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Analysing the *Shema* in the Light of the Neurobiology of Virtue

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Abstract: Moses's great command, known to us as the *Shema*, taught the Jewish people that the great goal of one's entire being must be love of God but that this outcome can be easily obscured in the face of distractions and competing pleasures. The task he describes may be understood as an exhortation to live and teach moral virtues, informed by faith in God: self-management of impulses and conditionings so that we can think clearly about the goals we pursue and love wisely. This study offers an analysis of the *Shema* through the lens of neurobiology. This approach supports a literal interpretation of the *Shema* to the extent that it provides a neurobiological explanation for the role of memory, positive emotion, and curated attention in establishing positive convictions and holding to them in the face of contrary stimuli. In doing so, it demonstrates that such applications of neurobiology can enrich our understanding of human behaviour because they offer insights into the internal dynamics at work in human choices and motivations, and into the need for coherence between our emotional responses and our convictions.

Keywords: virtue; cardinal virtues; neurobiology; Old Testament; Thomistic/personalistic anthropology; love

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1. Unpacking the *Shema*

The passage known as the *Shema*[1] is one of the most recognisable passages from the Bible. Every morning and evening, observant Jews still recite these verses in their families. This text from the book of Deuteronomy commences with the words 'Hear O Israel (*shema yisra'el*)' and is known popularly as the *Shema*. Moses warns the Hebrews to love God completely, and to be constantly reminding themselves and their children of this great truth, because, in the land of milk and honey, they will be surrounded by abundance, and with their material desires satisfied, they may forget God and their own dependence upon him.

Moses admonishes the Hebrews in the desert.

> Hear, O Israel: The Lord our God, the Lord is one. Love the Lord your God with all your heart and with all your soul and with all your strength. The commands I give you this day must be written on thy heart, so that thou canst teach them to thy sons, and keep them in mind continually, at home and on thy travels, sleeping and waking.

Moses emphasises in practical detail that parents must keep these commands present for themselves and their children.

> Talk about them when you sit at home and when you walk along the road, when you lie down and when you get up. Tie them as symbols on your hands and bind them on your foreheads. Write them on the doorframes of your houses and on your gates.

And he tells us the reason why this constant keeping-present is so important:

> When the Lord your God brings you into the land he swore to your fathers, to Abraham, Isaac and Jacob, to give you—a land with large, flourishing cities you did not build, houses filled with all kinds of good things you did not provide, wells you did not dig, and vineyards and olive groves you did not plant—then when you eat and are satisfied, be careful that you do not forget the Lord, who brought you out of Egypt, out of the land of slavery.

It is an uncompromising text—'all your heart… all your soul… all your strength', multiple urgent strategies so that the conviction is 'written on your heart', seemingly figurative commands like 'tie them on your hands and bind them on your foreheads', and the assertion that a satisfying meal could lead to forgetfulness of God's blessings. All this could seem powerful but ultimately not meant to be taken literally.

In this paper, I analyse the *Shema* by drawing on a specialist knowledge of the neurobiology of virtue. Neurobiological analysis adds weight to a literal reading of the text: the utter priority of fulfilment in a loving relationship; that love is preferential to punitive threats and that we need to work tirelessly at reinforcing such convictions; that visual stimuli and thoughts easily lead to desire; that memory is crucial for sustaining love; that gratitude is a powerful motivator; that we easily revert to former behaviours in the face of sense gratification. Furthermore, it can be argued that a diligent response to Moses' admonition requires virtuous behaviours facilitated by the cardinal virtues and that these suggest some correlation to the trichotomy of 'heart, soul and strength'. In all these matters, a grasp of neurobiology may be seen to assist authentic interpretation of the text.

A literal confirmation of the text therefore adds weight to the view that the passage reveals timeless anthropological and psychological insights into human nature. Indeed, the prediction of the *Shema* seems realised. In the West, we have an abundance of milk (our material needs) and much of the honey (the sweet extras). We are in the midst of the most affluent and comfortable age in the history of mankind, and yet more than at any time in history, it would seem we are forgetting God, given the rise of atheism in areas of the developed world.

2. A Virtue-Oriented Analysis of the *Shema*

As a fundamental paradigm, we study the text in the light of a Thomistic/personalistic anthropology that posits virtues as a key to wellbeing and, ultimately, beatitude. Although other approaches could utilised, I adopt a Thomistic notion of virtue and of the cardinal virtues because of its coherence with respect to rationality. Aquinas situated virtue within a rational anthropology, teaching that the four powers of concupiscible and irascible appetites, rational will, and intellect each require their specific perfecting habit. These habits are the cardinal virtues.[2]

Now, in recent decades, as the neurobiological systems and processes of virtuous behaviours are being progressively described, it is possible to marry the two disciplines to investigate the neural bases of virtue. In this paper, I examine the psychology described in the *Shema* and interpret this in the light of virtue, of the cardinal virtues, and of the underpinning neurobiological discoveries. This approach adds weight to the view that virtues are not merely arbitrary constructs for describing behaviour, but that they capture objective attributes which are good for us as human beings. The neural analysis offers a clarity of appreciation of the text and its psychological insights.

3. A Metaphysical Caveat

This paper presupposes a metaphysical foundation for discussion of human action in the light of neurobiology. Were human beings but smart monkeys, and therefore animals

for which rationality is not essential but accidental, it would be metaphysically incoherent to propose that human beings alone should be fulfilled in intentional relationships of love, yet this is precisely the position advocated by the *Shema* text. Roger Scruton noted, 'there is a problem about accounting for rationality and the general difference between man and the other animals. . . in the end we need some kind of teleological metaphysics to make sense of our condition' (Mullins 2017).

The distinctive feature of human existence within such an anthropology is that humans are embodied but spiritual. Human freedom and fulfilment in intentional loving relationships with another person (God or human) imply that human beings can transcend sense experience. Rationality, as an essential characteristic, may not be reduced to pathways, brain regions and chemical processes and mechanisms, nor to the processes of reasoning, nor to consciousness or qualia. 'Rationality should not be seen as a ghostly process exclusive of the world of matter, but rather as a transcendent process within matter itself by virtue of a participated power' (Mullins 2022a, p. 83).[3]

Such a foundation posits a metaphysics of soul as a principle of being, rationality, and function. If soul is understood as a participated but non-substantial principle, a philosophically and scientifically coherent account of free will and our non-material capacities for understanding and love follows (Mullins 2022b, p. 191). Without soul understood as such, it may be more difficult to account for the contingency of living persons. Cornelio Fabro taught that participation in *esse subsistens* is the key to Aquinas' metaphysics: 'It is from the concept of *esse* as ground-laying first act that Thomas develops his own notion of participation and his entire metaphysic' (Fabro 1974). Aquinas' argument for participation starts with observations of contingency. He notes that existence and essence are distinct notions:

> Every essence or quiddity can be understood without understanding anything about its existence: I can understand what a man is or what a phoenix is and nevertheless not know whether either has existence in reality. Therefore, it is clear that existence is something other than the essence or quiddity. (Aquinas 1965a, *De ente et essentia*. IV)

It is directly through the *actus essendi* of the human soul that the human being exists. The soul is the principle of contingent existence, unity and function. It participates in Being, in *esse subsistens*, what Norris Clarke calls 'the Ultimate Source' (Norris Clarke 2015, p. 87).

In contrast, emergence and non-reductive materialism are the most common positions held by neuroscientists, who on scientific grounds oppose dualism, yet both these alternatives are open to metaphysical challenges.

It is beyond the scope of this paper to delve further into the philosophical justification for explorations of the neurobiological underpinnings of virtue and rationality (Mullins 2016, 2017). A reasoned defence of such approaches is to be found elsewhere. The purpose of this paper, building on these foundations, is to explore specific psychological and anthropological insights that can be gained by reflection on what is happening at the biophysical level.

4. Methodology

The originality of this paper lies in the examination of this psychologically rich passage of the *Shema* utilising current research into neurobiological mechanisms, pathways, systems and regions as a tool of analysis. The neurobiological analysis, while hypothetical, is thoroughly founded on current research into neurobiological mechanisms, pathways, systems and regions.[4]

In each of the following subsections, I first draw attention to aspects of the *Shema* text and place it in context, drawing out aspects of Aristotelian–Thomistic virtue. Second, I discuss the underpinning neurobiology, maintaining a primary focus on the behaviours

described by Moses, with a minor focus on the reactions of the listeners who are hearing his words. For each section, I offer a commentary on new or clearer insights that such an analysis offers. In conclusion, I suggest a number of aspects of the text that are clarified in this method.

Frequent reference will be made to *neural plasticity*, which is the underpinning mechanism for all learning in the brain. *Use-induced plasticity* is a principal mechanism for consolidation of *neural pathways*, which are the connections in the brain allowing messages from one part of the brain to another, or to and from parts of the body to the brain. The more a pathway is utilised, the more preferred and efficient it becomes.

In this analysis of aspects of limbic and cortical response and action, of particular note is the *prefrontal cortex* (PFC), which is the frontal brain area most active in the awareness and self-regulation of emotion. Mediating these functions in the PFC are the *orbitofrontal cortex* (OFC) and the *ventromedial PFC* (VMPFC), associated with consciousness of emotion, and the *dorsolateral prefrontal cortex* (DLPFC), with conscious regulation of emotion. Deeply implicated with these regions, we find the *limbic system*, and especially the *amygdala*, which mediates emotional response and memory. Adjacent to the limbic system are found the *basil ganglia* (BG), including the *striatum*, the *nucleus accumbens* (NA), and the *substantia nigra* (SN). These are now viewed as major players linking centres for emotion, reward, and both conscious and unconscious habit formation. The neurotransmitter *dopamine* (DA) also plays a prominent role in the discussion that follows. Further abbreviations will be flagged in the text below as they occur.

5. Analysis and Commentary

5.1. 'Hear O Israel.'

Attention is a prerequisite for all conscious learning.

At a neural level, by use of induced plasticity and by our choices, our attentional responses can be trained to focus on other persons in preference to the self-directed goals of daily living, or even self-indulgent behaviours and material rewards.

Moses' appeal triggers the *fronto-parietal attentional system* in his listeners (Froemke et al. 2007; Doidge 2007, pp. 84–88). The excitatory neurotransmitter *acetylcholine* (Ach) is released from the *nucleus basalis* into the *thalamus* and into areas of the *parietal, frontal and cingulated cortices*, heightening attentiveness. *Anterior cingulate cortex* (ACC) involvement in attentional systems appears necessary for learning and a prerequisite for goal election and executive command (Markowitsch et al. 2003).

Habits of attention are created by plasticity in the attentional systems. Attentional loops between the BG and the cortex are established. The BG play an integral role in attention regulation (Markowitsch et al. 2003; Doidge 2007, pp. 84–88; Kaas and Stepniewska 2002) and in these attentional loops (Doidge 2007, pp. 84–88). DA release is activated for emotional and reward responses and acts also as a facilitator of attention and plasticity.

This call to attention includes the highly emotive words 'O Israel'. The Hebrews are addressed as children of their father, Israel. These emotion-charged memories principally reside in the amygdala, with rich interconnection to the PFC areas of conscious deliberation. To hear these words is likely to elicit release of the neurotransmitter oxytocin from the hypothalamus, associated with an emotional surge of personal connection and trust. Possibly further DA release associated with joyful anticipation is triggered also, principally from the SN, and also *serotonin* (5-HT) from the raphe nuclei in the brainstem.

Commentary

We learn a great deal about ourselves from what we pay attention to: we pay attention to what we value.[5] Our attentional system is deeply implicated in will and choice. Mind-

fulness of where our attention is going can facilitate greater self-awareness and consequent greater self-management. The very formation of habits of paying attention pays dividends in the personal qualities we develop. If we invest our attention in something, we value it; a call to attention is a call to transfer that value into our own lives.

Here, we see the interconnection of attentional brain systems and memory and emotional memory, opening a cascade of consciousness of past experiences and convictions. A task of human maturity is to give order and purpose to the potential for interconnection in the brain. Virtue can be understood as a state of mature harmonisation of neural resources. A task of growing in virtue is to ensure that our emotional lives, our capacities for emotional regulation, goal setting and action plans, and the faith convictions that we maintain in our conscious memory are all fully integrated.

5.2. 'The Lord Our God, the Lord Is One.'

The *Shema* offers a complex and interrelated vision incorporating both material and spiritual realities.

It opens with a declaration of the existence of the ultimate and foundational spiritual reality. Yet while the contrast between the physical and the non-material is evident, the text suggests that depth of conviction in the spiritual can be fostered by physical behaviours and material reminders. The metaphysical foundation for this is that it holds to a view of human beings as embodied spiritual natures, and it is therefore within their scope to grasp spiritual realities and their effects, to reason with abstract concepts, and to derive spiritual benefit from material realities. Through the metaphysics of participation, bestowing upon them the capacities for spiritual operations, human beings possess a type of spiritual connaturality with God, enabling us to know and love him.

Although we human beings are capable of spiritual operations, we interact with the world first through our senses and emotional responses. We have the capacity to curate these sense-laden and emotional experiences, to educate our appetites and develop capacities for refined feeling so that our choices effectively moderate the sense experience and that as persons we respond to the call to love. This is the task of virtue: to train our appetitive responses so that we can think clearly and love wisely, thus developing a personality that integrates the emotional and cognitive, empowering us to love other persons.

Commentary

In our state as embodied spirits, animated bodies, we carry out spiritual operations within the body. Every mental event has a biophysical signature (Mullins 2022b, p. 182). We are not dualists. Our rationality is truly embodied. Virtue is the means whereby we integrate the spiritual/rational powers we possess with the sensitive/material elements of senses, appetites and emotions.

We develop our character and personalities through the development of virtue in our bodies, and this requires both training of the biophysical elements and education of the mind (Aristotle 2014, 1103a15-15). A study of the neurobiology of virtue reveals that pathways of self-control and the development of resilience in fear responses take time to develop as they are biophysically constructed. An advantage, however, is that, once established as virtues, they facilitate future action. Furthermore, if we define prudence as the capacity to operate in reality, including moral reality, and to set goals accordingly, the impact of convictions of faith on prudence may be readily seen... a person is now operating in the conviction that spiritual realities inform all their actions and choices.

5.3. 'Love the Lord Your God'

The *Shema* exhorts the Hebrews to 'love' without dissipation.

It is an imperative command, cumulatively emphasised by the three objective qualifiers: with all one's heart, soul and strength. 'Heart' can be understood as the sum total of our desires, both impulsive and reflective. 'Soul' suggests our whole being, and 'strength' reminds us we must love despite all the obstacles we encounter, presupposing the capacity to learn and change intentionally. It suggests that the capacity to love is the worthiest goal one can strive for and that one is called to love with all one's being.

Thomistic personalism proposes that human beings are fulfilled in truth and love, leading to a deeper appreciation, in accord with the basic hylomorphic tenets that knowing and loving can only take place in this embodied life, with the biophysical as material cause. The human being is understood as a person, an embodied soul, an animated body, with rational powers, and therefore fulfilled not only by sense knowledge and pleasure, nutrition and security, and movement and emotional life, but essentially by operations in the rational order of knowing truth and choosing, and ultimately, by the free gift of self in loving relationships. Every action and every choice disposes us either towards, or away from, this excellence in knowing and loving. Every moral action strengthens or bypasses predisposing neural pathways that support a commitment to reality and interpersonal love.

Commentary

Love may be both a desire arising subconsciously and an intentional choice based on convictions. In different ways, both demand harmonisation of all one's neural resources if we are to obtain peace. The text from the *Shema*, however, draws attention to love as a conviction, albeit fuelled by gratitude and knowledge.

In the calling to love articulated by Moses, love is the duty of religion, the reciprocation in justice for all that has been received. Significantly, Moses' demand is a positive framing of this duty. Encouragement and positive affect are recognised as predisposing factors for neural plasticity… we learn better when we are encouraged, not threatened. It is not a threat but a reminder that if it is ignored, it will bring its own consequences, a return to slavery of a different kind. This tells us very much about the relationship God seeks with his people, and very much about God as a father.

5.4. '…With All Your Heart and with All Your Soul…'

Love that is intentional requires capacities for self-management, virtues, stable capacities to manage emotional responses and appetites and to make wise choices.

From Socrates and Plato, Western philosophy has given pride of place amongst the virtues to the cardinal virtues, as the umbrella virtues required for human flourishing. The Thomistic understanding of the cardinal virtues as the perfecting habits for the four powers of a human being—of the sensitive appetites, the rational appetite and the intellect—finds remarkable validation in neuroscience. Within this taxonomy, virtue should not be seen as an arbitrary wish list of qualities but of perfections of the specific powers of a human being. These cardinal virtues are usually nominated as temperance, fortitude, justice and prudence.

Given that these cardinal virtues perform specialised and individuated tasks, it is possible to offer a plausible model of the implicated neurobiology.

Temperance, from a neurobiological perspective, involves modifications to neural pathways and specific areas of the prefrontal cortex (PFC) that regulate impulsive responses originating in the midbrain and limbic areas. Through the mechanism of neuroplasticity, we can train our attention and desires to disregard distractions and irrelevant impulses, allowing us to focus on and seek actions and objects traditionally associated with the good, the true, and the beautiful. Essentially, temperance consists of refined responses to pleasure.

Fortitude, on the other hand, represents resilience against pain—whether subjective or objective, major or minor, physical or mental. Neurobiologically, it involves developing pathways that enable cortical regulation of fear responses and anxiety-inducing memories. This intentional conditioning of fear responses prevents paralysis and underperformance, relying on rich fear-dampening connectivity between the amygdala and specific areas of the prefrontal cortex, where we have resources to help process and manage fears.

Justice at the neural level is supported by systems of empathy and cortical areas that help us consider the moral consequences of our actions and make ethical decisions. This process is influenced by memory and the reward systems activated by the joy of helping others, conditioning attentional systems to prioritise the welfare of others.[6]

Prudence, neurologically, is facilitated by pathways and systems for retaining convictions in memory, selecting goals, and deliberating on means to achieve them. It is supported by the neural processes associated with temperance, fortitude, and justice.

It follows that a calling to love with one's whole being requires intentional direction of pleasure-seeking and optimisation of resilience so that appetitive responses do not drag the person away from intended action, and in particular, that they do not detract from well-founded convictions of service generosity and commitment to others. In a religious framework informed by faith, those convictions are founded on gratitude to God our creator above all other personal relationships and material aspirations.

Commentary

An understanding of the neurobiology underpinning the cardinal virtues assists us in grasping the challenge of rationality. The key is the unity of the virtues and to grasp the manner in which the virtues integrate all one's psychological resources.

Through an understanding of how character is constructed, we can set about this task in efficacious ways across the four domains of human action. We can establish preferential desires for enjoyment—education of our attentional systems is at the heart of temperance. Our expectations of pleasurable rewards will be triggered by sensations and memories that relate to our own past experiences. These stimuli must be carefully curated so that they trigger positive behaviours that establish preferential pathways of behaviour. Without strong convictions about interpersonal duty, we easily revert to self-indulgent behaviours in the presence of stimuli that call to mind past pleasures.

We have the capacity to forego comfort in the pursuit of choices. The *Shema* reminds us we are called to love with our whole strength, placing fortitude at the service of justice, undertaking resolute and arduous training lest we easily lapse into self-indulgence. Honest self-reflection requires fortitude. Without effective management of our fear responses, virtuous action is not possible, not within the Christian paradigm at least. But fortitude can be acquired. Fear responses have the capacity for plastic reformation.

The interpersonal commitments of justice and love are supported by efforts to build and maintain ongoing attention to the other party. Justice is the capacity to reflect deeply before we act on how those actions will affect those to whom we have responsibilities. To love with one's whole being requires discipline of the heart, forming one's desires to be oriented towards the other. A man reveals his true nature by the desires in his heart. To love with one's whole soul suggests the radical orientation of one's whole being: one's will is fixed on fulfilling the will of the other lest we default to self-oriented goals.

And the last of the four domains is prudence, which may be understood in a Thomistic sense as the habitual capacity to seek reality, including the moral reality of conscience attuned to the demands of rational nature and the capacity, albeit in a limited way, to set realistic goals for ourselves.

5.5. '. . .With All Your Strength.'

The development of habit requires effortful attention to goals. Here, we focus on the arduous development of the automaticity of effective thought and efficient action. Such ease of action is primarily a result of the neuronal mechanisms and systems and areas implicated in the formation of intentional habits.

Mechanisms of habit learning, of automatisation, offer an explanation for the phenomenon of behaviours that appear to remain robust in the absence of immediate rewards. *Action–outcome* (A-O) paradigms give way to *stimulus–response* (S-R) paradigms with lower cortical demand: action becomes more efficient as action moves from high levels of cortical activation to simpler patterns of activation that are associated with automaticity. And once a disposition is acquired, the intrinsic reward thereafter is associated with μ-opioid and phasic DA signalling in the BG, NAc, pallidum and PFC (Leknes and Tracey 2008). The preferential pathways established by mechanisms of plasticity in motor, emotional and deliberative areas of the cortex and cerebellum are decisive. The BG mediate the subconscious facilitation of habits, cognition and action (Martin 2003, p. 327), and they are now recognised as areas contributing to conscious control of established behaviours. Within the BG, the putamen, an area of the sensorimotor striatum (Yin and Knowlton 2006), involved in learning and movement initiation and neuromodulated by DA from the SNpc, is also enriched by reward pathways. The cerebellum assists in movement and motor habits and is now recognised to likely have a role in the formation of cognitive habits (Kalat 2001, p. 238; Ito 2001; Hof et al. 2008). Furthermore, there is now evidence that the cerebellum and the BG are far more interconnected, via a cerebello-thalamo-striatal pathway, and are therefore more interactive, than has been long thought (Hoshi et al. 2005). Axonal myelination also contributes to the efficiency that habit bestows.

Commentary

There is substantial literature describing the neurobiology of intentional habits.[7] Habit formation can be the result of training by a third party, or of personal goal setting, and it is required across the four domains of the cardinal virtues: through the rigour of training in self-control and resilience in the face of challenging situations, in the persistence of reflection in order to come to the truth of a situation, and in the development of habitual compassion, empathy, kindness and cheerfulness, which manifest the virtue of justice. In all these areas, consistency of goal setting and repetition of behaviours are essential in order to lay down the preferential pathways of habit. In parenting, consistency of expectations and inculcation of routines and personal responsibility all serve to promote the consolidation of behaviours and desires. Such habit formation is the raw material of virtue and will come to fruition as virtue when there is personal agency and due attention to one's responsibilities towards others.

5.6. 'The Commands I Give You This Day Must Be Written on Thy Heart. . .'

The underpinning neurobiological process for all learning is neural plasticity. All change, all acquisition of new behaviours and modification of past behaviours, all moral learning too, utilises the various mechanisms of plasticity that may be functional in the short term but always structural in the long term.

The brain possesses a virtually ubiquitous capacity for plastic change and for acquiring and modifying preferential neural pathways. The explanation for stable personality traits lies first in genetic factors, but then in the brain's capacity to incorporate use-induced structural plasticities, which elicit permanent structural changes at the neural level across systems, including those for emotional management, reward evaluation, cognition and deliberation, and predisposing thereby to changed behaviours (Butz et al. 2009).

Use-induced plasticity facilitates the experiential learning at the heart of virtue. This is the fundamental process of character development. By repeated practice, and by personal goal setting, we train ourselves, or retrain ourselves, so that certain actions become, as Aristotle says, 'second nature' (2014, 1147a21–22).

We develop the internal capacities to love wholeheartedly by developing specific character strengths in our personality. Within the virtue-based frame of this study, this is the task of good habits: 'Moral virtue comes about as a result of habit' (2014, 1103a), proclaims Aristotle. Plasticity and the capacity for habit formation together mean that we have the capacity to establish preferential pathways of behaviour. New appetitive and fear response neural pathways for the management of emotion can be established, and this will mean that rational choices are informed and enriched but not compromised by self-indulgent emotional responses.

Commentary

The *Shema* calls for a stable state of loving, not a passing fascination, inviting the Hebrews to become the sort of people who love with their whole beings. The words of Moses here call for authenticity of life, as opposed to passing beliefs and ephemeral desires—rock-solid predispositions for future action. To be 'written on one's heart' seems to suggest that they must in a sense be embodied, changing the listeners permanently.

This underscores the difference between habits and other, less neurobiologically specific terms like enduring concerns, states, and strong desires. These terms refer to phenomena rather than stable, well-established aspects of personality, which are action-oriented through the integration and reinforcement of neural pathways for emotion and reward responses. Such pathways are moderated by brain systems involved in managing emotions and selecting goals.

5.7. 'The Commands I Give You This Day Must Be Written on Thy Heart, So That Thou Canst Teach Them to Thy Sons . . .'

We can impart learning to others by certain strategies. The text draws attention above all to personal authenticity as an essential prerequisite for effective education of others in virtue. Here, we focus on intrinsic motivation as an essential feature of authenticity, and on subsequent mechanisms supporting imitation.

Through the virtue of justice which, by the Thomistic understanding, is always present in virtuous action, actions are assessed according to one's duty towards the good of others. This may be understood as a form of intrinsic motivation because there is no conscious hedonic benefit sought by the protagonist in interpersonal relationships. Within this view, actions disposed by virtue will be intrinsically rewarding, triggering the contentment mediated neurobiologically by reward systems.

The consequent imitation relies also on plastic changes in the neuronal structures of the learner, allowing the adoption of new behaviours. Remarkably, by the mechanism of mirror neurons, we possess a capacity to imitate in a way that can be completely subconscious. Mechanisms for learning behaviours, for learning moral behaviours and attitudes, and for learning empathy through imitation consist of the activation of mirror neurons present in areas of the cortex, most particularly in the left frontal operculum area (Broca's area) and the right anterior parietal cortex (Iacoboni et al. 1999). Imitative mechanisms involve activity in the fronto-parietal and the superior temporal cortex, the amygdala, and the insula (Carr et al. 2003).

There is also an association of mirror neurons with the development of empathy, to read the feelings of others. In addition, the OFC is regarded as having a major role in processing the 'interpersonal signals necessary for the initiation of social interactions between individuals'. The OFC operates in a limbic circuit comprising the OFC (Nitschke

et al. 2003; Arden and Linford 2009, p. 103), AC gyrus, amygdala and temporal pole. It would appear too that the right orbitofrontal and right anterior insula cortices are components of a pathway that integrates bodily responses with attentional and emotional states (Schore 2001). The PFC and the complex integration of brain areas, including the lateral and medial PFC, are associated with deliberation about emotional content that is also involved. Effective emotional modulation of deliberation is essential for sound reasoning, particularly in areas requiring empathy with others, understanding of others' viewpoints, etc. (Nussbaum 2001).

Commentary

An understanding of the neurobiology of virtue gives us insights into how we build character. Example, encouragement and positive affect in communication, the provision of opportunities for repeated practice, and for correction, and for personal goal setting, all contribute to an effective learning environment.

5.8. 'Keep Them in Mind Continually…'

The text stresses the importance of keeping the goal in mind that love of God comes prior to all other activities and preoccupations. This form of memory, that of keeping something in mind, is the specific task of declarative memory that is explicit and may be either episodic, which is the memory of events, or semantic, meaning factual. The complex interconnection of brain areas allows regions encoding memory to cooperate. Hence, 'the hippocampus (along with entorhinal, perirhinal, and parahippocampal cortices) is active for formation of declarative memory but it seems that the amygdala, in the limbic system, plays a key role in modulating declarative memories, prioritising them for emotional salience' (Manns and Bass 2016). The more emotionally laden an experience is, the more likely we are to be conscious of it. Emotion is a facilitator of plasticity, except in extreme cases such as fearful memories that can be suppressed from consciousness. Unless intense arousal is involved, emotional arousal appears to promote synaptic plasticity in memory, promoting learning (Bechara et al. 2000; see Cahill et al. 1995).

When we choose to focus on gratitude, we call up emotional memories and trigger emotional responses. Furthermore, we keep these emotive memories present by visual and auditory stimuli and by patterns of behaviour, which we have conditioned ourselves to follow, and by keeping those memories present, we keep enkindled desires and convictions, in this case of love of God. The Hebbian principle of neuronal interconnection serves here to integrate behaviours with convictions about commitment to others as gratitude is by its nature an other-oriented emotion disposing one for interpersonal attention.

Commentary

That emotional memory can assist in the consolidation of memory of facts and convictions carries significant implications. Reverence and awe, gratitude, heartfelt petition in prayer, repentance, and, in fact, all emotion-laden activities associated with religious duty can strengthen declarative memory about religion, and in this case, a duty to love God. The more we engage in these emotive actions, the deeper the convictions we consolidate. By visualising incentives, we move ourselves to act. By keeping those incentives present in our conscious memory, we maintain those desires.

5.9. 'Write Them on the Doorframes of Your Houses and on Your Gates. Bind Them on Your Foreheads…'

Here, we focus on the link between attention and the habitual desires and loves that we entertain in our lives. The *Shema* stresses to the Hebrews the need to surround themselves with visual and stimuli reminding them of the duty to centre their lives on God. Attention

also interlinks with emotion. Here, we see Moses advocating to the Hebrews that they should have wearable reminders. He wants them emotionally invested in very practical ways so that they never forget their duty.

Emotion-laden events cause the release of epinephrine (adrenaline) and glucocorticoids by the adrenal glands, leading to the release of the neurotransmitter/hormone norepinephrine (NE) into the amygdala, increasing its activity and thereby consolidating memory in other parts of the brain (directly by connections to striatum, hippocampus or cortex; and indirectly by connections with nucleus basalis, which innervates much of the cortex).[8]

Commentary

What is happening here? We see that the Hebrews are being urged to take an active role in forming their own characters by means of providing constant reminders for themselves. Beneath this is an inescapable reality about the formation of character: character is formed over time because it has a biophysical element. Literally, our character and personality are under construction by our choices, desires and actions, and by our environment and experiences. In particular, our desires are important because desires have a strong emotional salience. Therefore, to foster desires to act is a powerful way of engaging emotion in the task of self-education.

5.10. 'When the Lord Your God Brings You into the Land He Swore to Your Fathers, to Abraham, Isaac and Jacob, to Give You—A Land with Large, Flourishing Cities You Did Not Build, Houses Filled with All Kinds of Good Things You Did Not Provide, Wells You Did Not Dig, and Vineyards and Olive Groves You Did Not Plant. . .'

Here, we look at the mechanisms of motivation and the motivational effect of anticipated rewards. As this is central to goal election, we will enter in more detail into the neurobiology and this will reveal aspects of motivation at both the impulsive and intentional levels, bearing in mind that Moses is urging intentional motivation in preference to impulsive gratification.

Moses invites the Hebrews to visualise the good things ahead promised by God. His words seem calculated to contrast with the agonies of the wilderness where they find themselves, to engage their imaginations eliciting gratitude, but then shame, in the immediately following words, at the potential they have for forgetting the God who will give all these things to them.

We can understand motivation as the hit of the neurotransmitter DA we get from the anticipation of an action we enjoy. Past reward experiences playing into future rewards visualised in our imaginations are central the development of motivation. Motivation is curated by selective reinforcement of the neural reward pathways facilitating behaviour. Emotionally charged experiences and calling up emotional memories stored in areas of the amygdala are the triggers for this mechanism. Our neural reward system not only explains the satisfaction we derive from an activity but also the motivation we develop by the anticipation of future satisfaction or reward of some form or other.

We catalogue things in our brains as desirable or undesirable. When we bring to mind positive emotional memories, we trigger DA incentives to action. Of course, this incentivisation can be associated with good actions (such as helping others) or damaging actions (such as eating too much, getting even, unleashing our anger, etc.), or actions that are neither good nor bad in themselves (such as gaming); the artform of modifying our motivations is to curate reward expectations that are actually good for us.

The law of association governs neural networks. 'Neurons that fire together wire together', is the neural law coined by neuroscientist Donald Hebb in 1949. We can train ourselves to associate positive emotion with actions that are good for us. We do this first of all by associating emotional reinforcement (positive or negative) with specific actions.

Past associations remain linked. For example, as adults, we may continue to find delight in sports or music that we enjoyed as children. This is also true for forms of conditioned learning. We have the power to trigger specific actions by creating connections to cues or rewards.

Our neural reward systems serve to explain our capacity to build up predispositions to certain behaviours. Memory plays into these mechanisms: emotional memories are powerful motivators for impulsive and aversive responses, but the association of the refined emotion of duty, or gratitude, or of bringing joy to others, can also motivate behaviour. Think, for example, of the delight we gain from giving a present to somebody we love. This very delight powers further generosity.

The amygdala, BG, and OFC are regarded as major reward 'centres' of the brain (Schultz and Tremblay 2006; Wagner and Silber 2004, p. 193), and they are richly interconnected. Cue–reward learning (associated with training ourselves to behave in certain ways) and synaptic plasticity in the amygdala, more particularly in the lateral amygdala, appear to be a decisive mechanism underpinning goal-directed behaviour. Note that goal-directed behaviour does not necessarily imply consciously elected action.

At the neural level, our likes and dislikes are mediated by the complex systems of neurotransmitter release and diffusion: of the exciting DA-driven and the blissful endorphin-driven systems. There are two major DA systems in the brain: one projecting from the SNpc to the caudate and the putamen in the striatum and in a minor way to the NAc.[9] This midbrain DA system appears to provide reward signals to the PFC, strengthening specific connections for particular behaviours (Miller and Cohen 2001; Wagner and Silber 2004, p. 213).

On the other hand, hedonic reward has been long believed to be mediated by another, the mesocorticolimbic DA system originating in the VTA and innervating the NAc, the amygdala and the various parts of the cortex, particularly the PFC (Di Filippo et al. 2009, p. 116; McCormick 2008).[10] This second system is regarded as central to the brain's reward circuit (Martin 2003, p. 390; Bear et al. 2007, p. 526) and critical to the facilitation of incentive motivation (Depue and Collins 1999, p. 500). These DA systems, triggered by cortico-limbic afferents (Pollak 2005) in response to novel reward stimuli are the principal reward signals acting on the PFC to strengthen specific connections for particular behaviours (Miller and Cohen 2001; Da Cunha et al. 2009, p. 166). The hormone oxytocin manufactured in the hypothalamus provides a specialised reward incentive, upregulating the mood. A further type of reward activation involves 5-HT release into the limbic area and hypothalamus (Bear et al. 2007, p. 581; Guyton and Hall 2006, p. 730), where 5-HT receptors are found in nerve endings throughout brain (Deutch and Roth 2008).

Reward representations in the OFC are associated with goal-directed, conscious choices of action (O'Doherty and Dolan 2006). The OFC, through its rich reciprocal connections to the limbic system and to the striatum, plays a major integrating role (Price 2006). Plasticity in the OFC enables cortical processing of reward representations. . . we are conscious of pleasure. The OFC is the key area for volitional goal election. The OFC permits association information to access representational memory promoting 'voluntary, cognitive, and goal directed (not stimulus driven) behaviour and facilitating new learning' (Roesch and Schoenbaum 2006, p. 229). It is activated by tasks where the processing of rewarding or emotional information is required (Wagner and Silber 2004, p. 193; Davidson 2008; Roberts and Parkinson 2006, p. 250) and where information about rewards and punishments is integrated with their predictors to select goals for action (Roesch and Schoenbaum 2006, p. 201; O'Doherty and Dolan 2006, p. 266). The medial OFC appears implicated in reward and the lateral OFC in punishment (O'Doherty and Dolan 2006, p. 269).

Plasticity in the DA pathways and uptake in the PFC facilitates cortical processing of reward representations. A large proportion of PFC neurons assisted by DA release encode

rewards linking behaviours to goal-directed consequences (Miller and Wallis 2013, p. 1217). And further, it is postulated that DA neurons in the midbrain respond when a reward seems imminent (Miller and Wallis 2013, p. 1217).

The BG represent another strategic centre for motivation. Plasticity in areas of the BG (in which the striatum is integral) facilitates conscious reward processing (Yin and Knowlton 2006, p. 465). The striatum is activated in association with movement for an expected reward (Barbas and Zikopoulos 2006, p. 64; Wickens 2002, p. 120). The BG contain inhibitory GABAergic neurons (Da Cunha et al. 2009, p. 159), requiring strong and coherent excitatory cortical inputs from almost all the cortical areas to become active (Yin and Knowlton 2006, p. 464). Over time, consciously goal-oriented, A-O behaviours activating the ventral striatum give way to S-R behaviours, delivering a degree of automaticity (Wickens 2002, p. 125; Graybiel 2008, p. 364). Nevertheless, S-R behaviours can also be conscious, deliberate and therefore remain volitional (Berretta et al. 2008, p. 349). Plasticity in the connectivity between the BG and the OFC is crucial to the body's reward system, and hence to its systems for goal election. Cells of the striatum become active in anticipation of reward, mirroring reward coding in the OFC (Horvitz 2009, p. 133; Horvitz 2009, p. 133). DA is released into the striatum, leading to further limbic modification of neural transmission. DA modulation in the BG in turn brings about a decisive modulatory effect on the cortex via the cortical–BG–cortical pathways. Striatal DA depletion is shown to lead to severe disruption of learned movement sequences (Horvitz 2009, p. 135). This further supports the view that there is an interconnection, at the level of the BG, between reward pathways and learned sequential behaviours. The DA system acts as a learning signal for behavioural reinforcement but also may well be involved in attention and motivation before all important events, both positive and negative. Its action is facilitated by neural loops (Pollak 2005, p. 747).

Consciousness of wellbeing and inner peacefulness as a consequence of the release of opioids from the hypothalamus (Sunderland 2006, p. 87) and the release of the cortical (i.e., conscious) DA reward will be further possible indicators of virtue.

The BG play a major role in learning owing to their plasticity, presence in the reward and emotional regulation pathways, and efferent neuronal pathways to sensory cortices allowing somatic and sensory feedback (Squire et al. 2008). Closed cortical (lateral PFC, OFC, and the premotor cortex) striatal loops appear to enable the PFC to link complex anticipated behaviours with rewards, relying on the rapid plasticities of the striatum (Koch 2008, p. 1220). Note the role of the striatum is essential in reward and motivation, organising somatosensory representations in a topographic manner. It draws cortical inputs from many areas of the cerebral cortex (Manns and Hichenbaum 2008, p. 1165).

Commentary

From the above, it is evident that mechanisms, regions and processes across the whole cortical and lower brain complex contribute to the reward and motivational systems. This very complexity attests to the necessary integrating task of virtue at the neurobiological level. An understanding of the reward system, and how we can use it to our advantage in teaching ourselves new behaviours, is central to the task of the formation of personality and development of virtue. Mindfulness of the motivations in our heart is essential if we are to act freely of unintended impulsive and aversive responses.

5.11. '…When You Eat and Are Satisfied…'

In this charged phrasing, 'satisfied' suggests hedonic satisfaction. This can be opposed to the notion of *eudaimonia*, used by Aristotle to denote wellbeing. Within Thomistic virtue, this state of beatitude also denotes holiness, union with God, perfect love of God.

Moses is teaching that self-indulgent material pleasures must never take priority over interpersonal love.

Commentary

This excerpt brings a focus on the phenomenon whereby immersion in immediate hedonic rewards can blind us to our great duties to others. Hence, justice must be present in all actions. We also see in this admonition the great fickleness of our capacity for resolutions, a fickleness for which the *Shema* proposes a solution: to keep surrounding ourselves with material reminders, and specific repeated behaviours (talking, binding, writing), which are loaded with a positive emotional salience and so which are capable of offsetting other hedonic attractions.

This excerpt also leads us to reflect on the notion of vice, an established pathway for behaviours that are not good for us, not good for our nature as human beings, not good for our nature as believers. Note the word 'satisfied'. The mere act of eating is not the target of Moses' criticism but the drawing of satisfaction, implying complacency with the action. We could think of vice therefore not merely as actions contrary to our welfare but as actions that we have given our intellectual assent to, actions of free choice.

5.12. '. . .Be Careful That You Do Not Forget the Lord, Who Brought You out of Egypt, out of the Land of Slavery.'

In this final extract, I focus on the power of emotion-laden advice as a motivator for future action. Moses jars his listeners by awakening them to the realisation that they would once again become slaves, no longer to Pharaoh but to their own passions and appetites.

Moses initially calls up a succession of cortical representations of hedonic bliss, but the word 'slavery' surprises the listeners. Surprise triggers attentional responses. In neural terms, the Hebrews are led to cortical representations of sadness and shame for their own betrayal after they have received so many blessings. This awareness floods the emotional memory of the listeners. A negative emotional state overwhelms their consciousness.

The urgency of the tone, the elevated and noble concepts, the appeal to gratitude, and the potential for shame all lead to a further surge for the listeners, one of emotional memory inputs flooding into the basolateral amygdala via reciprocal connections to the hippocampal and striatal memory systems. There may be neural activations of fear, sadness, anger and possibly also disgust (in the *anterior insula*). Limbic afferents to the PFC via the OFC trigger consciousness of the emotional response and provide an initial justification-based hippocampal call up of DA-mediated, short-term memories of the terrible wandering in the desert, of gratitude for God's providence.

Moses' goal is to lead them to react with deliberation, consideration of consequences, and explicit choice. Many listeners may be able to fall back on prior learning of the habits of prudence, justice, fortitude and temperance, leading to DA-mediated reinforcement of regulatory pathways triggered in the OFC and *amygdala.* Cognition and the capacity to reach the truth lead to a positive reaction from the listeners.

Commentary

We are led to think about what we need to do if we are to change our behaviours away from actions that are bad for us. Once certain behaviours are established, those pathways, for better or worse, now exist in the brain, along with the paths of the associated reward expectations. These cannot be severed simply by a decision of the will. The only way to circumvent these actions in the future is to establish pathways of greater preference through repeated behaviours that build up the pathway by use-induced plasticity and by plasticity-inducing emotional salience (regret, shame, loving attraction, delight in causing

joy for loved ones, etc). We must build workarounds or neural bypasses. This is the fundamental challenge of building character.

6. Discussion

The central conclusion of this exercise is that a neurobiological analysis illuminates the wisdom of the moral teaching of the *Shema* and its wisdom about loving God well. Within a Thomistic and personalist psychology, the passage announces the calling to love, and specifically love of God. It offers the view that human beings are relational and fulfilled in loving relationships with other persons, first of all with God.

While a devout exegesis might simply accept the text as a rhetorical assertion, this analysis supports a substantially literal reading of the text: that the loving relationship needs to be pursued with all one's desire, strength and very being; that positive admonitions are more effective than direct, immediate and perhaps punitive threats; that great energy is required to establish convictions of loving duty; that memory is crucial for sustaining love; that gratitude is a key motivational tool in relationships; that sense desires can be triggered by thoughts and visual stimuli; and that sense gratification can easily undermine commitment to cherished convictions.

A neurobiological analysis is not an end in itself but a light that throws aspects of human behaviour and psychology into relief. Emotion and reason possess complementary roles in a balanced, happy life. Loving intention is not just a feeling but also a choice, but to some extent, it is a product of the stimuli and reminders we provide for ourselves. The neurobiology of the cardinal virtues is the hardwiring of this integration of the material and the spiritual, the sense appetitive and the rational. Reflection on the complementary perfecting habits these virtues supply for the four domains of action, sense appetition, rational appetition, and practical intellect, leads to a conclusion that all are implicated in each virtuous action and that self-control and courage exist for the sake of loving relationships. There can be no room for reward or aversive responses that do not take duties to others into account or are the result of compromised choices. With respect to God, who is the author of all the benefits the Hebrews enjoy, there can be no half-hearted response.

The philosophical notion of unity of the virtues thus finds ratification in light of the neurobiology and demands that due regard for others suffuse every action… love needs to be wholehearted. Unity of the virtues also assists in understanding the need to harmonise appetite and reason, interpreting the significance of vice as a complacent satisfaction in self-gratification.

The decisive contribution of the neurobiology underpinning intentional action within the metaphysics of participation throws into relief the unique qualities of human nature where the non-material and the material are harmonised, or at least have the potential to be harmonised. Cortical regulation of emotion at the neurobiological level requires limbic-cortical connectivity permitting bottom-up modification of cortical 'decision making' and top-down direction and regulation. Neural pathways strengthen with use and can fall into atrophy with disuse, so the very presence of substantial reciprocal neural pathways is firm evidence of both cortical direction and subcortical modification of regulation and decision making. But these pathways are consolidated by the choices we make. The cognitive activity of the PFC needs the complement of the subcortical structures of the limbic system and the BG for effective emotion regulation and goal election. The involvement of the BG appears crucial, not only by its implication in emotion and reward pathways but also because the BG are the principal seat of the automaticity of actions. Such automaticity is not necessarily opposed to conscious, voluntary goal election.

Cognitive goal election can be supported by the reward systems of the brain that integrate with cortical structures. The capacity for a loving intention and the slavery of

unbridled impulse are both grasped when we understand the mechanisms of reward and motivation at work at a subconscious level, disposing us to experiences of the past, or that are picked up by our imagination based loosely on past experiences. Also, for this reason, personal reflection and goal setting are important. If we fail to set goals for ourselves and our attention is dissipated, we easily overlook convictions of duty and responsibilities to others. Thus, neurobiology gives insights also into human freedom. . . in the grip of slavery little can be done, but we have some capacity to choose the context in which we live our lives and so we have some way of reconfiguring our desires. The very arduous nature of acquisition of virtue finds explanation also in the capacity we have, by our choices, to materially recondition our expectations for reward, and our fears and anxieties.

Our neural systems of responses to pleasure, pathways for fear responses, reward evaluation, goal setting, motivation and executive control are all supported by 'upstream' systems of plasticity, learning and memory, and capacities for attention, critical learning, and imitation and empathy. The *Shema* text reminds us that self-management of sense-triggered appetitive responses is possible and that such self-management is empowering of love. We have the capacity to form, or reform, our very biophysical constitution by free and conscious efforts into neural structures that are more capable of supporting effective self-management at the rational level. This is the neurobiological process whereby virtue is acquired and freedom augmented.

A grasp of the dynamics of the reward and motivational pathways, along with notions of use-induced plasticity, communicates the virtually compelling nature of sense gratification and clarifies that substantial ongoing effort would be required to provide the ingrained rectitude of moderation in goal election and indulgence required to offset gratifications overwhelming sense apprehensions in such an immediate and consuming manner. Sense satisfactions experienced through the reward systems of the brain can derail our good intentions, but we can also use the same principle to our advantage if we surround ourselves by positive sense input.

The realisation that memories all have an emotive salience, and that they play directly into motivation and desire, can assist us in maintaining greater self-management. We can to some extent manage the memories and desires we trigger by the surroundings in which we choose to place ourselves. We have some capacity to manage our attention, to refocus from external stimuli to internal convictions and grateful memories as a strategy to overcome such potentially overwhelming inputs. Intentional self-control is possible.

These insights make us more aware of the way our characters are formed and a life of faith facilitated, according to the Thomistic principle that grace builds on nature. Insights into the activation of the neural attentional systems bring to the fore an appreciation of the relationship between attention and the things we value, that attention correlates with desire, and to the extent that desires follow on sense apprehensions, we can say that the things we pay attention to trigger desires. Memories and routines grounded in convictions can provide an effective inhibitor for impulsive responses. Grateful memories facilitate convictions and are powerful motivators for wise choices and decisions. Attention is central to temperance and goal election.

Behaviours, desires, thoughts, and both passive and active experiences physically change our brains. These experiences through mechanisms of use-induced plasticity develop pathways facilitating future behaviours. This brings to the fore a heightened appreciation of managing the details, for the default pattern of future behaviours will be the projection of our current choices and experiences. Repetition builds habit, and habit builds virtuous character.

Human fulfilment requires loving commitment not material satisfaction. The peace and integrity of virtue correlate at the neurobiological level with the harmonisation of

behaviours, our emotional responses, and our intentional choices and convictions, including faith-based convictions. This gives us insights into how we can develop peace of heart more effectively. The development of Aristotelian and Thomistic virtue requires that we develop refined feelings so that these are in step with convictions and choices; yet even feelings can be reconstituted by means of neural plasticity. By managing our loves and desires in this way, we can stop complaining and achieve greater peace of heart. The *Shema* too teaches that we can train ourselves to forgo attachments to material satisfactions when those satisfactions eclipse the love of God.

The capacity for economies of interconnection in the brain leads to an understanding of the state of a virtue as a complex of systems. Hence, it may be seen that virtue has a material foundation in the neural structures, systems and processes of the brain. These material aspects can be identified and they manifest, in their maturity of expression and integration across the entire brain, the role that virtue plays in human fulfilment itself. The necessary conclusion is that human beings possess a biological aptitude and *predisposition* for the development of virtue.

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Notes

1 Dt 6: 4-12.

2 Aquinas (1965b, I-II, q. 61, a. 2): 'Every power which may be variously directed to act, needs a habit whereby it is well disposed to its act.'; I-II, q. 50, a. 5: 'Every power which may be variously directed to act, needs a habit whereby it is well disposed to its act'.

3 For an extended discussion of A Thomistic Metaphysics of Participation, see also Mullins (in press).

4 Data accord with standard reference neurobiological texts such as (Squire et al. 2008; Kandel et al. 2001; Bear et al. 2007). Many detailed references are also available in Mullins (2012). An excellent resource to access introductory diagrammatic explanations is to be found at https://www.bna.org.uk/resources-archive/online-resources/ (accessed on 16 January 2025).

5 I thank a reviewer for pointing out the need for caution in the use of 'we' as the *Shema* is first of all addressed to a specific community of believers, and also for the observation that the *Shema* is within Jewish traditions a 'confession', having a distinctive neural signature as such, as well as a call to attention.

6 Note that it can be only the person as the subject of the action when we are considering a human act. However, when we are not referring to a human act but to unconscious responses by parts of the body (e.g., ACh heightens attentiveness) or to the action of part of the body (e.g., my eye blinked, my amygdala responded to emotional input), I adopt the convention of specifying a non-personal subject.

7 A leader in the field is Ann Graybiel.

8 For distinct forms of memory systems and the story of their discovery, the principal source of material that follows (Manns and Hichenbaum 2008).

9 Linked to the laying down of procedural memory, and possibly to higher-order personality traits.

10 DA is diffused in the cortex, with 80% of the DA concentrated in the corpus striatum. DA release is the condition for synaptic plasticity in the BG synapses between cortico-striatal neurons and MSNs, possibly involving reverberation in the cortico-striatal loop.

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