increasing.

What would a productive neurohumanities research program look like? In the best of all possible worlds, one should learn both something about the domain in question (i.e., language, music, emotion, history, morality, art, etc.) *and* something principled about neurobiology. The best cognitive neuroscience research manages to illuminate brain organization and function and can adjudicate between interesting theoretical alternatives within a cognitive domain (for review, see Poeppel et al., 2020). A second-best (and still excellent) outcome would be interdisciplinary work that succeeds in making a substantive contribution to neuroscientific questions *or* to issues raised by the humanistic research. There are such examples: the interdisciplinary field of neuroeconomics, leveraging formalisms from behavioral economics, has yielded important insights into the neural computations underlying evaluations and decisions (Glimcher and Rustichini, 2004). A third and decidedly undesirable outcome—and this may be the modal situation—is interdisciplinary cross-sterilization. Rather than synergistic interaction between the questions, methods, and theories at stake, the research succeeds in yielding nothing of consequence to either discipline, or at best, produces descriptively acceptable datasets. So how to proceed? We outline three ideas that in our view merit careful consideration, if the endgame is to stimulate principled research at the intersection of the humanities and neuroscience.

The Simple-to-Complex, Small-to-Big Research Strategy Will Not Work

How we use language—across contexts ranging from the banal ("pass the salt") to the exalted ("I thought that love would last forever, I was wrong") —is an area of inquiry that has been at the center of the humanities. However, not all of language studies are particularly useful when linking to neuroscience. Research that aims to understand how language is represented and computed in the brain has a long history, and there has been remarkable progress (Hagoort 2019). That being said, the aspect of language research that has formed the basis for neurobiological studies builds on questions and techniques from computational and psycholinguistics, not questions that arise in a humanities context. The standard research program on brain and language—one which we endorse and which underpins our own work—addresses relatively low-level questions, ranging from topics in speech perception (e.g., how are syllables processed) to word recognition (e.g., where are lexical items stored) to sentence comprehension (e.g., when are syntactic operations executed). These topics can be addressed in a theoretically principled, computationally explicit, and methodologically thorough manner. Broadly speaking, the aim can be characterized as a search for brain mechanisms that make language processing possible. In

practice, based on research in linguistics, cognitive science, and psychology, we construct "parts lists" of linguistic primitives (e.g., feature, morpheme, verb phrase, concatenation, etc.) and try to identify linking hypotheses to neurobiological primitives that result from neuroscientific research (e.g., dendrite, cortical column, oscillation, etc.) (Embick and Poeppel, 2015).

A similarly reductionist research agenda has also been productive in the study of emotion and music. Within affective neuroscience, extensive cross-species research methodically quantifying and manipulating overt emotion-related behaviors (e.g., freezing in rodents) has yielded a detailed model of the neural circuitry underlying the expression of defensive emotional responses. A growing body of research in music cognition has also connected in important ways with neuroanatomy (e.g., are there cortical regions specialized for music) and neurophysiology (e.g., does auditory cortex entrain to beats). The goals typically include questions of this form: how is musical pitch encoded? What are the cerebral structures underlying rhythm perception? Are there differences between musicians and non-musicians in processing harmonic prediction?

If we take the (relatively narrow, well-delineated, and actionable) perspective that language, music, and emotion are inherently "concepts of the humanities" that can be explored in productive ways from the vantage points of psychology, computation, neuroscience, then we are basically done! Neurohumanities research is then simply research on concepts *traditionally* associated with the humanities that are *now* investigated using the perspectives and methods of these scientific disciplines. Although our own research is relentlessly reductionist and "decompositional" in its approach, and as such, very much in the tradition of the standard research program we outline above, we contend that this is *not* the type of research agenda that can address the central concerns of a *humanities*-inspired research program. There is a mismatch in the granularity of the phenomena and concerns.

To be sure, a formal analysis of meter in a poem or the goal to capture the "prose rhythm" of a particular writer can closely relate to what psychology and linguistics typically explore. However, the aspects of language that the humanities seek to characterize, in our view, go beyond the pursuits of linguistics, cognitive science, computation, and psychology. Likewise, in the case of emotion, can research programs drawing from studies of animal behavior and physiology lead to models of emotion that connect in a satisfying way to humanistic inquiry into the subjective experience of emotion (LeDoux and Hofmann, 2018)?

The question we ask ourselves is whether we can expect that by scaling up a research program focused on the neurobiology of simple psychological phenomena, we might eventually reach an understanding of humanistic experience. That is to say, will models of Gabor patch perception ultimately link to and illuminate the appreciation of the subtlety of a complex novel one is reading? Will our understanding of a simple acoustic stimulus scale up to the understanding of word recognition? And will that scale up to an understanding of sentences in a discourse? And—here is a huge step—does that in turn connect to an experience of identification and rapture in reading a Ferrante novel? The standard reductionist research agenda presupposes that studying simpler, smaller things can in some cases ultimately lead to a satisfactory understanding and explanation of complex phenomena. But we have no reason to believe that this is correct, as it's certainly not true in other domains of the sciences (Anderson, 1972).

If the formal characterization of the experience will not scale up from the stimulus, a successful neurohumanities research program cannot simply build on experiments from cognitive science and experimental psychology; rather, it must embrace the conceptual infrastructure of the humanities disciplines themselves. If the endgame is to develop a comprehensive understanding of these complex and subtle domains, we must consider the possibility that new insight can be gained by looking toward conceptualizations that the humanities make available and that we ignore at our peril. We suggest that the *goal of a neurohumanities research program that genuinely builds on the principles of both intellectual traditions* is roughly as follows: The humanities approaches to language, music, or emotion illuminate the rich subjective experiences that depend on properties of the individual, considerations of identity, and cultural context. As a consequence, the research might aim to *discover the neural principles that govern the construction of the subjective experience elicited by the natural socio-cultural stimuli that comprise the experience of language, music, and emotion*. A neurohumanities research program must negotiate between the desideratum to find regularity—a fundamental attribute of scientific inquiry—and the incorporation of individual experience into explanatory frameworks.

Embracing Ecologically Valid Naturalistic Experimentation May Be Necessary but Is Not Sufficient

There is currently tremendous enthusiasm in the field for using naturalistic materials in cognitive neuroscience experimentation. There has been a considerable amount of research using movies or music, pairing such audiovisual materials with techniques such as functional MRI, patient-based electrocorticography, electroencephalography, etc. (e.g., Baldassano et al., 2017; Salimpoor et al., 2013). There is also a growing body of work using real narratives, on the view that these types of materials capture ecologically valid experience more faithfully (Willems et al., 2020). Will it suffice to proceed with the existing research logic by simply using more complex, naturalistic stimuli? Does measuring the brain responses elicited by such materials provide a natural connection to the humanities by virtue of the materials themselves?

In our view, this research is to be lauded for the richness of the stimuli, their evocative properties, and the idiosyncratic personal experience elicited in each listener or viewer. These features of naturalistic stimuli may be necessary in any attempt to link to the concerns of humanities-inspired research. It is undoubtedly a reasonable conjecture that these types of materials yield experiences that are closer to the types of concerns of the humanities in light of such intrinsic properties. That said, now the links to the *neurobiological* questions are extremely difficult to establish. It is not easy to obtain insight into the biological principles that

underlie complex individual experience by looking at the response of virtually the entire brain to such complex materials. The extraordinarily complicated and extensive pattern of neural responses that are generated by, say, several minutes of an emotionally powerful symphony or a film, are very difficult indeed to parse into constituent operations that allow us to interpret the biology in a more principled and mechanistic manner. To be sure, we are—perhaps naively—optimistic that mechanistic progress *can* be made by studying experimental participants during increasingly natural experiences (Baldassano et al., 2017; Heller et al., 2020). The challenge is to find a balance between the naturalism of the experimental materials and the careful control that permits precise biological interpretation. This is possible, but it requires very thorough characterization of the materials at many levels and very well-developed predictions about how stimulus attributes interact with the brain—without giving in to reductionist predilections.

The Biggest Homework: Identifying Actionable Linking Hypotheses

The major challenge is to formulate *linking hypotheses* that provide a conceptual substrate on the basis of which to design new experiments at the humanities-neuroscience interface. But this is a very deep and difficult problem. How, for example, are we to conceive of the link between the "stuff of thought" (such as "transitive verb" or "harmonic progression" or "feeling of achievement") and the "stuff of the brain" (like "dendritic spine" or "cortical oscillation")? The basic concepts, or primitives, are ontologically incommensurable. One critical, intermediate step to a vibrant neurohumanities, therefore, will be the development of linking hypotheses that are equally well motivated from a humanistic perspective and tractable with neurobiological methodology. Because this problem is rather significant even when one looks at well-defined, cognitive science research (i.e., we don't have an understanding of the experience of joy, so why would it be easy to have an understanding of the experience of rapture in the reading of a book?), the development of linking hypotheses between humanities-based concepts and neuroscience-based ones is even more charged with complexity.

What would a serious neurohumanities research program in these domains look like, one that is intellectually sensitive to key concepts of the humanities while simultaneously providing experimental agendas that are actionable given what we know about human neuroscience? We submit that the novel, to-be-developed linking hypotheses embrace the serious study of subjective experience. This must include the study of systematic ways in which subjective experience is influenced by prior knowledge. In the end, the work should seek to provide an account of the biological embedding of an individual's context and culture. And to make this valuable from the perspective of human neuroscience, the data obtained from experimentation should be more than just another measurement made in response to some stimulus. There should be the ambition to understand the organization of the brain and exactly how it gives rise to rich naturalistic experience.

Current progress on the brain basis of language, music, and emotion is exciting and spurs legitimate optimism, but one must bear in mind clear limitations: the insights remain by-and-large correlational, not explanatory. The relation between neuroscience and these three deeply human experiences are increasingly well characterized. The spatial resolution of the imaging methods and the temporal resolution of the recording methods allow ever greater descriptive characterization. However, we still lack the appropriate "conceptual resolution" to develop in a comprehensive, mechanistic, and explanatory fashion how these domains of rich individual experience are implemented in a brain.

REFERENCES

Anderson, P.W. (1972). More is different. Science *177*, 393–396.

Baldassano, C., Chen, J., Zadbood, A., Pillow, J.W., Hasson, U., and Norman, K.A. (2017). Discovering event structure in continuous narrative perception and memory. Neuron *95*, 709–721.e5.

Embick, D., and Poeppel, D. (2015). Towards a computational(ist) neurobiology of language: *Correlational*, *integrated*, and *explanatory* neurolinguistics. Lang. Cogn. Neurosci. *30*, 357–366.

Glimcher, P.W., and Rustichini, A. (2004). Neuroeconomics: the consilience of brain and decision. Science *306*, 447–452.

P. Hagoort, ed. (2019). Human language: From genes and brains to behavior (MIT Press).

Heller, A.S., Shi, T.C., Ezie, C.E.C., Reneau, T.R., Baez, L.M., Gibbons, C.J., and Hartley, C.A. (2020). Association between real-world experiential diversity and positive affect relates to hippocampal-striatal functional connectivity. Nat. Neurosci. *23*, 800–804.

LeDoux, J.E., and Hofmann, S.G. (2018). The subjective experience of emotion: a fearful view. Curr. Opin. Behav. Sci. *19*, 67–72.

D. Poeppel, G.R. Mangun, and M.S. Gazzaniga, eds. (2020). The Cognitive Neurosciences (MIT Press).

Salimpoor, V.N., van den Bosch, I., Kovacevic, N., McIntosh, A.R., Dagher, A., and Zatorre, R.J. (2013). Interactions between the nucleus accumbens and auditory cortices predict music reward value. Science *340*, 216–219.

Willems, R.M., Nastase, S.A., and Milivojevic, B. (2020). Narratives for Neuroscience. Trends Neurosci. *43*, 271–273.