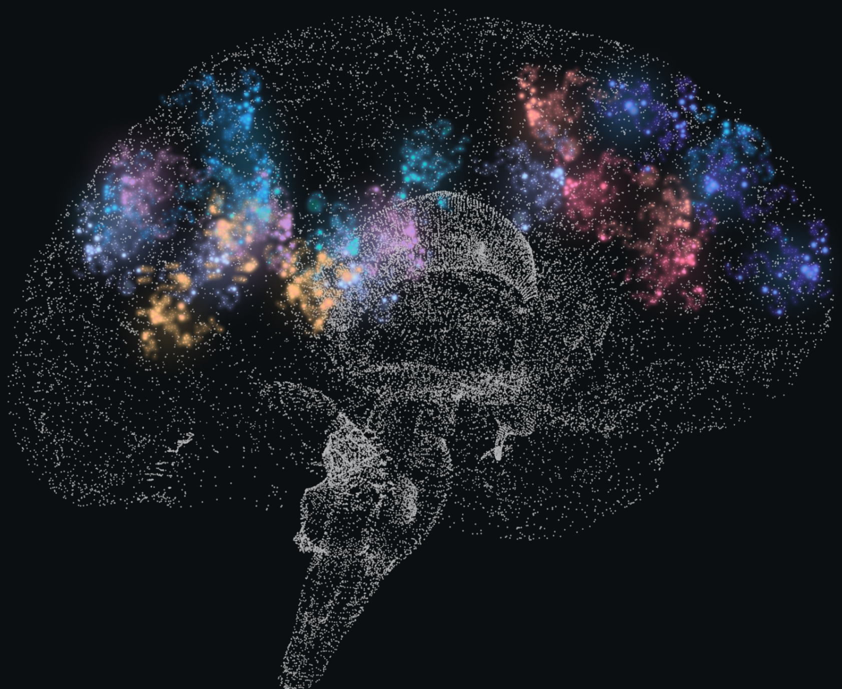
A new framework for understanding human happiness



Matter Neuroscience
May 2024

Introduction

Our world is faced with a rising mental health challenge. The quest for happiness has never been more important. While feeling happy is often considered just a pleasant state of being, science has shown that it is far more. Happiness has been linked to a host of physical health benefits, including increased longevity and a reduced risk of chronic diseases. And yet, despite the clear benefits of happiness, it's not straightforward for us to realize. We are flooded with well-intentioned but often over-simplified, unspecific, or unactionable advice on how to be happy. And despite all the advice that's out there, rates of depression, anxiety, addiction, and suicide continue to climb worldwide. Society needs innovative approaches that actively promote and sustain well-being.

Matter Neuroscience endeavors to address this issue by unifying the fields of positive psychology, high field brain imaging technology, and molecular neuroscience to help individuals cultivate happiness in their daily lives. This unique study program has developed universal biological tools to provide personalized, actionable guidance for living a happier life.

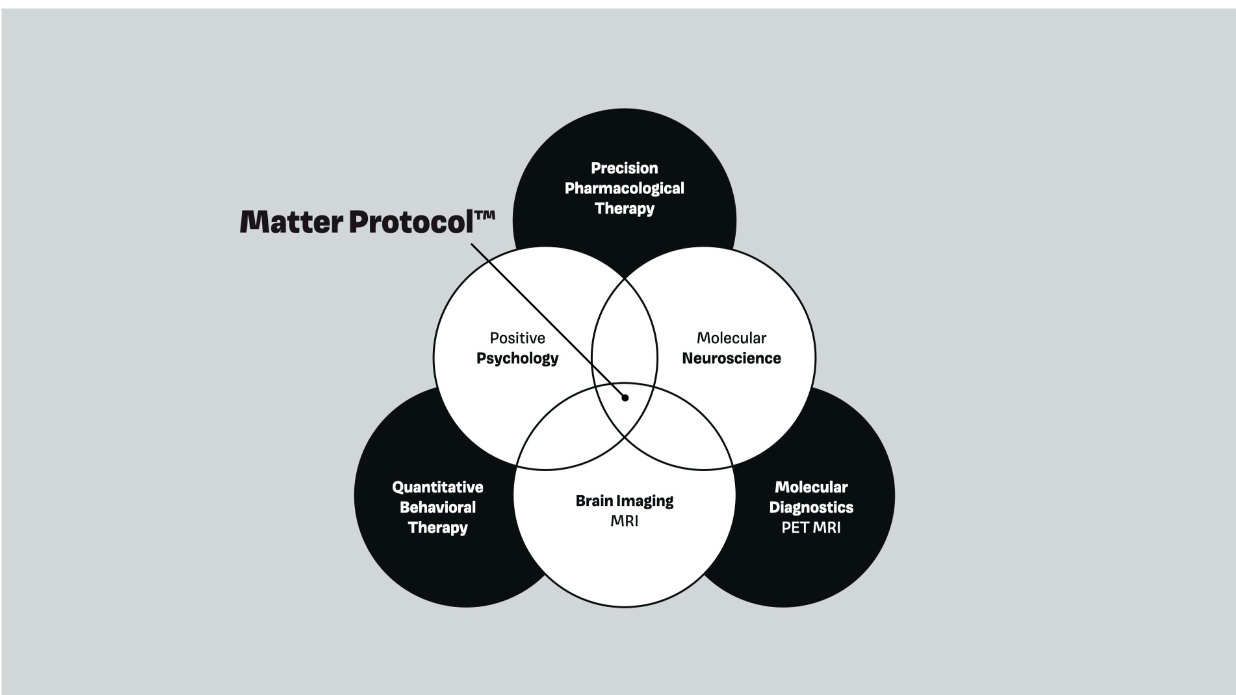


FIGURE 1. INTEGRATION OF POSITIVE PSYCHOLOGY, MOLECULAR NEUROSCIENCE, AND ULTRA HIGH FIELD BRAIN IMAGING ARE THE BASIS FOR THE MATTER PROTOCOL

Central to these tools is the Matter Protocol™, a proprietary protocol that identifies distinct neurotransmitter deficiencies and leverages users' memories to generate recommendations for happiness-boosting activities. The protocol was developed based on research focused on the brain's reward systems, which is regulated by a complex interplay of neurotransmitters. These reward systems are universal in nature to all humans.

Matter aims to catalyze long-term changes in brain structure and function that support lasting happiness. Through education and consistent engagement with our mobile app, users develop a habit around happy memory making and a rich portfolio of happy memories. The chapters that follow outline this process and the science behind it:

Chapter 1: The neuroscience of happiness

As we navigate our lives, we are faced with uncertain futures contingent upon options we are responsible for choosing. While good decisions increase the probability of good outcomes, the inherent uncertainty around our choices present individuals with difficulty in finding the 'right' path for a happy life. We receive mixed signals from our friends, from our colleagues, from wellness gurus, and from the media, and can struggle to understand what's actually most important for our happiness. (Hint – there is no 'right' path, it's going to be different for each of us.) Our focus on survival in the lower economic strata and consumption in the upper economic strata also limits our scope for understanding true fulfillment. Technological 'advancements' most notoriously, social media, leaves us relentlessly pursuing short term gratification and recognition. Our success in finding happiness, therefore, hinges on our ability to make the choices that satisfy higher order needs beyond fulfillment and recognition. And then we need to learn from the results, and seek more from those sources of happiness.

In fact, we all have the innate ability to make choices that are good for us — we've just dulled our ability to listen to that guidance. Evolution has selected for reward systems that reinforce behaviors that promote survival and success by generating nine distinct emotions we can consciously feel when our needs are met. (Shiota et al., 2017) When we engage in activities that fulfill our needs, our brain releases "feel-good chemicals", neurotransmitters create a sensation of satisfaction and reward. This reinforcement mechanism encourages us to repeat these behaviors, ensuring our continued well-being. This is our neuroscientific definition of happiness.

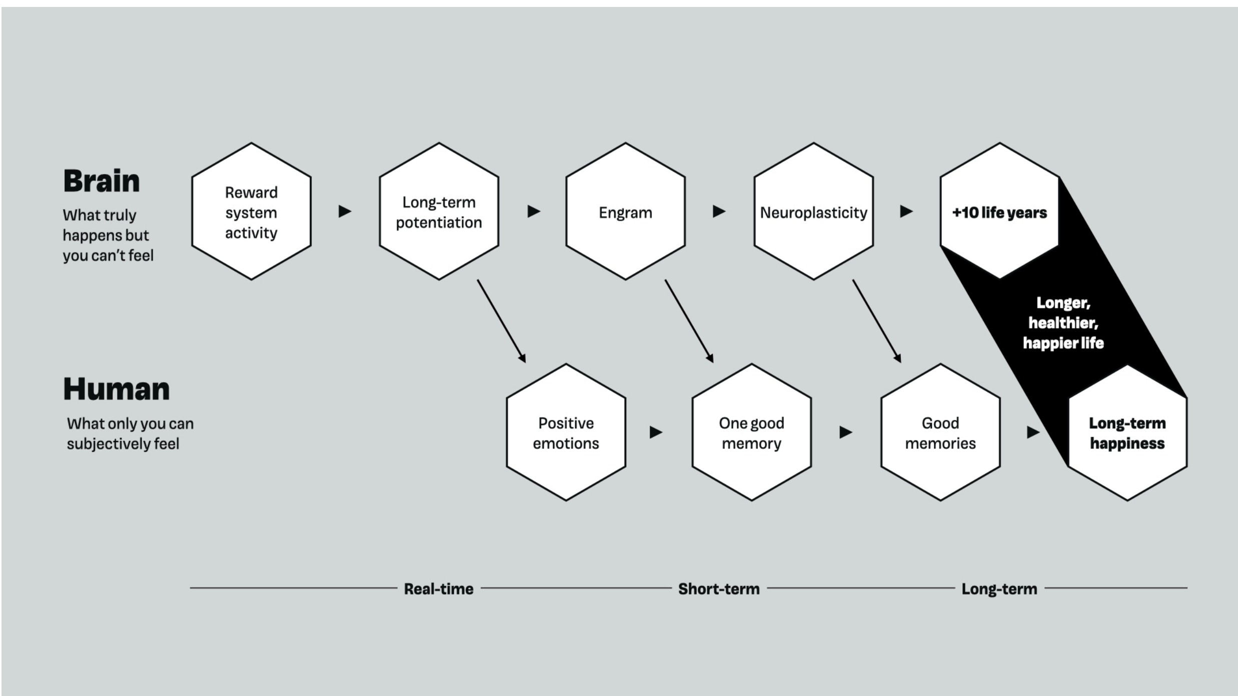


FIGURE 2. THE ORIGIN AND CAUSALITY OF HAPPINESS

Reward systems

The system is comprised of a large neural network that leverages dopaminergic neurons throughout key regions of the brain (Kringelbach & Berridge, 2017). This network plays a crucial role in motivation, learning, and decision-making as we pursue rewarding stimuli and experiences (Alexander et al., 2021).

Brain activity and emotions

Brain activity in areas of the reward system has been linked to different positive emotions. In rodents, regions of the basal ganglia are involved in pleasure responses to rewarding stimuli like sweet tastes (Pecina and Berridge, 2005; Smith and Berridge, 2005). Additionally, it was found that human pleasure is a function of satisfaction, in addition to stimulus, as evidenced by correlated activity in the orbitofrontal cortex (OFC) (Kringelbach et al., 2003). The OFC has also been implicated in decoding and representing pleasant touch as a positive reinforcer in humans, contributing to the hedonic experience of touch (McCabe et al., 2008; Rolls, 2000). The left dorsal lateral prefrontal cortex (dlPFC) has been shown to play a specific role in processing positive emotions, although the lateralization of emotion processing may depend on the specific task or context (Davidson, 1992; Harmon-Jones, 1997; Wager et al., 2003). The left dlPFC is targeted during repetitive transcranial magnetic stimulation (rTMS) treatment for Major Depressive Disorder due to its effectiveness in improving depressive symptom severity (Sonmez et al., 2019). In fact, it's likely that most or all the reward system areas (i.e., anterior insula, rostral anterior cingulate cortext (ACC)/ventromedial prefrontal cortex, dorsal ACC, amygdala, ventral striatum, thalamus, occipitotemporal cortex, etc.) are involved in both positivity and negativity as part of a "flexible affective workspace", which allows for the integration of various sensory, cognitive, and affective processes (Lindquist et al., 2016).

Positive emotions and neurotransmitters

Emotions are distinct from subjective feelings, although the terms are often used interchangeably in everyday language. Emotions are psychological mechanisms orchestrating adaptive responses through cognitive, physiological, and behavioral processes, while feelings represent the internal, subjective experience (Ekman, 1992; Levenson, 1999; Tooby & Cosmides, 2008). Studies have established nine differentiated positive emotions, as defined above: enthusiasm, sexual desire, pride/recognition, nurturant/family love, contentment/awe, amusement, attachment love/friendship love, liking/pleasure, and gratitude (Shiota et al., 2017). Additionally, there are six main neurotransmitters involved in their occurrence: dopamine, testosterone, serotonin, oxytocin, cannabinoids, and opioids.

The nine positive emotions outlined by Shiota et al. (2017) were chosen for the Matter app because they represent the range of distinct positive affective experiences. Each has been linked to specific neurotransmitters, providing our biological definition of

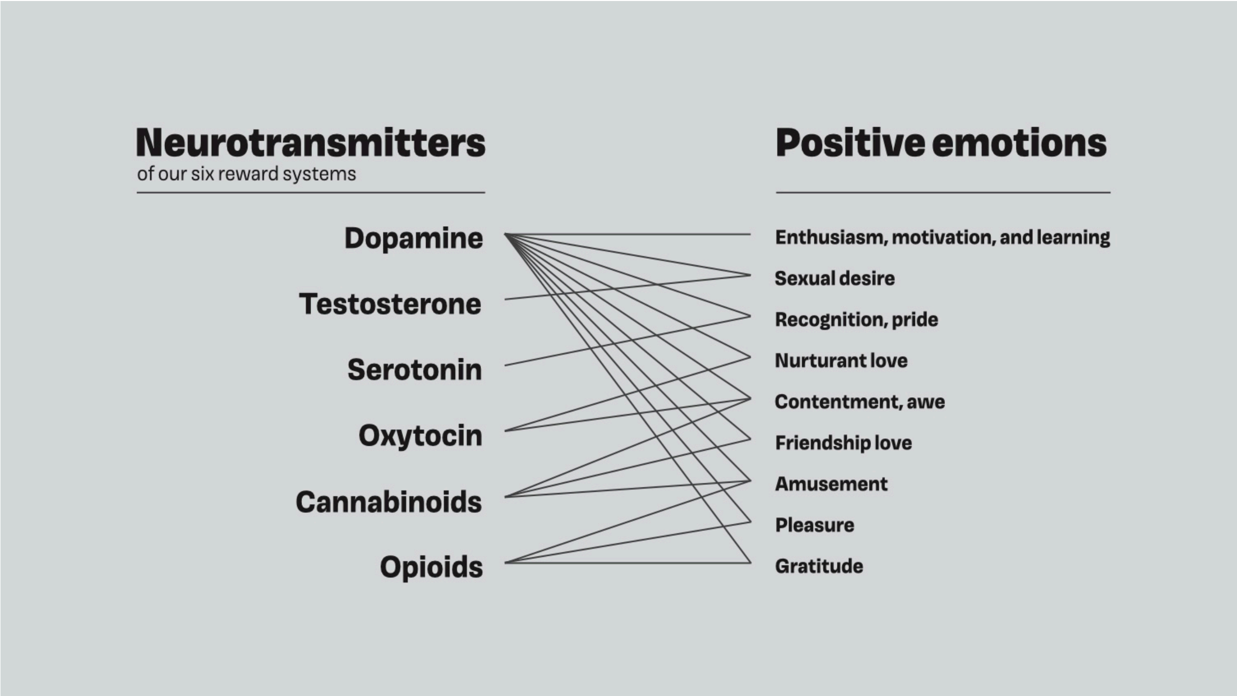


FIGURE 3. POSITIVE EMOTIONS AND NEUROTRANSMITTERS

happiness – more neurotransmitter activity. By focusing on these nine emotions and their associated neurotransmitters, the Matter Protocol™ (see Chapter 4) accounts for the full spectrum of positive emotional experiences.

Each positive emotion is associated with specific combinations of neurotransmitters.

Enthusiasm is understood as an anticipatory or appetitive state whereby all attentional resources are focused on the acquisition of a material resource like money or food (Griskevicius, Shiota, & Neufeld, 2010; Shiota et al., 2011). The neurotransmitter associated with the feeling of enthusiasm is Dopamine, a neurotransmitter that also plays a role in all positive emotions as a major regulator of the reward pathway (Robinson, Sandstrom, Denenberg, & Palmiter, 2005).

Sexual desire is a wish, need, or drive to engage in sexual activities or to seek out sexual objects (Diamond, 2003; Regan & Berscheid, 1995). Testosterone is an androgen that drives the development of the masculine phenotype and plays a significant role in male and female sexual desire (Diamond, 2003; Wallen, 1995). Its administration can increase sexual arousal in men and its deficiency has been shown to reduce sexual desire and functioning (Gray et al., 2005; O'Carroll & Bancroft, 1984; Bagatell, Heiman, Rivier, & Bremner, 1994). In line with the phylogenetic data, testosterone plays a central role in the brain driving female sexual desire (Burger, 2002, Abraham, 1974 Longcope, 1986, Weiss, 2010). Using very low, natural doses of testosterone could confirm a positive impact on female sexual desire short term while long term male hormonal effects were creating side effects (Clayton, 2018, Clayton, 2009, Weiss, 2019, Simon, 2018, Shifren, 2014).

Pride is considered as an emotional response to the opportunity of high social status with human display similar to the dominance display of primates and other mammals (Tracy & Robins, 2007; Tracy & Robins, 2008; Tracy, Robins, & Tangney, 2007). Serotonin is a neurotransmitter which supports behavior modulation as a function of the social environment and especially social status cues (Homberg & Lesch, 2011; Chiao, 2010; Edwards & Kravitz, 1997).

Nurturant love is an emotional response to offspring and other vulnerable kin which results in vigilant attention to the environment (Hrdy, 2006). Oxytocin has been shown to mediate this effect, driving long-term familial commitment (Carter, DeVries, & Getz, 1995; Gonzaga et al., 2006; Insel & Shapiro, 1992; Levine, Zagoory-Sharon, Feldman, & Weller, 2007).

Contentment is an emotion associated with satiety after obtaining or consuming a resource and is related to comfort (Griskevicius, Shiota, & Nowlis, 2010; Shiota et al., 2017). While some literature associates serotonin with contentment, we have decided not to include it based on our clinical study observations (Burton-Freeman, Gietzen, & Schneeman, 1999). Additionally, cannabinoids may contribute to contentment experienced with activities like exercise (Fuss et al., 2015), although more evidence is needed to confirm this connection.

Amusement is an emotion linked to opportunities for humor and play, which may have evolved to facilitate social bonding and learning (Griskevicius, Shiota, & Neufeld, 2010). Play behavior is modulated by the cannabinoid and opioid systems in the brain, suggesting that these neurotransmitters play a role in the rewarding nature of social interactions (Trezza, Baarendse, & Vanderschuren, 2010).

Friendship love is an emotion that promotes close social bonds and arises during opportunities of affiliation, interdependence, and intimacy. Oxytocin promotes feelings of trust, empathy, and social bonding (Kosfeld et al., 2005; Zak et al., 2007). The endogenous opioid system also plays a role in the positive feelings associated with social bonding (Machin & Dunbar, 2011).

Liking and pleasure are emotions that arise in response to rewarding stimuli and motivate approach behavior. Opioids contribute to the experience of pleasure, especially in social rewards (Loseth et al., 2014).

Gratitude is an emotion that arises when an individual perceives that they have received a valuable benefit from another person, promoting reciprocal altruism and social bonding (Algoe, 2012). While some literature suggests a role for oxytocin in gratitude (Algoe & Way, 2014), our clinical studies have not confirmed this connection. The specific neurotransmitters involved in gratitude remain an active area of research. This complex emotion clearly involves opioids, we see similar areas activated in pleasure. To understand the full set of neurotransmitters activated with feelings of gratitude is an active research field by Matter and others.

Recalling positive memories

Recalling positive memories from one's past has been shown to increase positive affect and wellbeing in the present moment (Speer, Bhanji, & Delgado, 2014). This may be due to the reactivation of neural reward circuits that were engaged during the original positive experience.

The types of positive memories recalled likely correspond to the positive emotions experienced during the original event. For example, recalling a time of bonding with loved ones reactivates neural circuits involved in the experience of friendship love, such as oxytocin signaling. Mentally reliving an exciting, novelty-filled experience may boost dopamine associated with enthusiasm felt by recalling this memory.

Enjoying positive memories not only provides in-the-moment reward reactivation, but also motivates future behavior by increasing the perceived value of similar experiences that could be pursued (Lempert & Phelps, 2016). Recalling the contentment felt after a satisfying meal could drive someone to seek out that restaurant again. Bringing to mind amusing moments with a friend encourages spending more time with them. In this way, positive memories of different emotions act as incentivizing, guiding behavior to create more moments that will engender positive emotions in the future. By driving people to seek out additional positive experiences, the recall of positive memories sets them on a path of continuous improvement in wellbeing.

So, positive memories provide opportunities to re-engage the neural circuits of positive emotions, providing boosts in affect and wellbeing while also motivating future behavior. Regularly recalling them may also increase the likelihood of their recurrence. The neuroscience of positive memories thus offers both explanatory and translational insights to increase happiness.

Recently, it has been demonstrated that positive memory recall guiding positive event training is increasing the mood in adolescents (Bogaert et al. 2024).

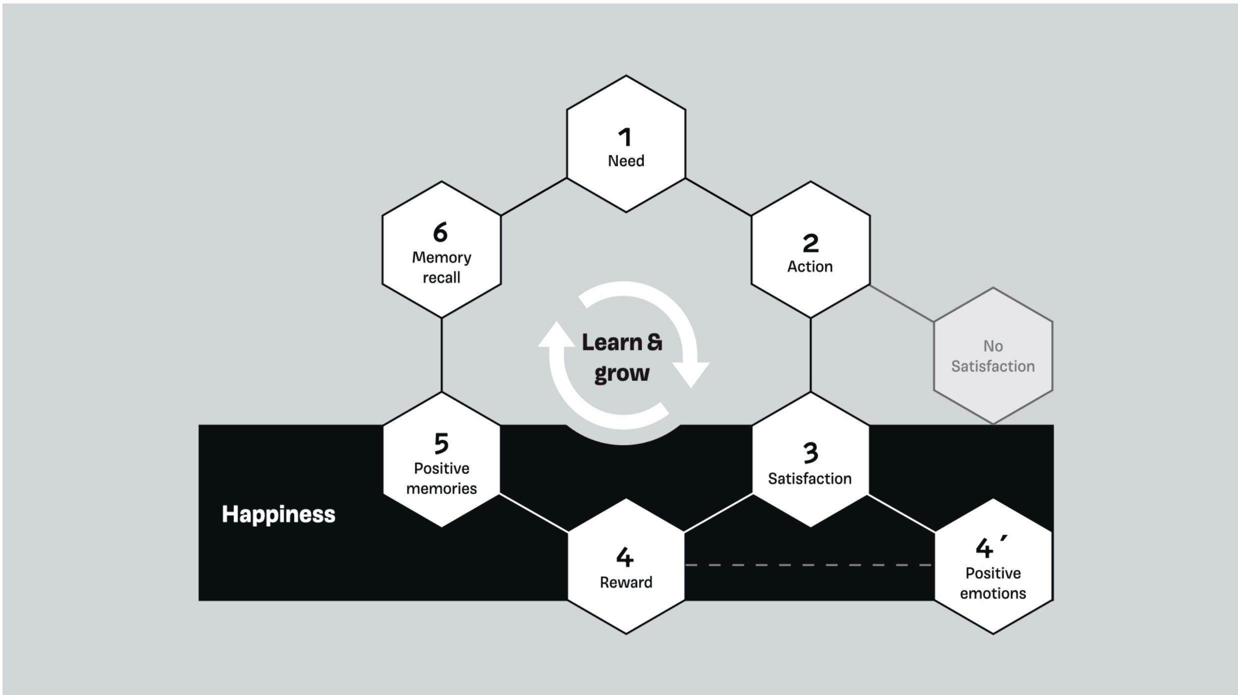


FIGURE 4. FOR US AT MATTER, HAPPINESS IS WHAT IS IN THIS BOX

Neuroplasticity

Neuroplasticity refers to the brain's ability to change and reorganize in response to internal and external stimuli. This process is thought to enable learning, memory formation, and even changes in subjective well-being over time (Davidson & McEwen, 2012). The neural circuits involved in positive emotions likely exhibit plasticity that allows for upward spirals of positivity and increased happiness. Importantly, neuroplasticity supports active learning and memory formation throughout life, representing the brain's lifelong capacity for change (Draganski et al., 2004).

Greater well-being has been associated with increased gray matter volume in the right parahippocampal gyrus and decreased gray matter volume in the left precuneus and left ventromedial prefrontal cortex (Kong et al., 2015). Eudaimonic well-being, which relates to feelings of personal growth, purpose, and autonomy, was positively associated with gray matter volume in the right insular cortex (Lewis et al., 2014). These findings suggest that brain regions involved in memory formation (parahippocampal gyrus), self-reflection (precuneus), emotional regulation (ventromedial prefrontal cortex), and interoceptive awareness (insular cortex) may play a role in shaping individual differences in well-being.

Examining the neural underpinnings of subjective happiness, researchers found that happier people had greater gray matter volume in the right precuneus (Sato et al., 2015). The precuneus is a central hub of the default mode network involved in self-referential processing. Greater volume in this region could indicate greater capacity for positive self-reflection.

Another key brain development process is adult neurogenesis, the generation of new neurons in the adult. This process is primarily driven by brain-derived neurotrophic factor (BDNF) (Marosi & Mattson, 2014). BDNF impacts the neurotransmitters associated with positive emotions through its modulation of dopaminergic and serotonergic transmission in the brain (Hyman et al., 1991; Guillin et al., 2001; Martinowich & Lu, 2008). It also interacts with the cannabinoid system to influence synaptic plasticity and neuronal survival (Maison et al., 2009; Zhao et al., 2015).

It's clear that experiencing positive emotions can lead to changes in brain structure in regions supporting emotional processing, self-referential thought, and interoception. Leveraging neuroplasticity by repeatedly engaging positive emotion circuits, such as through regular practice of recalling positive memories, may be crucial to cultivating lasting improvements in happiness and well-being. For Matter, we consider neuroplasticity to encompass both its traditional definition and the process of adult neurogenesis, recognizing the brain's lifelong capacity for change.

Longer, healthier, happier life

Studies have consistently shown that higher levels of subjective wellbeing are associated with reduced risk of illness and increased lifespan (Diener & Chan, 2011; Martín-María, 2017; Steptoe, 2019; Xu & Roberts, 2010). Xu and Roberts (2010) demonstrated the power of positive emotions, showing that subjective well-being predicted longevity over a 28-year period in a general population. Zaninotto and Steptoe (2019) found an association between subjective well-being and living longer, healthier lives. A co-twin control study, which affords greater control over genetic and early environmental factors, also found that higher subjective well-being was associated with increased longevity, indicating a potentially causal effect of wellbeing on lifespan (Sadler, Miller, Christensen, & McGue, 2011). However, the heritability of longevity could serve as a confound.

Positive emotions, mediated by neurotransmitter activity, have been associated with lower levels of cortisol, a stress hormone linked to various negative health outcomes (Dockray & Steptoe, 2010). This effect on stress physiology may be a key mechanism underlying the health benefits of positive emotions.

In addition to physiological effects, positive emotions may also promote health by motivating healthy behaviors. Positive affect is associated with higher levels of physical activity, better sleep quality, more nutritious diet, and less smoking (Boehm & Kubzansky, 2012; Sin, 2016). These behaviors are likely driven by the motivation and social engagement that accompany positive emotional states.

Cultivating positive emotions and happiness can have profound effects on physical health and longevity. The consistent associations found between subjective wellbeing and positive health outcomes make a case for prioritizing happiness and life satisfaction as key components of a healthy lifestyle. Interventions and societal changes that promote happiness may have the potential to significantly improve public health and extend lifespans on a broad scale.

Chapter 2: Measuring reward system activity

To provide actionable guidance for individual wishing to take proactive steps toward being happier, and to measure the activity of the brain's reward system, it is crucial for understanding the neural basis of positive emotions and happiness. A biomarker, described as "a defined characteristic that is measured as an indicator of normal biological processes, pathogenic processes, or biological responses to an exposure or intervention, including therapeutic interventions" (BEST Resource, 2016), would provide valuable insight into the mechanisms underlying human happiness. However, there are several challenges that limit our ability to assess reward system function accurately and comprehensively in real-world settings. This chapter explores four key challenges: the limitations of MRI brain scans during real-life activities, the limitations of peripheral signals and consumer wearables, the limitations of emotion terminology and semantics, and the limitations of subjective and objective data retrieval from information stored in our brains.

Constraints of MRI brain scans in natural contexts

Functional magnetic resonance imaging (fMRI) is a powerful tool for identifying brain regions involved in reward processing and positive emotions (Kringelbach & Berridge, 2017). However, fMRI has several limitations that restrict its generalizability to real-life situations.

One major constraint is that participants must lie still in the scanner and cannot move around, preventing the study of reward system activity during natural behaviors and social interactions in real life (Matusz, Dikker, Huth, & Perrodin, 2019). The scanner's enclosed space and loud noises can also create anxiety and discomfort, such as claustrophobia, altering emotional and physiological responses (Muehlhan, Lueken, Wittchen, & Kirschbaum, 2011).

fMRI does not directly measure rapid neural firing which occurs on the order of milliseconds, but rather the slower hemodynamic response in neurons, which occurs on the order of seconds. This may limit its ability to capture the neural dynamics underlying some emotional experiences (Cohen, 2014). Despite advances in technology from major manufacturers, this limitation is physiologically constrained. Importantly, our unpublished studies suggest that 3T fMRI lacks the resolution to reliably identify signals of specific emotions, even with using personalized stimuli like autobiographical memories. This casts doubt on the validity of prior fMRI emotion studies. Techniques using electroencephalography (EEG) and functional near-infrared spectroscopy (fNIRS) allow for more naturalistic experiments, but they lack the spatial precision of fMRI (Cohen, 2014), cannot easily measure activity in deep subcortical reward regions (Quaresima & Ferrari, 2019) and, according to our unpublished studies, are highly susceptible to motion artifacts from muscle activity in real-world settings. Our studies also suggest that while EEG can detect changes in arousal under controlled lab conditions, it struggles to differentiate specific positive emotions. As a result of these shortcomings, it is likely that researchers will move away from using EEG for diagnostic purposes.

Shortcomings of peripheral signals and consumer wearables

Physiological metrics, such as heart rate, respiration, and skin conductance, have been used as proxies for measuring emotional responses (Shiota et al., 2011; Shiota et al., 2017). While these metrics are more accessible to measure than brain activity, especially with the proliferation of consumer wearable devices, they have several shortcomings in terms of specificity and reliability.

Changes in physiology can reflect general arousal and are unreliable for identifying a specific emotional state (Kreibig, 2010). For example, increased heart rate could indicate excitement and enthusiasm or anxiety and fear. Additionally, there is significant variability in peripheral responses to emotional stimuli, making it difficult to establish universal patterns (Siegel et al., 2018).

Our research team has conducted eight tests using various wearables, including the Oura ring, Apple Watch, Fitbit, Garmin, Whoop, and an MRI-compatible wrist sensor patch developed in collaboration with partners, to assess their ability to detect positive emotions. While some devices were able to detect arousal states, none could reliably qualify or quantify the nine specific positive emotions outlined in this paper.

Additionally, consumer wearables like smartwatches and fitness trackers often use photoplethysmography (PPG) sensors to measure heart rate. However, these sensors can be affected by various factors, like device and activity type, that impact their accuracy (Bent et al., 2020). While consumer wearables offer convenient access to certain physiological metrics, caution should be exercised when interpreting data from these devices.

Ambiguity of emotion terminology and semantics

Another challenge in studying positive emotions is the ambiguity and inconsistency of terminology used to describe emotional states. There is ongoing debate about how to best classify and define emotional experiences (Adolphs, 2017).

One proposal outlines a limited set of universal and innate “basic” emotions, such as enjoyment, sadness, fear, anger, and disgust (Ekman, 1992). However, other models argue for a dimensional approach, characterizing emotions based on valence (pleasure to displeasure) and arousal (high to low alertness) (Posner et al., 2005).

This diversity of emotion models and terminology can lead to confusion and prevent the integration of findings across studies. Historically, the term "happiness" has been used to refer to a range of positive states, from sensory pleasure to feelings of life satisfaction and eudemonic well-being (Kringelbach & Berridge, 2010). However, “happiness” may comprise several distinct positive emotional states with unique functional neural mechanisms (Shiota et al., 2017). Greater precision and standardization of emotion terminology is needed to help clarify the specific psychological phenomena being investigated.

The Matter Protocol™ addresses the challenge of emotion terminology ambiguity by adopting the nine positive emotions proposed by Shiota et al. (2017). The validity of these nine emotions is founded in evolutionary theory and a vast amount of data from other researchers (see references in Shiota et al., 2017), and has been further confirmed by our own phylogenetic analysis (unpublished data). This standardized approach allows for more precise targeting of specific emotional deficits and helps users develop a shared understanding of their emotional experiences.

Constraints on accessing subjective feelings and objective emotional information

Studying emotions requires both subjective self-report data about experiences and objective measures of brain and physiological activity. However, there are challenges associated with accessing and integrating these two types of information.

Subjective reports are used when researchers must rely on individuals to accurately record their feelings through surveys and interviews (Mehl & Conner, 2012). However, self-report measures are susceptible to biases and limitations of introspective awareness (Robinson & Clore, 2002). Retrospective reports are also vulnerable to memory biases and may not fully capture emotional experiences (Miron-Shatz et al., 2009). Despite these limitations, changes in subjective emotions are what matter most, as objective biomarker changes are meaningless if not accompanied by a felt subjective experience.

Objective biomarkers of emotions are transparent and not subject to the same self-report biases. However, these measures are limited by their invasiveness, temporal resolution, and real-world generalizability (Cohen, 2014). Additionally, there is not always a clear link between patterns of physiological or brain activity and specific subjective states (Siegel et al., 2018).

Another challenge is that emotional experiences arise at a preconscious or unconscious level (Kihlstrom, 1987). This makes it difficult to link subjective reports with objective biomarkers.

Multimodal approaches are needed to produce frameworks that can bridge the gap between subjective and objective levels of analysis. Cognitive behavioral therapy (CBT) is a clinically proven method that incorporates subjective emotion journaling. However, CBT is heavily impacted by low retention rates, especially with healthy individuals and those with severe mental illness. This journaling approach is central to the Alcoholics Anonymous (AA) program and has been successful in that context. However, the challenge of retention with healthy individuals has not yet been overcome (Bouchon, 2019).

Chapter 3: Imagining a digital tool

In 2019, Matter Neuroscience established its vision to enhance the biological processes underlying positive emotions and drive happiness. This vision encompassed three key objectives: (a) build a method or tool that allows measuring key brain molecules in real-time, (b) make it accessible to all humans as a guiding indicator for happiness every day, and (c) establish a platform to share and receive tangible recognition in return for making others happy, emotionally and molecularly.

To achieve these objectives, a digital tool should be designed to measure and differentiate between positive emotions in real-time, facilitate decision-making that promotes personal growth and mental well-being, and provide positive reinforcement through personalized feedback. Additionally, the tool should leverage the innate human tendencies for learning and cooperation. Finally, a framework is proposed for how such a tool could drive happiness in a manner analogous to how society uses capitalism to grow GDP.

Real-time emotion recognition and differentiation

A primary objective of the digital tool is to accurately read and report on the user's positive emotions in real-time. This requires the ability to differentiate between specific positive emotions, such as enthusiasm, contentment, and friendship (Shiota et al., 2017). By identifying the distinct neural and physiological signatures associated with each positive emotion, the tool can provide a detailed report of the user's emotional state.

Real-time emotion recognition can be achieved by integrating multiple data streams, including the use of autobiographical memories for emotion induction, brain activity, peripheral physiology, and subjective self-report (Calvo & D'Mello, 2010). In our fMRI studies, we consistently use MRI-compatible wearables measuring heart rate variability, respiration, and skin conductance to explore potential correlations between these metrics and brain activity. Advances in machine learning algorithms could enable the tool to classify emotional states based on patterns in the data (Zhang, Yin, Chen, & Nichele, 2020). Our ongoing research aims to leverage 7T fMRI data to train artificial intelligence models that can be integrated into wearables, potentially enabling more accurate detection of specific emotional states based on brain activity signals. The AI's base training would be updated using real-life scenarios by prompting users to qualify their emotional experiences when arousal signals are detected. However, as discussed in Chapter 2, the limitations of current emotion measurement techniques must be considered, and a healthy skepticism would be warranted when reviewing results.

Emotion-driven decision support

Another key objective is to facilitate real-time decisions that drive happiness in the form of personal growth and mental well-being. The tool should use emotion recognition data to provide personalized recommendations and support decision-making. It can utilize information about gaps in areas where improvement is needed and assist by generating ideas and strategies promoting positive activities, social connections, and healthy behaviors (Sin & Lyubomirsky, 2009).

For example, if the tool detects a deficiency in a specific neurotransmitter, it may suggest various positive activities that can increase its levels. Dopamine can be boosted by engaging in any rewarding activity, while serotonin levels can only be raised through experiences that enhance self-esteem or pride in oneself, others, or one's community. Oxytocin can be increased through nurturing interactions with family, pets, or students, or by experiencing contentment in nature. Cannabinoid levels can be elevated through friendship, contentment in nature, or amusement and laughter. Opioids can be boosted through laughter, various sources of pleasure, or practicing gratitude through mindfulness. By focusing on specific neurotransmitter deficits rather than emotions, the tool can provide users with a neutral framework for addressing imbalances, which may enhance motivation and engagement.

Positive reinforcement through feedback

To drive engagement and behavior change, the digital tool should provide positive reinforcement by reporting on the results of the user's decisions in real-time. As the user engages in activities and behaviors recommended by the tool, positive emotion readouts can serve as immediate feedback, reinforcing the benefits of these actions.

This feedback loop aligns with the principles of reinforcement learning, which underlie the brain's reward system and play a crucial role in shaping behavior (Sutton & Barto, 1998).

Leveraging innate learning and cooperation tendencies

The digital tool should be designed to leverage our innate tendencies for learning and cooperation, which have been instrumental in human survival and progress (Boyd & Richerson, 2009). The reward system discussed in Chapter 1 is one of the main neural circuits underlying this ability.

By providing positive feedback for social behaviors and encouraging cooperation, the tool can tap into our natural inclination for support and connection. Accordingly, a social aspect could be incorporated into the tool, allowing users to share their progress and exchange insights on increasing happiness. This sharing can enhance individual well-being. Our preliminary 7T MRI studies have shown that social memories drive more extensive brain activity compared to solo memories (unpublished data). This suggests that social interactions and shared experiences may be particularly effective in activating reward circuits and promoting positive emotions.

A framework for driving happiness

A framework can be used to conceptualize how a digital tool can drive happiness, analogous to how society uses capitalism to grow GDP. Table 1 outlines this framework, comparing the main components driving return on investment (ROI) in a capitalist economy to potential drivers of return on happiness (ROH) in a “happiness economy.” (Bouchon 2019)

This framework provides a starting point for designing a digital tool that supports behaviors and decisions promoting happiness.

By aligning the tool’s objectives with the biological processes and biomarkers underlying positive emotions, it can motivate users to engage in positive behaviors and decisions that promote their happiness and well-being.

	Driving ROI (Return on investment)	**Driving ROH** (Return on happiness)
Framework	Capitalism, global mixed economy	Universal happiness hierarchy
Pricing	Supply- and demand-based (driven by the market; illogical, emotional)	Need-based (driven by individual neural reward systems; scientific, non-emotional)
Currency	Financial capital: medium to exchange, common measure of value and store of value	Happiness capital: medium to exchange, common measure of value and store of value
Focus	Creating, producing, marketing, and selling of goods and services to other people (at a profit)	Creating, sharing, and rewarding goods, services, and actions driving happiness for other people

FIGURE 5. A FRAMEWORK FOR DRIVING HAPPINESS (COURTESY OF AML ONE)

Chapter 4: The Matter Protocol™

Matter aims to translate neuroscience research to help users achieve happiness and wellbeing in daily life. It proposes that happiness can be cultivated through a continuous cycle of meaningful actions and the preservation of positive memories that are rewarding and reinforce memory formation. This contrasts with traditional philosophical notions that tie the good life to virtuous character traits, which can feel abstract and unattainable. Instead, Matter provides a more tangible and accessible path using a digital tool that operationalizes key insights from research on happiness.

At the heart of the Matter system is the Matter Protocol™ - a proprietary algorithm designed to activate a self-reinforcing loop of real-life actions, emotions, memories, and personalized recommendations to drive long-term happiness (Matter Neuroscience Inc, 2024). The protocol interfaces with the user's "core biological engine", leveraging real-time emotional and molecular data to inform its suggestions in an iterative cycle.

The Matter Protocol™ algorithm takes in data points from the user's recorded memories. It then generates personalized recommendations in the form of action cards, which suggest activities or experiences to boost the user's overall happiness and

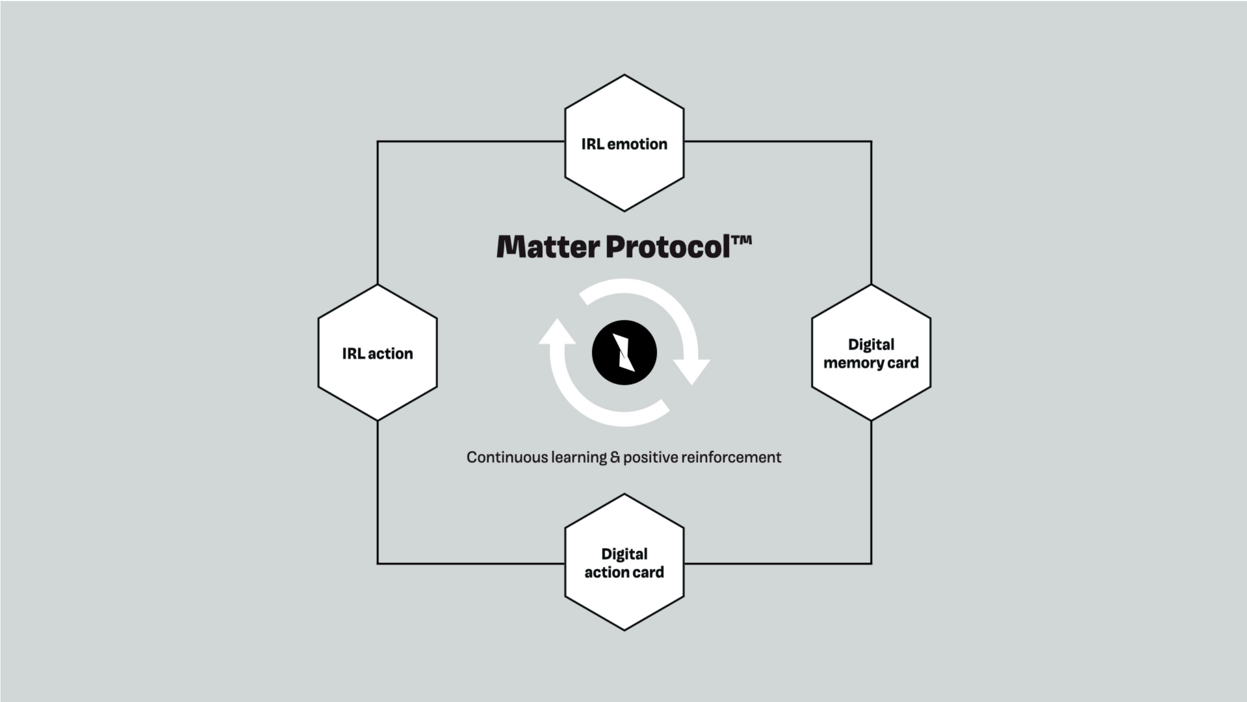


FIGURE 6. MATTER PROTOCOL: CONTINUOUS LEARNING & POSITIVE REINFORCEMENT

address any neurotransmitter deficits. As the user continues to record new memories and provide feedback, the algorithm refines its suggestions to optimize well-being.

To activate the Matter Protocol™, users are prompted to record their peak memories for each of the nine positive emotions during the initial "activation phase". These peak memories serve as a benchmark for the user's brain activation capacity. By capturing the strongest neural representations of each positive emotion, the Matter Protocol™ can generate personalized recommendations that are calibrated to the user's emotional profile. The activation phase is discussed in more detail in Chapter 9.

The user is encouraged to complete actions in real life - pursuing meaningful experiences and connections. The protocol then prompts the user to record key moments from these actions in the form of "digital memory cards" within the Matter app. These memories represent the most salient cognitive and affective elements of the experience. The process of recording serves to educate the user on the relationship between their subjective experience, positive emotions, and the neurotransmitters that underlie those emotions. Once recorded, the memory cards become a permanent source of positivity that can be revisited within the app to provide mood-enhancing reminders and motivation.

Leveraging the user's growing memory bank, real-time emotional data, and happiness research, the Matter Protocol™ can generate recommended actions to promote happy experiences. These personalized suggestions are crafted to target neurotransmitters the app has flagged as needing activation based on the user's memories and emotional patterns.

In this way, the Matter Protocol™ tries to guide the user through a continuous growth cycle, leveraging small positive actions to grow happiness over time. The protocol should become more personalized and effective over time as the user builds their memory portfolio.

The Matter journey is marked by key milestones, such as the activation of the Matter Protocol™, the accumulation of memories, and the progression through the Leverage and Growth phases. The phases are proposed to correlate with enhancement in emotional well-being as well as positive structural brain changes over time (Matter Neuroscience Inc, 2024). In particular, engaging with the Matter Protocol is hypothesized to promote neuroplasticity in networks involved in positive emotions and reward - though additional research is being conducted to substantiate these claims.

Ultimately, Matter strives to make the cultivation of happiness an accessible daily practice rooted in neuroscientific research.

Chapter 5: Recording a memory

Recorded memories serve as the foundation for the Matter Protocol's™ personalized recommendations and happiness-boosting effects. The process involves users selecting a photo that represents a memory and providing additional context that can enhance recall. By creating these "memory cards," users build a portfolio of positive experiences that can be revisited to evoke the original emotions.

The primary recall anchor for each memory card is the chosen photo. Images can evoke vivid autobiographical memories, serving as effective cues for retrieval (Conway & Pleydell-Pearce, 2000). Users are also able to provide secondary recall anchors, such as the location, relevant people, and associated music. These additional cues create a multi-sensory memory representation that can enhance emotional intensity during recall.

After a memory is recorded, the Matter Protocol™ analyzes the associated emotions to identify the specific combination of neurotransmitters involved. This "emotional fingerprint" is thought to reflect the neural mechanisms underlying the experience of the positive emotion, such as the dopaminergic enthusiasm or the oxytocin-mediated nurturant love discussed in Chapter 1. When viewing the memory card again later, it is suggested that users can reactivate this same pattern of neurotransmitter activity, resulting in a recurrence of the original emotion (Speer, Bhanji, & Delgado, 2014).

The Matter Protocol™ also protects against potential overuse of memory recall. Excessive replay of a memory can lead to its emotional salience fading, where the positive feelings associated with an experience diminish over time (Walker et al., 2003; Ritchie et al., 2006). To protect against this, the Matter algorithm monitors the frequency of memory card usage and skips those that have been reviewed too often. This process ensures that each memory retains its intended effects.

Chapter 6: Memory vault

The memory vault serves as a personal archive for users' memory cards, preserving the original emotion ratings and contextual details associated with each experience. These memory cards are organized chronologically and can be easily accessed for later recall and reflection.

This digital storage system is designed to augment the brain's biological memory by providing an emotional "source of truth" that remains stable over time. Memories are subject to fading and distortion over time, a phenomenon known as transience (Schacter, 1999). This can be accompanied by a degradation in the fidelity of the emotions involved in a particular memory. By preserving the original emotion ratings within the memory vault, users can reliably access the "emotional fingerprint", even if their recollection of the experience has diminished or changed over time.

Users can identify patterns and insights about the people, activities, and environments that contribute to their happiness by browsing their vaults. This process is enhanced by incorporating secondary memory anchors, such as location, relevant people, and associated music, which have been shown to enhance memory recall. Additionally, the concept of state-dependent memory suggests that recalling a memory is easier when the individual is in the same emotional state as when the memory was formed (Eich, 1995). By providing a digital record of the original emotional context, the memory vault may help users more easily access and relive positive experiences. This information can be used to inform decisions that maximize well-being. For example, if a user sees that a relatively large number of connections with a certain friend is linked to peaks in pleasure and amusement, they may prioritize setting aside more time for that relationship.

For the vault to be effective, users must be sure to consistently record memories over time. This will ensure that past emotional experiences can be relied upon for sustainable happiness boosts.

Chapter 7: Action cards

Action cards are designed to provide users with personalized recommendations for real-life activities that can boost positive emotions and address neurotransmitter deficits identified by the Matter Protocol™. These suggestions are generated from two main sources: (1) a scientific database of general recommendations based on clinical data, and (2) the user's own recent memories from their memory vault (Matter Neuroscience Inc, 2024). Recommendations from the scientific database are critical when users are first starting to fill their memory vault, as it provides evidence-based suggestions that can help them create new positive experiences. Action cards also serve as a reinforcing mechanism for the user to learn the connections between their actions and the neurotransmitters that underlie those actions. Over time it is expected that with this increased understanding, a user might be more quick to identify their own gaps and understand what actions they might take steps to close their gaps.

The content of the action cards Is based on the factors that influence the release of the six key neurotransmitters associated with happiness: dopamine, testosterone, serotonin, oxytocin, cannabinoids, and opioids. The Matter Protocol™ identifies which neurotransmitters may be lacking based on the user's emotional patterns and generates action cards targeting those specific deficits.

For example, if the Matter Protocol™ detects a lack of oxytocin-associated emotions like nurturant love in the user's recent memories, it might suggest an action card prompting the user to spend quality time with family or close friends. The card may recommend specific activities known to promote oxytocin release, such as giving a heartfelt hug (Holt-Lunstad, Birmingham & Light, 2008) or engaging in acts of affectionate touch like feeding someone with your hands (Meinlschmidt & Heim, 2007). It also might suggest interacting with or hugging puppies to increase oxytocin levels (Beetz et al., 2012). However, the Matter Protocol™ should not recommend this activity if the user’s memory vault indicated a dog hair allergy or fear of dogs. By following personalized suggestions, the user can work to close the identified oxytocin gap. As the user continues to record memories, the Matter Protocol™ increasingly draws from their own experiences over the past 3-6 months to generate more personalized and actionable recommendations.

In addition to using action cards to close neurotransmitter gaps, challenges and community activities can be used to create positive emotions within the context of a time-bound group event. Challenges might involve a prompt to record memories comprising all 6 associated neurotransmitters over a week. Community activities could include real-world events where users meet up to share memories and action card experiences, driving social bonds and generating new positive emotions in the process.

Action cards, challenges, and community activities provide structured opportunities and personalized recommendations for growing happiness.

Chapter 8: Key performance indicators

Several key performance indicators (KPIs) are tracked during the user journey to cultivate happiness: the number of memories recorded, the Matter Score™, and Joyalties™. These are represented individually in the app and collectively their impact is represented in the Brain ID, an image that responds to user activity and informed by our clinical studies. A user's Brain ID is their unique avatar on Matter.

Number of memories

The number of memories a user records is a critical input for the algorithm to enhance individual happiness. As users add more memories to their vault, the Matter Protocol™ gains a richer dataset to learn from and generate personalized recommendations. Accordingly, as the number of memories increases, the protocol becomes more targeted and effective in guiding the user towards positive experiences and emotional well-being.

Studies support the importance of memory quantity in driving happiness growth. In a 6-week Matter “"game”" where Matter participants grew their memory vault over time, those who completed the full 42 days showed a significant increase in average daily Matter Score™ compared to the control group (Matter Neuroscience Inc, 2024). The treatment group also reported higher gains in life satisfaction, positive affect, and flourishing assessed by subjective measures. These findings suggest that consistent engagement in recording memories is key to receiving the benefits of the Matter Protocol™.

The Matter Score™

The Matter Score™ is an indicator used to quantify the positive impact a memory or group of memories has on a user's well-being. It aims to capture the complex dynamics of the brain's reward system that give rise to happiness, such as neurotransmitter activity . The score is expressed in minutes, suggesting that the user's healthy lifespan may be extended by this amount because of the positive benefits associated with happiness (#reference).

The Matter Score™ can range from 0 to 1,666 minutes. A score of zero represents a day that was not good, while a good day is defined as one with a score of 10 or above. As such, a user's primary objective while using Matter is to accumulate as many good days as possible. The median Matter Score™ is tracked over time, and when a day's memory yields a score above this median, it is in the user's top 50% of good days. These above-median days signify personal progression and growth.

The Matter Score™ is normalized such that it can be compared across users. This normalization occurs as each individual rates the emotions associated with their memories relative to the full spectrum of emotions they have experienced over their entire life.

Preliminary brain imaging studies suggest that memories associated with high Matter Scores™ elicit greater activity in regions linked to positive affect and reward processing compared to low-scoring memories (Matter Neuroscience Inc, 2024).

Joyalties™

Joyalties™ are based on the premise that happiness is most often found in connection with other people. Four out of the six neurotransmitters associated with positive emotions (serotonin, oxytocin, cannabinoids, and opioids) are typically triggered through social interactions (Shiota et al., 2017). Additionally, there is a widely accepted understanding that happiness comes from sharing one's gifts and positivity with others (Aknin et al., 2013).

Joyalties™ in the Matter app represent a quantitative "thank you" that a user can give to someone who contributed to their happiness. Joyalties are designed to mimic our biological response to smiles and positive facial communication. The neurotransmitters creating our positive emotions are centrally driving distinct muscle contractions in our face. With it, the neurotransmitters generate distinct types of smile representing our key emotions. Such a smile on our face can travel visually when it is seen and recognized by someone who observes our smile. On the receiving end of a smile, the brain response with the release of the same neurotransmitters, e.g. Dopamine generates excitement and a characteristic exciting smile – such a smile triggers the same smile on an other person observing that smile what in turn catalyzes excitement and Dopamine release. In a way that's the contagious path of positive emotions: we positively infect other people by our smiles.

Joyalties are using the same concept but extending it from smiles to forwarding a quantitative Thank You to a person who contributed to a positive memory. Such an incoming "Thank You", we call Joyalties. The quantity of joyalties shares is identical to the Matter Score created.

When a user shares a memory and its associated Matter Score™ from an event that occurred with another person, it is converted into a Joyalty™ upon receipt. In this way, Joyalties™ function as a way of thanking or acknowledging someone for contributing to the giver's own Matter score.

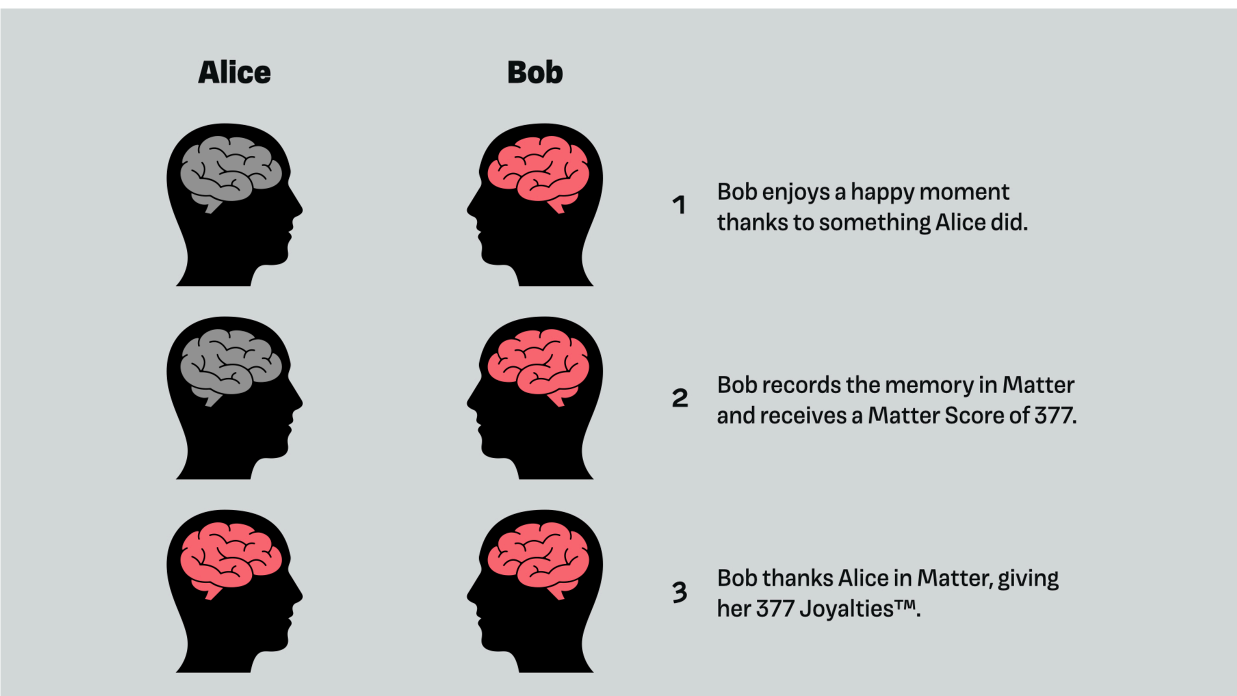


FIGURE 7. JOYALTIES™ OFFER A RETURN ON PROVIDING HAPPINESS

Joyalties™ accumulate to a user bank like a monetary currency. However, there is a key distinction between Joyalties™ and monetary currencies. Joyalties™ act as a secondary reinforcer, incentivizing actions that enhance the well-being of others. This encompasses a much wider range of prosocial behaviors compared to traditional currencies, which primarily motivate actions that enrich the individual. By assigning value to interpersonal acts of friendship and support, Joyalties™ aim to foster a culture of giving that can reward and magnify net increased happiness across social networks, rather than treating happiness as a zero-sum game.

Brain ID

Based on the universal brain activation patterns per emotion identified during our fMRI studies, Matter generates a personalized Brain ID for each user (unpublished data). The Brain ID simulates the intensity and location of brain activity associated with each recorded memory and presents it as a creative illustration. Viewing this unique "emotional fingerprint" is intended to represent the neuroplasticity created with each action a user takes to be happier, motivating users' continued engagement with positive experiences.

By capturing indicators of engagement, emotional impact, prosocial behavior, and simulating neural activation patterns, these KPIs provide a comprehensive picture of how the user is leveraging the neuroscience of positive emotions to create a net increase in happiness for themselves and others.

Chapter 9: The Matter journey

The Matter journey is designed to guide users through a process of cultivating happiness in three distinct phases: activation, leverage, and personal growth (Matter Neuroscience Inc., 2024).

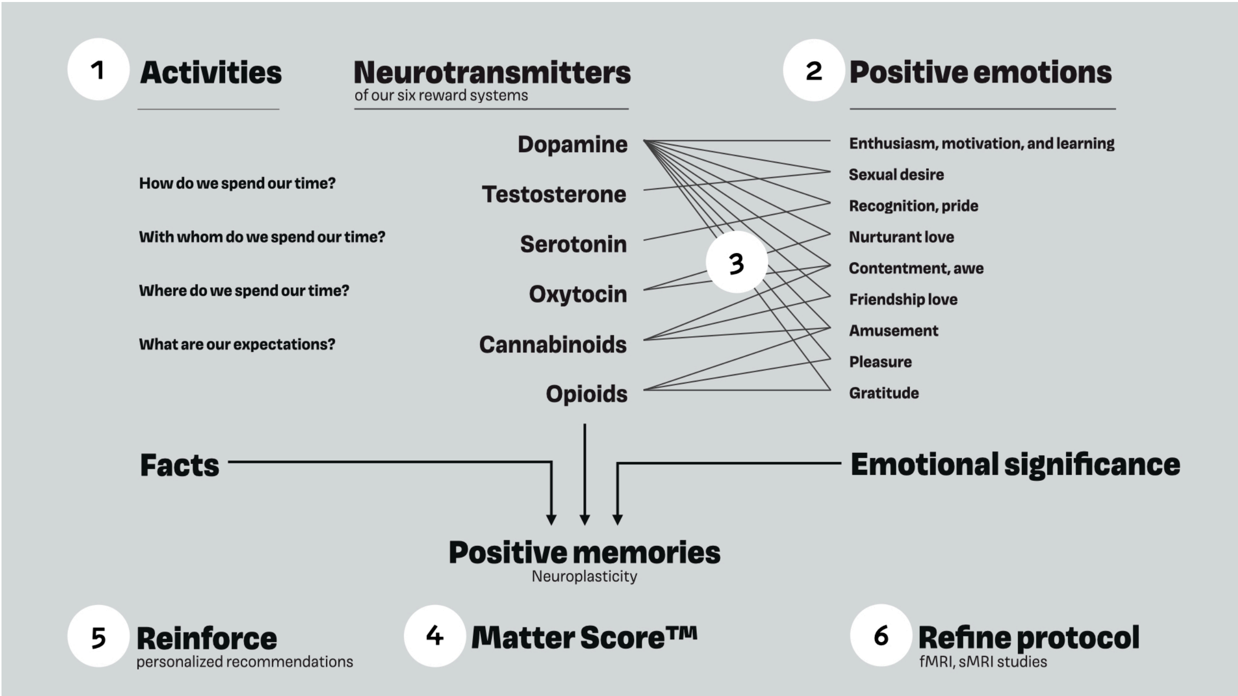


FIGURE 8. HOW MATTER WORKS: 1. RECORD ACTIVITIES, 2. RATE EMOTIONS, 3. MATTER PROTOCOL, 4. MATTER SCORE, 5. REINFORCE, 6. REFINE PROTOCOL

Activation Phase

The initial activation phase focuses on providing the Matter Protocol™ with a sufficient baseline of emotional data to generate personalized recommendations. It serves as a calibration period, allowing the Matter Protocol™ to adapt to the user's unique emotional profile.

During this stage, users are prompted to record at least three peak memories for each of the nine positive emotions (enthusiasm, sexual desire, pride, nurturant love, contentment/awe, amusement, friendship love, pleasure, and gratitude). These 27 memories should represent the moments when the user experienced each emotion at its strongest intensity. Capturing peak emotional experiences is crucial because these memories likely encode the most potent neural representations of each positive emotion for that individual. By using these peak memories as a benchmark, the Matter Protocol™ can calibrate its recommendations to the user's personal emotional range.

In addition to logging peak memories, users should record at least 23 recent memories of varying emotional intensities across the nine emotions. This ensures that the Matter Protocol™ has a sufficiently diverse pool of memories to draw from when curating memory recall prompts and action suggestions. Additionally, as explained in Chapter 5, a large and diverse memory pool will make it easier for the Matter Protocol™ to ensure that the emotional salience of memories doesn't decay and that their potency is maintained.

Leverage Phase

After activation is complete, the user transitions into the leverage phase. The primary objectives during this period are to expand the user's memory bank and translate these positive experiences into actionable insights for happiness.

To grow the pool of memories, the user is prompted to consider adding photos from the photo roll to their vault. The app prompts the user to record a new memory, streamlining the process of capturing positive moments.

Preliminary data suggests that consistent engagement with the Matter app during the leverage phase may result in adaptive changes in neural structure and function (Matter Neuroscience Inc, 2024). These changes are hypothesized to drive lasting improvements in emotional well-being that extend beyond the duration of app usage.

This phase typically concludes once the user has recorded a total of 200 positive memories in their vault.

Growth Phase

In the final growth phase, users progress to a more self-directed approach to growing happiness. Instead of relying solely on the app's prompts, individuals can proactively select which neurotransmitter systems they wish to target for further development.

For example, if a user notices a deficit of memories associated with pride or recognition in their vault, they may prioritize engaging in confidence-boosting activities like learning a new skill or taking on a leadership role. By seeking out experiences that can stimulate the release of specific neurotransmitters, users can take a more active role in their journey.

The goal during this phase is to enjoy an increasing frequency of "good days" and to record at least one memory per day with a Matter Score™ of 10 or above. Much like physical exercise builds strength and endurance through consistent practice over time, regularly engaging in strong positive experiences may lead to a longer, healthier, and happier life, as described in Chapter 1.Progress in this phase is achieved by consistently prioritizing activities and experiences that result in relatively strong positive emotions.

The Matter Protocol's™ three-phase approach provides a structured yet flexible framework for growing happiness that adapts to everyone's unique needs and circumstances.

Conclusion

Our research suggests that humans possess a universal brain map for positive emotions that can serve as a biomarker for happiness. This has the potential to revolutionize our understanding of well-being. Guided by this insight gained in our clinical studies, we made the decision to rapidly translate our laboratory findings into a publicly accessible tool. We launched the Matter app as a beta version, enabling us to collaborate directly with users in refining its features and user experience. Our goal is to help users grow their happiness with a consumer-friendly app that is engaging, effective, and enjoyable to use.

In parallel, we are continuing our research efforts to further validate and expand upon this emotional biomarker. By combining user feedback with scientific investigation, we aim to promote mental health and happiness on a global scale.

Matter's mission is to promote a greater understanding of the role and importance of the brain's reward systems in order for individuals to maximize their well-being and extend their healthy years on earth. We seek to elevate the pursuit happiness to be a goal shared by all. Matter Neuroscience wants to cure unhappiness.

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