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An Integrative Neurological Model for Basic Observable Human Behavior

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An Integrative Neurological Model for Basic Observable Human Behavior

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Abstract

The scientific method uncovers information from the natural world in small increments. This spurs the design of models to explain how the pieces fit together and to identify future targets of research. This is especially the case in psychology, where visualizing concepts is an advantageous practice. One all too common criticism of cognitive and behavioral models in psychology is the lack of a biological basis. This paper aims to alleviate part of this issue by integrating currently understood biological and neurological mechanisms that drive psychological phenomena into a predictive and descriptive model for basic human behavior. To accomplish this task, this paper explores numerous scientific reviews and studies regarding sensory perception, emotion, learning, and memory. This paper also features original research about decision making. Creating this model is a necessary first step for targeting possible future research and clinical practices related to human behavior.

Keywords: sensory perception, emotion, learning, memory, decision making, behavior

An Integrative Neurological Model for Basic Observable Human Behavior

Creating a biologically-derived model for psychological behavior can provide further legitimacy to the field, as well as provide unique targets for future research and clinical practice. To create such a model, it is first necessary to demonstrate how human behavior is a natural consequence of biological mechanisms. Doing so requires demonstrating the mechanisms thought to drive behavior. According to the proposed model, perception is the first step, and consequently must be understood biologically. Following perception is emotion, as well as learning, memory, and decision making behavior. All of these concepts must be demonstrated in a mechanistic fashion to fit as working, moving parts in an integrative biological model for behavior.

Literature Review

Vision is an important method of perception for human beings, as we rely on it the most in everyday life. Almost every conceivable human action is benefitted by or dependent on vision. Despite this, vision does not truly exist in the way one may think. The world outside is not what human beings see. At the back of the eyes reside the retinae, consisting of modified cells called rods and cones that react to light. They do so by transducing, or converting light into chemical signals using stacked discs of rhodopsin channels for rods and cone opsin for cones (Koch & Dell'Orco, 2015). As Koch and Dell'Orco describe, rhodopsin channels are activated by contact with photons from light that catalyzes multiple downstream enzyme, chemical, and calcium-induced reactions that result in the rod or cone firing to later processing neurons in the eye called retinal ganglion cells. The reason rods and cones use different opsins is because rods are used for black and white vision, while cones are used for color (Koch & Dell'Orco, 2015).

Light simply collides with our photoreceptors and imprints a shape of activation in the retina by doing so—the outside world is never seen as it truly is; it is represented through a pattern of activation. This is analogous to judging the shape of an object by its shadow rather than by looking directly at it. (Peirce, 2015) explains how activated rods and cones send signals to nearby retinal ganglion cells to be processed and sent to the brain. As described, the two noteworthy parallel regions of the brain that receive these signals are referred to as the lateral geniculate nuclei—the left processing the right visual hemisphere, and the right processing the left hemisphere. These nuclei then send their processed visual signals to area V1 in the visual cortex, where vison can be deconstructed and reconstructed. After this follows many other processing areas and pathways. The visual pathway is retinotopic, or topographically similar to the picture received by the retina. From retina to occipital lobe, these inputs retain the light source's shape and properties (Peirce, 2015).

Auditory perception is also important, as humans rely on it to hear voices, notice threats, interpret language, listen to music, among many other activities. Despite this, sound does not exist outside of perception, as it is actually a phenomenon of the mind. Humorously, this provides evidence that if no live animal were around to hear a tree fall, it would not actually make a sound—it would simply displace air. The mechanism behind auditory perception transduces air pressure waves into perceived sound. According to (Frolenkov, Belyantseva, Griffith, & Friedman, 2004), these pressure waves travel through the medium of air, and funnel into the ear drum. This causes the eardrum to vibrate in sync with the frequency of the pressure waves, where the energy is then transferred to three small bones deep inside of the ear called the ossicles. These bones, the incus, malleus, and stapes, are physically connected to the ear drum, and thus rattle in sync with it. This mechanical energy is then transferred into a fluid-filled,

coiled structure called the cochlea which closely resembles a snail. The resulting fluid pressure waves interact with a membrane connected to hair cells. These hair cells are connected to each other via small links. When stressed or given slack by movement of the membrane reacting to the frequency of incoming sound, channels are opened in these hair cells. These channels allow ions to flood into the cell to initiate neuron-like firing that cascades downstream into the brain (Frolenkov, et al., 2004).

Somatosensory, the sensation of touch, and proprioception, the sensation of the orientation of one's limbs are very important senses for human beings. Speaking requires somatosensory and proprioceptive perception as does walking, eating, and many other human functions. Such perception is transduced through special touch-sensitive cells. (Fleming & Luo, 2013) provide an intriguing review on this subject matter, and explain how displacement of skin cells by physical stimuli induces physical pressure upon mechanoreceptors (mechanically activated receptor cells), which squeezes open ion channels causing the cell to send signals up the spinal cord and into the brain. As the authors explain, each mechanoreceptor reacts to different forms of touch. The Merkel receptor provides shape and edge detection, while the Ruffini corpuscle provides proprioception by getting stretched by nearby skin, and the Meissner's corpuscle transduces textural information, as the Pacinian corpuscle responds best to movement of the body due to its sensitivity to vibration (Fleming & Luo, 2013). As these specialized neurons fire up the spinal cord and into the brain, they are separated into specific regions of the brain, as described by (Nakamura, et al., 1998). Touch-relevant information is segregated to specific regions of the sensorimotor cortex, a strip-like region spanning the middle of the brain, under the top-middle of the skull down to just in front of the ears.

When looked at linearly along its strip-like orientation, each section of the sensorimotor cortex's corresponding bodily area is in the same order that human beings physically exist; toes to mouth. Fascinatingly, if a man were to be poked on the left arm, the limb would never feel it. Rather, the middle of the right hemisphere of his somatosensory strip would feel the sensation of touch via neural signaling. The brain's activation along a region in the somatosensory cortex from a subsequent body section is the actual feeling of touch—brains feel touch, not limbs. As performed by (Nakamura et al., 1998), mapping the sensitivity of body regions creates the homunculus. As the authors describe, the homunculus resembles the human body, but the body regions are represented in proportion to the sensitivity of each area, and thus look disproportional to an actual human. The hands, fingers, head, facial structures, genitals, feet, and toes of humans are extremely sensitive, and thus appear abnormally large on a human homunculus. This study sought to verify this preexisting map by using Magnetoencephalography (MEG) instead of previously used surgical methods (Nakamura et al., 1998). MEG is a method of brain scanning which uses magnets on the exterior of the cranium. The study was able to provide further support for previous surgically-derived methods of homunculus mapping.

Animals with a strong sense of smell can find prey easily and avoid predators more readily. Smell also aids animals in avoiding hazardous environments, and the same applies to human beings. Taste is just as important. The taste of rotting food turns most humans away, and there is good reason for this. Rotten food likely contains harmful microcellular organisms and compounds, so avoidance of such rotten food is beneficial. Taste and smell are very similar processes, as they rely on chemicals physically binding to receptors. A layer of skin inside of the nasal cavity, studded with olfactory receptor neurons called the olfactory epithelium receives chemical signals emitted by what is being smelled (Snyder, Sklar, & Pevsner, 1988). As

explained by the authors, the mucus inside of the epithelium traps these chemical signals, where they physically bind with the branching olfactory receptor neurons. These neurons then transmit chemical information through projections into the olfactory bulb, a structure in the bottom of the frontal region of the brain. Similar to olfactory receptor neurons, taste receptors are modified skin cells, that when bundled together, form a taste bud (Snyder, et al., 1988). As (Sugita, 2006) explains, taste buds respond to bitter, sweet, salty, sour, and umami tastes. The receptors work by receiving flavor molecules followed by differing intracellular operations that produce an increase or decrease in the rate of electrochemical impulses emitted by later associated nerves. The impulses then feed through the brain stem into the gustatory cortex, an area of the brain responsible for identifying tastes (Sugita, 2006). One does not smell or taste a given stimulus due to some inherent quality within it; rather, actual particles from the stimulus bind with modified cells that send signals to the brain. Unfortunately, due to these processes, this means the unpleasant smell of manure is caused by actual manure particles invading the olfactory epithelium.

Similar to the five major senses, emotion is also perceived. Human beings rely on a system in the brain called the limbic system to perceive emotion, and coordinate it with learning and memory. According to (Phillips, Drevets, Rauch, & Lane, 2003), the amygdala, insula, ventral striatum, and regions of the anterior cingulate gyrus, all located roughly in the center of the brain, as well as the prefrontal cortex, the front-most region of the brain, detect emotionally significant stimuli and produce responses accordingly. This system is described by the authors as an appraisal mechanism. The brain appraises incoming stimuli, either relevant to previous behavior, behavior about to occur, or both. The hippocampus, prefrontal cortex, and other regions of the anterior cingulate gyrus regulate these responses (Phillips, et al., 2003). What is so

important about emotion is that it is the most basic form of preference or avoidance in humans. An emotional response to a given stimulus can determine the route of behavior taken. Emotion is also very important in learning, as the structures associated with it have many connections with learning systems, as they are all a part of the limbic system.

The authors' review contains a compelling model for how the neural mechanisms work in relation to emotion and behavior. As an outside stimulus is brought into the brain through perception mechanisms where the limbic system appraises it, an affective state is produced within the organism. As described, the affective state is a type of physiological or behavioral reaction which is regulated by the frontal lobe and learning centers that either inhibit or enhance the appraisal and affective state respectively (Phillips, et al., 2003). This can be incorporated into any number of thought experiments. For instance, Gerald likes pizza, and spies his friend eating some. Gerald appraises the pizza, and is reminded that he likes it. Gerald is now salivating and wants to eat some of the pizza. At this point, his frontal lobe and learning areas regulate the urge, reminding him of the context of the situation—eating his friend's pizza without permission most likely won't end well, and so his affective state is revised. Gerald may now decide to go buy his own pizza, or ask his friend if he is willing to share. The biological and psychological basis behind emotion is important for any model concerning human behavior.

The consequence of appraising stimuli is learning about it and storing such knowledge internally. Associative learning, one of the most basic forms of learning, is vastly important to the field of behavioral neuroscience. Ivan Pavlov discovered this phenomenon while studying the salivary glands in dogs, as described by (Marks, 2004). Classical conditioning, a form of associative learning, relies on two stimuli and a response. In his foundational study, Pavlov would ring a bell before presenting meat powder to a dog. The dog would subsequently

salivate—an involuntary physical response. Eventually the dog would associate or pair the

ringing of the bell with the presentation of meat powder. Due to this, upon hearing the dinner

bell, the dog would immediately begin salivating. Pavlov played with this, and measured

learning times and outcomes. Pavlov discovered after the pairing was made, it would stay until

after a certain number of trials where no food was presented, causing the behavior to become

extinct. Continuing the trials regardless of that lack of salivation, Pavlov discovered a

phenomenon called spontaneous reacquisition. The animal would begin salivating again, despite

no presentation of food. Further, when retraining the dogs to salivate by pairing the bell with

food again, the dogs learned far quicker than the first time they had learned (Marks, 2004).

Following Pavlov's discovery, classical conditioning was hypothesized to have biological

correlates. Through classically conditioning a sea slug for certain behavior, (Carew, Hawkins,

Abrams, & Kandel, 1984) identified the neurons necessary for the behavior and removed them

for experimental purposes. Through experimentation, they found that neurons that send

information to other neurons could increase their efficacy or synaptic strength with the receiving

neuron through modification by receiving input from a nearby neuron. This three neuron

demonstration of physiological changes occurring due to classical conditioning provided major

evidence to classical learning being a consequence of biological actions.

Experiments using classical conditioning soon popped up all over academic journals, and

such behavioral studies are still carried out today. Conditioned fear learning is a very useful tool

for analyzing different aspects of classical conditioning, the nature of certain species, and even

the nature of a given stimulus. (Hsu, et al., 2012) conducted a study measuring blood pressure

variations reflecting contextual fear learning which serves as an excellent primer. This learning is

facilitated through pairing of a benign stimulus with an aversive stimulus. The way this is usually

done, and was also done in this experiment, was through the use of electric shock. Rats were

implanted with blood pressure sensors to measure physiological reactions to fear learning, and

motion sensors tracked the animal to identify startle activity. After recovery from surgery, rats

were put into a box (only one per box), and the benign stimulus (white noise) was played.

Following the noise, rats were shocked. Eventually the rats paired the white noise with the shock,

and would perform a fear response upon hearing the white noise. This study looked for blood

pressure changes in accordance with startle responses but perfectly illustrates fear learning and

provides an example for classical conditioning outside of simple salivation studies.

       (Sejnowski & Destexhe, 2000) explain in their review article the current research on

sleep's function. The hippocampus is related to many kinds of learning, and upon reading about

this brain region, it becomes clear why. As explained, the brain uses the hippocampus to

integrate information into memories, and later sends them in pieces to different parts of the

cerebral cortex (the lobes of the brain). During sleep, the brain actively rehearses the storage

pathways used, thus solidifying them in a process called consolidation (Sejnowski & Destexhe,

2000). This article explains the biological mechanisms through which the hippocampus stores

information in the cortex, and pairs well with the biological mechanisms through which classical

conditioning is conducted. As explained in the article, Hebb's postulate, a model for the forming

of associations between neurons, paired with a pathway-forging hippocampus allows for the

sensory and emotional information of a memory or environment to be reduced into a basic,

abstract form of a memory, which is subsequently mapped into the cortex in regions that can

expand upon the basic and abstract information (Sejnowski & Destexhe, 2000). This is similar to

compressing computer files, transmitting those files onto a more capable computer, and then

using an algorithm to uncompress the files for proper usage. This is an amazing data-driven

neurological model for sleep's function, but more importantly for how information is stored, and how pathways are formed to access memory.

While contextual fear learning may appear cruel, and in fact may be so, its utility in the scientific study of learning, memory, and behavior is undeniable. (Ramirez, et al., 2013) conducted a study at MIT using this conditioning method to biologically insert a false memory into mice. This was never done before, and provides heavyweight evidence for the case that learning and memory are purely biophysical. Manipulating neuronal variables described in the previous review to elicit behavior in a predicted fashion, shows the level of understanding that the field of neuroscience contains within its literature. The hippocampus' involvement in learning and memory is so vast that manipulating it can predictably falsify whole memories in certain cases. (Ramirez, et al., 2013) worked with mice that were genetically modified to grow light-sensitive protein channels on their hippocampal cells when infected with a specific virus, thus making these neurons fire when light is shone upon them, similar to rods and cons. These mice were also implanted with light-emitting fibers that could be turned on at the will of the researcher. The rats were exposed to environment A, a box with no present stimuli. They were then exposed to environment B, where they were shocked (conditioned fear learning). After this, the virus was activated in the brains of the mice. All neurons that were active during that day grew photosensitive protein channels. Once this was complete, the light emitting fiber was activated, causing the hippocampal neurons to fire in the proper phase to integrate all of the information into a single memory. This caused environment A to bundle in with environment B's contextual fear. The result was a fear response in both environment B and A. The mice never received electrical shock in environment A. To make sure this response wasn't universal, they put the rats in environment C, which they had never been in before. The rats did not respond in

fear to environment C, thus showing that the rats' memories of environment A were falsified with information from environment B (Ramirez, et al., 2013). Behavior was actually manipulated by using currently understood biological memory mechanisms.

B.F. Skinner discovered a form of associative learning unlike classical conditioning—operant conditioning (Marks, 2004). As (Brembs, 2003) describes, operant conditioning is based on the consequences following an action. For example, if an animal exhibits a behavior such as urinating on an expensive rug, punishment will discourage this behavior in the future. Alternatively, if an animal sits down when told to, and in result is given a treat, the animal will follow the command more often. Brembs' (2003) review navigates studies that uncovered some possible biological components behind operant conditioning with three animals: fruit flies, sea slugs, and snails. The findings of the studies described in the review provide evidence that operant conditioning is a biological construct. Through describing a gene responsible for operant behavior in fruit fly neurons, nerve cells responsible for triggering reward in sea slugs, and pond snail neurons responsible for triggering behavior in an operant context, the article makes it quite clear that the future holds for more great discoveries regarding the biophysical mechanisms behind operant conditioning. Based on the evidence described, Brembs (2003) postulates that a mechanistic model for operant behavior that integrates this data would have to include the physical modification of neurons that change or cause behavior, the physical modification of those neurons' connections to other neurons, and neurally quantifiable firing which matches reward or punishment context through sensory neurons to initiate such cellular modifications.

While operant conditioning can explain a large amount of behavior, and is commonly recruited in parenting and animal training, there are certain phenomena that are too complex to describe with simple reward and punishment. The acquisition of money is not a direct reward.

Money is an arbitrary construct that has no real value, yet most humans spend large amounts of time attempting to accrue as much as possible. As (Smith, 1972) demonstrated through the use of tokens, this behavior is still very explainable under the operant paradigm. Smith's experiment included small children in an operant behavioral task. Through successful behavior, children repeatedly earned one of two kinds of tokens which could then be inserted into a slot. One type of token yielded trinkets coming out of another slot. The other type of token did not yield trinkets. Behavior changes were discovered between the two types of tokens; the trinket-paired tokens acted as secondary reinforcers, or stimuli indicating the requirement for another action to receive a reward, while the other tokens had no relevance to the children (Smith, 1972). This serves to illustrate how secondary reinforcers work in an operant context. While money cannot be eaten, mated with, or used as entertainment, money can certainly buy food, sex, and entertainment, and is thus paired with them. This pairing allows money to exist as operant reinforcement even though it lacks many of the qualities of primary reinforcers.

Decision making has an air of complexity to it. And, upon careful thought, is usually thought to be an operant process. But what if preference towards a specific choice was classically conditioned? My lab and I investigated this matter utilizing a seemingly operant rodent task our professor designed, and a computational model we designed to predict this behavior (Francis, Ortiz, Ender, Green, & Hyman, 2016). The equation used for this model was a modified form of the 1972 Rescorla-Wagner model, created to simulate and measure classical conditioning. The rats successfully learned the task and performed the required behavior with a fair amount of efficiency. Upon Kolmogorov-Smirnov and Regression analysis, we found that our classical conditioning model accurately simulated this seemingly operant decision making behavior. These results suggest that the two choices available to the rodents were both classically

conditioned, and the option that currently had the most learned preference was chosen. If

classical conditioning models can properly simulate supposedly operantly conditioned decision

making behavior, then at least this form of decision making is possibly a form of classical

conditioning and the mechanisms behind it can be explained with pre-established biological

mechanisms for classical learning. A strong theme for the proposed model is the idea that

between different pathways available, the most reinforced, or conditioned pathway available will

likely be taken.

Discussion

Using the studies and reviews supplied, a model can be formed. First, stimuli must be

perceived. At this point, the sensory information is carried into the limbic system where the

amygdala and relevant frontal lobe regions appraise the incoming sensory information and

modulate its physiological effects as well as effects on contingent behavior. While this occurs,

hippocampal regions recall related information from the cortex to modulate the contingent

behavior based on previous experience, and also update the cortex with the incoming sensory

stimuli and appraisal from the amygdala. Following this, decision making has the final control

over the contingent behavior. The decision made is dependent on the most hardwired

conditioning still relevant after the modulatory trimming is performed. According to this model,

if the contingent behavior to smelling a harmful chemical is to leave the nearby area, and two

pathways exist after the modulatory trimming such as a stay pathway or leave pathway, the most

hardwired, conditioned, or most strongly associated pathway will be taken. Once behavior

occurs, the consequence is perceived and assessed in the same way the initial stimuli were; (see

Figure 1). To test this model, demonstrate how it is used, and address possible counterarguments,

five hypothetical situations are described and rationalized with the model.

A man who has quit drinking for six years sees a bar sign and surprisingly binge drinks to the point of destructive intoxication. How did this occur? The man senses the bar sign, and his amygdala and hippocampus recall positive associations and a sense of desire. Decision making is overridden by the strong association between bars and satisfaction rather than the weaker association between sobriety and success. This can be seen as an explanation for spontaneous reacquisition of extinguished addiction behavior.

An ex-smoker and business owner is given a choice between two logos by a graphic designer. One has similar font and usage of color to a popular cigarette carton, and the other is another viable option. The business owner's perception of the cues from the first option recall associations to satisfaction and relief via the limbic system, thus biasing the decision made—the option that looks like cigarette packaging has a much stronger pathway. This makes the first option the highest rewarding stimulus, and thus it is chosen.

Sarah eats a bite of cake. Cake is full of sugar, and the taste perception neurons send signals into her limbic system to release enjoyment chemicals. The perception excites the amygdala, the hippocampus recalls similar tasting memories, and decision-making behavior is biased by the hardwired associations between sugar and the motor action of eating it, resulting in more bites taken. Why do people not always just sit down and eat cake? The reason for this could be in their frontal region modulating their limbic system and subsequent behavior, or perhaps the desire to look thin or be healthier is stronger and more rewarding than the desire to eat cake.

George has his first panic attack in a motor vehicle on the highway. Rebecca has a panic attack in a motor vehicle in a parking lot. George now avoids vehicles at all costs, even at the expense of his financial security. Rebecca will still enter vehicles, but she is petrified of parking

lots, and thus avoids them. Why do two people who both had panic attacks in motor vehicles have different avoidance behaviors? When George was driving on the highway, he was effectively driving in a straight line, so his attention was directed to stimuli inside his car, and other cars to avoid. A panic attack could be associated with those stimuli, causing his avoidance of them. Rebecca was driving in a parking lot; her attention was directed towards pedestrians, shopping carts, other traffic, buildings, parking lines, and barriers in the road such as curbs, crosswalks, and speed bumps. These stimuli fulfill the concept of a parking lot, and therefore that concept could have been paired with the panic attack. Looking at this from the model perspective is possible. George received sensory stimuli, the most salient being motor vehicles, and when his amygdala initiated the physiological affective state of a panic attack, the hippocampus paired them, and stored the association in the cortex. Subsequent behavior would base on this association, resulting in avoidance of motor vehicle stimuli. Rebecca received sensory stimuli that could cause the hippocampus to recall the context of a parking lot from the cortex, and keep it in place for the duration of her time in one. When her amygdala initiated the physiological affective state of the panic attack, her hippocampus could have paired the panic attack with the context of a parking lot, and encoded it into her cortex. Thus, the strong pairing of the two stimuli would influence behavior afterward.

Carl lives near his university, so he walks one mile to and from his classes every day. Carl is happy to do this, as it saves him money, and keeps him healthier than he would be alternatively. Despite his enthusiasm towards the activity, he noticed that he becomes more and more nervous as he approaches a four way stop sign where he crosses the road to his university. Looking at this from the model's perspective, it can be reduced into various components with ease. Carl's hippocampus previously associated the four way stop with an affective state from his

amygdala that induced enhanced arousal to make him more tense and aware of his surroundings, due to previous experience with dangerous drivers at the four way stop. Research has found neurons in the hippocampus that fire in correspondence with the organism's specific location, regardless of orientation; these are called "hippocampal place cells" (O'Keefe, 1976). Due to the hippocampus' ability to track place in time, the closer carl gets to the four way stop, the better his hippocampus can recruit relevant information from the cortex due to associations between the place cell firing and the context it contains. As a consequence of the association between the affective state, the stimuli, and Carl's distance from the stimuli, the closer Carl gets to the four way stop, the more nervous he will become.

Limitations

Due to time limitations, educated assumptions were made in place of scientific evidence regarding pathways and relationships between relevant brain regions used in the model. With more time and work, this model can be fully supported by the current scientific literature, or refuted by it—thus signaling a direction in which future models should not take. Another limitation is the use of personally conducted research that was presented and will be continually presented at research conferences. Including personal research implies biases, and the inclusion of data sets represented on a poster rather than a publication indicates a lack of unbiased third-party peer review. Finally, the model proposed is intended to supplement additional research in the future, and is in no way asserted as truth or fact—it is simply based on educated hypotheses, currently accepted data, popular conceptions in the literature, and personally conducted research.

<div align="center">

Conclusions and Further Study

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Understanding biological mechanisms for small aspects of behavior is important for both research and clinical applications, but knowing how these mechanisms fit together allows for

even greater explanation and predictability of behavior, as well as provides more research targets, and offers even greater clinical utility. A plethora of neurological and psychological disorders exist that cause tremendous suffering for a silent portion of the world, such as obsessive compulsive disorder, bipolar disorder, depression, panic disorder, phobias, anxiety, Alzheimer's disease, schizophrenia, and autism spectrum disorder. Creating biologically-relevant models to assess normal behavior allows researchers and clinicians to break one aspect of a model to see what happens. If the result matches certain ailments, the model could indicate future targets for research, therapy, and medication. After describing relevant research and related concepts, they were integrated into a working model for behavior which was applied to hypothetical behavior. Through this application, the model demonstrated its utility and ability to describe such behavior. Despite the stated limitations, this work provides one avenue to possibly alleviate the lack of biological validity in relevant psychological theories, benefit the treatment and research of disorders of the brain, and also serve as a starting platform for further work and hypothesis building for this subject matter, and more specifically, an integrative biologically-derived model for basic, observable human behavior.

References

Frolenkov, G. I., Belyantseva, I. A., Griffith, A. J., & Friedman, T. B. (2004). Genetic insights

into the morphogenesis of inner ear hair cells. *Nature Reviews Genetics, 5*(7), 489-498.

doi:10.1038/nrg1377

Brembs, B. (2003). Operant conditioning in invertebrates. *Current Opinion in Neurobiology,*

13(6), 710-717. doi:10.1016/j.conb.2003.10.002

Carew, T., Hawkins, R., Abrams, T., & Kandel, E. (1984). A test of hebb's postulate at identified

synapses which mediate classical conditioning in aplysia. *Journal of Neuroscience, 4*(5),

1217.

Fleming, M. S., & Luo, W. (2013). The anatomy, function, and development of mammalian Aβ

low-threshold mechanoreceptors. *Frontiers in Biology*, *8*(4), 10.1007/s11515–013–1271–

1. http://doi.org/10.1007/s11515-013-1271-1

Francis, R. M., Ortiz, A. A., Ender, L. A., Green, K. E., Hyman, J. M. (2016, March). *Predicting*

Preference: A Computational Model for Decision Making Behavior. Poster session

presented at the Spring 2016 Undergraduate Research Forum of the UNLV Office of

Undergraduate Research, Las Vegas, NV.

Hsu, Y., Yu, L., Chen, H., Lee, H., Kuo, Y., & Jen, C. J. (2012). Blood pressure variations real-

time reflect the conditioned fear learning and memory. *PloS One, 7*(4), e32855.

Koch, K., & Dell'Orco, D. (2015). Protein and signaling networks in vertebrate photoreceptor

cells. *Frontiers in Molecular Neuroscience, 8*, 67. doi:10.3389/fnmol.2015.00067

Marks, I. M. (2004). The Nobel Prize Award in Physiology to Ivan Petrovich Pavlov - 1904.

Australian and New Zealand Journal of Psychiatry, 38(9), 674-677. doi:10.1080/j.1440-

1614.2004.01440.x

Nakamura, A., Yamada, T., Goto, A., Kato, T., Ito, K., Abe, Y., …Kakigi, R. (1998).

  Somatosensory homunculus as drawn by MEG. *Neuroimage, 7*(4), 377-386.

  doi:10.1006/nimg.1998.0332

O'Keefe, J. (1976). Place units in the hippocampus of the freely moving rat. *Experimental*

  Neurology, 51(1), 78-109. doi:10.1016/0014-4886(76)90055-8

Peirce, J. W. (2015). Understanding mid-level representations in visual processing. *Journal of*

  Vision, 15(7), 5.

Phillips, M. L., Drevets, W. C., Rauch, S. L., & Lane, R. (2003). *Neurobiology of emotion*

  perception I: The neural basis of normal emotion perception. United States: Elsevier Inc.

  doi:10.1016/S0006-3223(03)00168-9

Ramirez, S., Liu, X., Lin, P., Suh, J., Pignatelli, M., Redondo, R. L., …Tonegawa, S. (2013).

  Creating a false memory in the hippocampus. *Science, 341*(6144), 387-391.

  doi:10.1126/science.1239073

Sejnowski, T. J., & Destexhe, A. (2000). Why do we sleep? *Brain Research, 886*(1-2), 208-223.

  doi:10.1016/S0006-8993(00)03007-9

Smith, T. D. (1972). Development of tokens as secondary reinforcers. *Journal of Experimental*

  Child Psychology, 14(1), 133-138. doi:10.1016/0022-0965(72)90038-0

Snyder, S. H., Sklar, P. B., & Pevsner, J. (1988). Molecular mechanisms of olfaction. *The*

  Journal of Biological Chemistry, 263(28), 13971.

Sugita, M. (2006). Taste perception and coding in the periphery. *Cellular and Molecular Life*

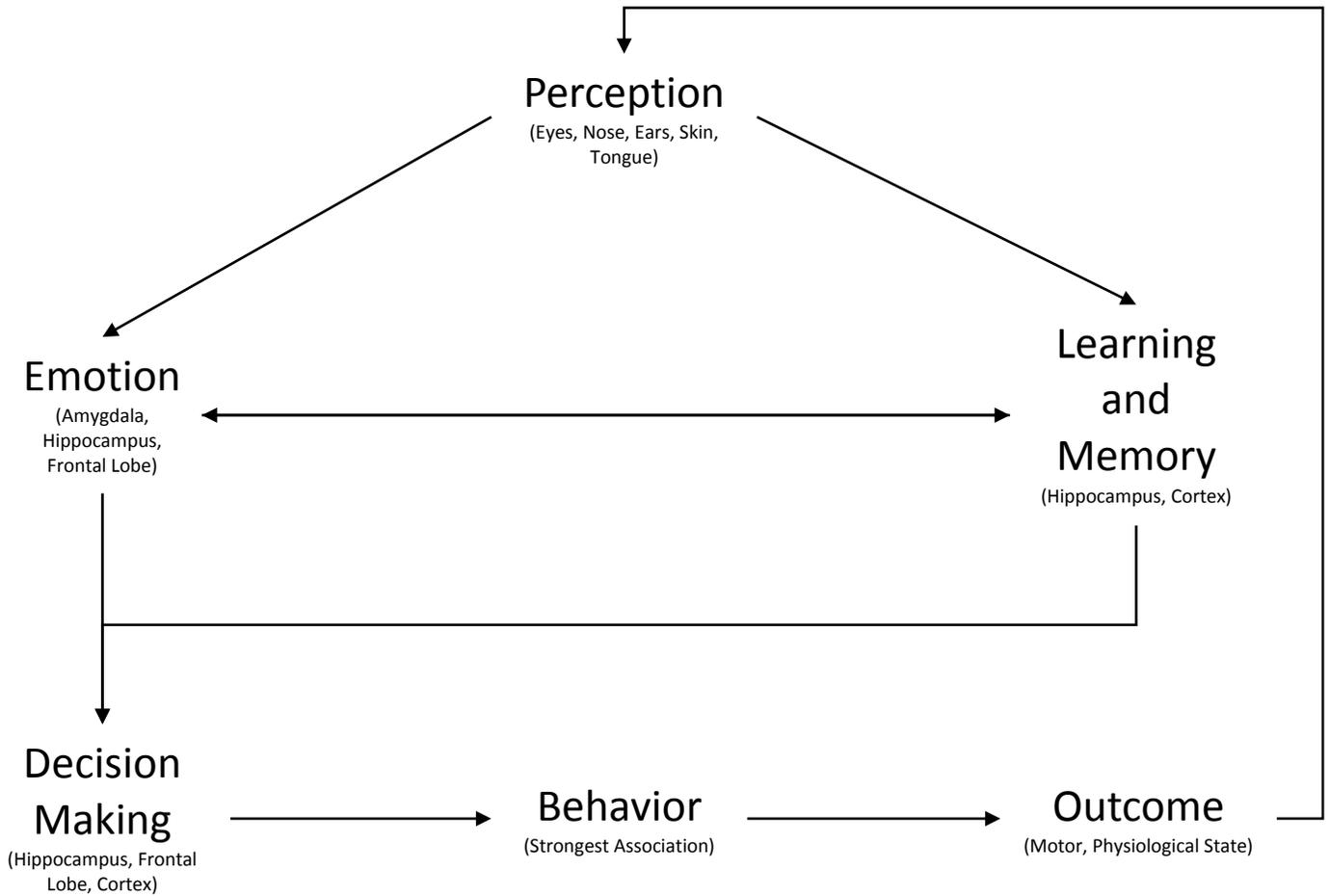 *Sciences, 63*(17), 2000-2015. doi:10.1007/s00018-006-6100-0

Figures

Figure 1. Perception is sent to the limbic system (emotion bodies and learning and memory bodies.) These bodies modulate each other, as well as decision making areas (hippocampus, frontal lobe, and cortex.) This information is then transmitted as behavior to motor areas, or bodies that control physiological states (the most ingrained pathway after modulatory trimming of options is chosen.)