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REVIEW ARTICLE

The place of Free Will: the freedom of the prisoner

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Abstract
Debates about the concept of Free Will date back to ancient times. About 40 years ago, Benjamin Libet designed an experiment showing that the conscious intention to move is preceded by a specific pattern of brain activation. His finding suggested that unconscious processes determine our decisions. Libet-style experiments have continued to dominate the debate about Free Will, pushing some authors to argue that the existence of Free Will is a mere illusion. We believe that this dispute is because we often measure Free Will using arbitrary human decisions rather than deliberate actions. After reviewing the definition of Free Will and the related literature, we conclude that the scientific evidence does not disprove the existence of Free Will. However, our will encounters several constraints and limitations that should be considered when evaluating our deeds' personal responsibility.

Keywords Free Will · Consciousness · Volition · Intentional action · Libet study · Readiness potential

Introduction

As you begin to read this sentence, you may think that our thoughts motivating this text were freely developed, and that the typing movements we used to put our thoughts in writing were also freely made. That is a strong presumption and is often articulated in support of a key cognitive difference between humanity and other species. This subjective intuition about freedom underlies many human behaviors including moral responsibility. However, despite the universal feeling of being the free conscious agents of what we think and what we do, the notion of *Free* Will remains obscure and controversial. For example, David Hume defined the will as: "…the internal impression we feel and are conscious of, when knowingly we give rise to any new motion of our body, or new perception of our mind" [1]. At the core of the concept of will, Hume put subjective experience. Indeed, if a person reports that an action was unwilled, there is no way to establish for sure that it was not.

The core issue for us for an understanding of the brain mechanisms of will is what is meant by free. The term free, in connection with the word "will" might be misleading. It does not mean that we can do whatever we want. We do have several constraints within which we can exercise our power to choose. There are three conditions that indicate that an action was free [2]: the ability to do otherwise, the control over our actions, and the responsiveness to reason.

Freedom is what we usually think we have and what we attribute to other adults, except those, for example, who are incarcerated or under the effect of drugs that can affect a person's behavior. However, neurotypical humans often act on impulse, sometimes even against their interests, unaware of the consequences of their acts. Living organisms are endowed with freedom as behavioral variability is an advantageous evolutionary trait. The selection pressure favors unpredictability [3]. The key point is how the cognitive system generates and controls the behavioral alternatives in each situation. In the domain of decision-making, "free" does not mean free of possible internal or external influences. Our will normally is biased by certain constraints. But does the presence of constraints contradict the notion of Free Will?

Indeed, there are absolute and relative constraints. Absolute constraints are those that limit our perception or our

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freedom of movement in ways we cannot overcome. This is the human *Umwelt*, which set barriers against understanding other peoples, other places, and other times. We cannot imagine what it is like to be a bat without sharing its fundamental structure [4]. Other constraints are effective but unable to completely block the human will. Rules and laws firmly push people to behave in specific ways often, but not always, according to moral judgments we share as members of human society. However, even in situations where their lives are at stake, people sometimes choose not to obey an order considered unjust. Other constraints are more subtle and can bias our choice in different situations, as when advertising convinces us to buy what we do not need or induces us to choose one brand over another. So, many of our decisions might depend on the influence of overt or covert constraints, but their prevalence is not absolute, and, in most cases, there is still room for choice.

It is claimed that submitting to the power of a constraint depends only on *predetermined* features of our character. In a sense, the universe and our behavior are determined only by its previous state(s). Causal determinism had been defined as the claim that "the prevailing laws of nature are such that there do not exist any two possible worlds which are exactly alike up to some time, which differ thereafter, and in which those laws are never violated" [5]. If we take this deterministic philosophical stance to its extreme consequences, our actions, our choices, and the brain activity that determines them would be caused only by preceding states. In this extreme view, there would be no room for Free Will. Everything would be pre-determined, as in the vision of those who believe in an almighty God who controls all our actions. However, the opposite view of a non-deterministic world does not necessarily endorse the idea that we have Free Will. Indeed, if the universe were non-deterministic, the alternative view would be that all undetermined events were at random. Then it would be chance, and not our will, that determines the course of events: a fact difficult to reconcile with the notion of Free Will.

Finally, there is a further possibility: that the universe might be in part ruled by probabilistic laws, that are characteristic of the behavior of living agents, and that these agents, by means of their evolutionary pressure, could have shaped the environment in which we humans live in. In that view, Free Will, strongly kinked with social responsibility, would be an emergent property of the evolution of the human brain function and organization.

Thus, it appears that there are only two philosophical positions that allow for Free Will: compatibilism and libertarianism. The former is the belief that Free Will is compatible with determinism. According to this view, causal determinism poses no threat to our status, as morally responsible agents as the freedom to do otherwise is sufficient for the kind of control an agent must possess to be morally responsible for her actions. Libertarians, on the contrary, think that Free Will can be saved only if the universe is indeterministic. Some libertarians think that the will is free within a physical universe characterized by a probabilistic behavior of particles at the subatomic level. Others are dualists, invoking the possibility that a non-physical mind can override physical causality. Among them, Rene Descartes maintained that the mind was a nonphysical substance that interacted with the body at the level of the pineal gland. More recent dualists were the philosopher of science Karl Popper and the neuroscientist John Eccles [6]. We think a scientific standing should be maintained within a monistic view, avoiding any stopgap solution that implies a kind of Cartesian theater where a conscious mind observes the sensory data collected by the brain. Indeed, we are our brain, and our mind comes out of it.

In recent years, the development of neuroscience has led to an ever-deeper understanding of the way in which the brain perceives and produces actions, generates thoughts, and determines relationships between humans. Some experimental studies have investigated the chain of events, out of awareness, that precede the activation of movements or simple decisions. This might lead some people to abandon the belief that we are free agents and follow the claim that free volition is nothing more than an illusion introduced by evolutionary selection to give humans a sense of responsibility, without which the human species would probably have destroyed itself [7–10]. Those authors have reported a wealth of examples to show how easily we can be misled. But it does not follow that our direct experiences of will are typically illusory. Furthermore, recent studies have demonstrated that neural activation only precedes the awareness of simple, arbitrary decisions but not more complex, deliberate choices.

Our view is that different choices including intentional choices tend to recruit specific neural networks regardless of whether the choice begins out of consciousness or whether the agent believes it is her choice. We claim that many factors constrain the choices we make that consistently limit, but not abolish, our freedom of choice. Limits and constraints do not disprove the general, philosophical, notion of Free Will, which is strongly linked to that of human choice and responsibility. Therefore, neuroscience research cannot solve the philosophical debate about Free Will, but by helping to describe the context of human decisions, can bring transformative effects on the legal approach to criminal law [11].

Below, we discuss two separate aspects of Free Will: the timing of will in relation to a movement and the sense of agency that people feel when deciding. These two processes concern overlapping but different brain networks. Later we will also discuss the relationship between consciousness and Free Will before returning to the role, if any, that cognitive

neuroscience can have in defining the limits of Free Will and personal responsibility.

Different choices and different brain networks

Recent examinations of Free Will have focused on a paradigm where the participant is asked to make a movement and report when the action begins. Besides self-report, electromyographic and response time measures are typically collected in such paradigms. The classical finding is that nonconscious movement commands precede the willed action.

When it comes to choosing a simple movement, we find decisions based on sensory discrimination and choices that originate from the intention to move. Such movements correspond to the activation, respectively, of the lateral or medial motor programming system [12]. Decisions based on sensory discrimination include, for example, stopping in front of a red light and starting to walk when the pedestrian light is green. In the laboratory, a two-alternative forced-choice paradigm is usually used, requiring participants to push a button whenever a red light appears and another key if the light is green. Using this paradigm with non-human primates has identified two regions of the lateral cortex that carry out this task: the intraparietal lateral cortex and the dorsolateral frontal cortex. Neuronal activity in both these areas covaries with the final decision but not with the stimulus. The neurons in these regions change their activity according to the motivation for action. The posterior parietal cortex appears to be specialized for multisensory integration and the coordinate transformation required to convert sensory input to enable motor output [13]. Besides being a node of the dorsal attention network, engaged by working memory, and executive functions, the dorsolateral frontal cortex supports cognitive selection of sensory information and response by comparing the output of different pools of neurons selectively tuned to specific kinds of stimuli [14]. Sensory discrimination may be simple, but it tends to be conscious and not automatic. As we next indicate, the conscious will *follow* the response to the stimuli.

The medial motor system is a network including the inferior parietal lobule and the medial precentral area (MPA), consisting of the supplementary motor area (SMA), the pre-supplementary motor area (pre-SMA) and their strong connections with the basal ganglia. In most cases, the intention to move is linked to the expected utility of the action that will follow.

The formal models that relate the parameters underlying this kind of choice, as in the reinforcement learning algorithms, are based on three steps: (1) the *attribution of value* to a set of possible competing actions; (2) the *selection* of the action (usually the one with the highest value); and (3) a *comparison* between the movement's effect with what was expected. Determining the value of an action typically depends on the expected reward or loss, on the cost to obtain the reward or to avoid the loss, and on the probability of success associated with the action. Note that this model assumes that the agent is always rationally motivated to act. However, several behavioral neuroeconomic studies have demonstrated that in humans, this is not always the case. As an example, we usually give greater weight to possible losses than gains and attribute different weights to the same actions in near versus remote future time points (hyperbolic time discounting) [15].

The neural networks encoding choices based on the value of the expected result include the dorsal and ventral striatal cortical loops. The dorsolateral striatum and its connection with somatosensory and motor-cortical regions are associated with automatic and stereotyped actions and behavioral schema, also referred to as habit [16]. Dorsomedial striatum and its connections with the orbito-frontal cortex are involved in goal-directed actions typically associated with controlled movements and behaviors that are sensitive to obtaining a desired outcome. Human ventral striatum changes its activity in relation to many kinds of rewards, ranging from food to abstract social or esthetic values and is involved in learning by trial-and-error [17]. Together with the ventral tegmental area and the nucleus accumbens, it forms a key circuit evaluating reward prediction errors [18]. The striatum and related regions are organized in series, so that the repetition of the action or behavior gradually shifts the activation from the most dorsal to the most ventral loops compatible with the attainment of a routine. In this way, the repetition of an action or a behavior becomes more and more automatic, with a parallel progressive *loss* of conscious control [19].

In attributing value to an action, the reward or punishment associated with it is of fundamental importance. Rewards and punishments are positive or negative reinforcers, respectively. The reinforcements are defined as "primary" if they are related to stimuli connected with the satisfaction of basic requests of our organism. Primary reinforcers are those concerning not only food, sex, and violence but also environmental and social interactions. A stimulus is a secondary reinforcer if it is permanently connected to primary reinforcements. In humans, a typical secondary reinforcer is money. The type and intensity of the reinforcers can vary enormously. However, while the representation of stimuli varies according to their characteristics (e.g., a visual stimulus-reinforcer has a representation in the visual cortex that of an olfactory stimulus-reinforcer in the corresponding olfactory cortex), the value of the decision to which they are associated is calculated by the same network that involves the striatum, the orbito-frontal cortex, and the ventromedial prefrontal cortex. In this way, the decision values can be

compared with the same metric, making it possible to select the most advantageous stimulus for responding.

To sum up this section, both choices based on sensory discrimination and decisions based on the expected value of reward may not be subject to conscious reflection. It appears that most of what we do in our everyday life might start automatically and become conscious only after the behavior is initiated. This has rather obvious implications for the idea of Free Will.

The timing of the intention to move

The demonstration that conscious volition can follow the preparation of a movement was first reported by Libet and colleagues [20]. Subjects sat on a lounge chair facing an oscilloscope where a spot of light moved clockwise near the circumference, simulating the secondhand sweep of a clock. Subjects made movements of the right hand whenever they wanted to and then reported the time of willing the movement (W) or of awareness of moving (M). Movement initiation was recorded by EMG over the activated muscle of the forearm. These times were compared with the EEG activity that preceded the movement: a slowly rising negative potential named the readiness potential (RP). Results showed that *M* was close to the actual movement, and *W* was about 300 ms before movement onset. RP onset was about 1 s before movement. i.e., occurring 700 ms prior to *W*, a compelling suggestion that movement preparation anticipates the conscious intention to move. Libet's experiment included only 5 subjects. However, its findings were replicated several times. A recent quantitative meta-analysis of the literature [21] revealed that the temporal pattern found by Libet and colleagues was robust, especially for the difference between unconscious brain activity and conscious intention to move, the most crucial time difference regarding implications about conscious causation and Free Will. A few methodological alterations of Libet's experiment yielded temporal patterns partially different from the original one [22, 23].

A similar experimental paradigm was investigated with functional magnetic resonance imaging (fMRI) instead of EEG to obtain a better spatial locus of participants' brain activity [24–26]. However, the time resolution of fMRI is very slow compared to EEG. The results showed that brain activity was predictive of the upcoming action about 10 s in advance of the performed movement, and that subjects had the subjective sense of deciding only about 1 s prior to the movement. Recording neuronal activity in 12 drug-resistant epilepsy patients implanted with depth electrodes to localize the focus of seizure onset, Fried et al. [27] showed a progressive increase or decrease of firing rate, particularly in the supplementary motor area (SMA), approximately 1500 ms before subjects reported making the decision to move. They also demonstrated that by stimulating the pre-SMA, patients reported "*an urge*" to move a specific part of the contralateral body. The results showed that small assemblies of single neurons in the medial frontal lobe not only precede volition but can also predict volition and its time of occurrence on a single trial basis.

Differences between studies also reflect the effect of the instructions given to the experimental subjects. It is particularly important to distinguish between wanting to do something and intending to do it. One might have competing "wants" and only later develop the intention to settle one plan. Furthermore, we should distinguish between intentions and urges. All these factors, related either to technical features or to behavioral and procedural differences, moderated the original pattern found by Libet et al. [20] but confirmed the main finding that brain activity can precede the conscious decision to move [28].

In this framework, intentions are not only states of mind but also brain states, and that many movements are made without formation of a conscious intention [28]. As an example, many action that we perform when driving are made automatically, without a conscious decision to act, but are considered to be voluntary.

One of the main arguments against the view that the Libet et al. [20] experiment provides evidence against a causal role for consciousness in human decision-making is that the repetitive small movements that participants were requested to make in the laboratory have nothing to do with Free Will, i.e., with a conscious *decision*. Indeed, in that experiment, the true decision was taken before entering the EEG laboratory or the MRI scanner, and it was that of taking part in the experimental procedure and preparing for a series of movement trials.

To investigate to what degree RP generalizes to deliberate, more ecological decisions, Maoz et al. [29] compared deliberated and arbitrary decision-making during a $1000-donation task to a non-profit organization. Results confirmed the presence of RPs for arbitrary decisions but not for the deliberate ones. These findings are congruent with the view that the RP represents accumulation of noisy, random fluctuations of brain activity driving simple and arbitrary decisions. Schurger et al. [30] elaborated this view proposing a leaky stochastic accumulator to model the neural decision to move in the absence of temporal cues. According to this model, the moment at which the decision threshold is crossed is determined by spontaneous sub-threshold fluctuations in neural activity. Crossing the threshold leads to movement and indeed, according to the model, fluctuations appear as a gradual increase in neuronal activity as demonstrated at the single-neuron level. They also demonstrated that stimulating the pre-SMA, patients reported "an urge" to move a specific part of the contralateral body [27, 31].

Libet [32] also noted that movements initiated unconsciously could be consciously vetoed. In essence, he argued that freedom was reduced from "Free Will" to "Free Won't." Using fMRI, Brass and Haggard [33] showed that a specific area of the frontal-medial cortex is more strongly activated when people prepare manual actions but then intentionally cancel them, compared with when they prepare and then complete the same actions. Further studies [34] have documented that antecedent brain activity RP can predict not only the decision to perform an action but also that to inhibit it.

In summary, the human brain contains a network associated with intentional actions. That network is centered on the frontal-medial cortex, including the pre-supplementary motor area (pre-SMA) and the cingulate motor area (CMA). Inhibition of intentional actions involves a fronto-median cortical area distinct both from pre-SMA and CMA. As demonstrated in the Libet-style experiments, activity in the network involved in intentional actions precedes the conscious decision of initiating the movement or to inhibit it. However, experimental evidence collected with the Libet procedure concern arbitrary motor decisions, which have little to do with the Free Will debate, in which it is necessary to collect evidence concerning deliberate purposeful decisions in contextually meaningful circumstances.

Agency

Agency (more specifically self-agency) is when a person realizes that she has decided to act or to make a specific action. This is the feeling that leads us to attribute an action to ourselves rather than to another person. The process that allows self-agency involves matching the planned movement with the observation of a compatible movement that follows. This requires a match/mismatch detector and a close temporal relationship between what was willed and the result. The brain performs this computation by comparing the motor command with the feed-forward signal issued together with it and the feedback signal detected by the sensory system. To investigate the neural substrate that allows the sense of agency, Farrer et al. [35] used a joystick device and modulated the feedback by showing on a computer screen the movement of a virtual hand that was either compatible or had different degrees of discrepancy between what was executed, and the movement seen on the screen. The main findings relying upon blood flow positron emission tomography (PET) were that the less subjects felt in control of the movements of the virtual hand, the higher the level of activation in the inferior part of the right temporal parietal junction (TPJ), while a reverse covariation was observed in the right posterior insula. Similar results were obtained by Nahab et al. [36] using fMRI. Subjects wore a data glove that registered the movement at each finger joint. This information was used to drive the image of the glove on a screen where it could mirror exactly the hand movement or provide various mixtures of true and arbitrary signals. The results showed two temporal patterns in brain areas involved in the modulation of self-agency. The leading network was characterized by early activation and moderate decline during task repetition and included the right temporal parietal junction, anterior insula, and precuneus. The lagging network had a delayed onset and a very slow decline during task repetition and included the middle frontal gyrus and the inferior parietal lobule. The results were interpreted with the leading network serving the role of mismatch detector and the lagging network receiving this information and mediating its elevation to conscious awareness, giving rise to self-agency.

Patients with functional movement disorders, who display motor symptoms (e.g., tremor) without a neurological cause, use normal voluntary motor pathways but paradoxically experience that tremor as involuntary, an example of impaired self-agency. Interestingly, Voon et al. [37] showed with fMRI that those patients had a right TPJ hypoactivity and a lower connectivity between right TPJ, sensorimotor regions (sensorimotor cortex and cerebellar vermis), and limbic regions (ventral anterior cingulate and right ventral striatum). They proposed that in patients with functional movement disorders, the lack of a match for the proprioceptive feedback could lead to perception that the abnormal movement is not self-generated.

Noninvasive brain stimulation in the right parietal area can affect the experience of self-agency [38–40]. Extensive acute lesions of the right hemisphere including the parietal lobe are often associated not only with neglect (failure to orient attention toward the contralesional space) but also with palsy anosognosia (lack of awareness of a contralateral palsy) [41] or asomatognosia (loss of the sense of ownership of a limb) [42], sometimes associated with somatoparaphrenia [43] (i.e., delusional misidentification and confabulation concerning the palsy limb). Among the striking examples that one of us (PN) has repeatedly witnessed in his clinical practice are people with complete left hemiplegia who, when asked to clap their hands as in applauding, did the movement of clapping only with the right hand and then, when confronted with the lack of any clap sound, said they did not want to make noise in a hospital environment. In a case of somatoparaphrenia [44], the patient, after a right hemisphere stroke, was convinced that her sister's hand was in her hospital bed and described it as hard and unable to move. When asked to give a rational explanation, she admitted that "strange things happen in the subconscious mind." Other instances that are encountered in a clinical setting are those of the alien hand syndrome, a neuropsychological disorder in which the person experiences that one hand does not obey, as if it was operating with a mind of its own. Those cases are either due to callosal lesions or lesions of the pre-SMA

contralateral to the affected limb [45, 46]. These patients both grope and grasp objects with the affected hand, while at the same time trying to stop the unwanted movement with the intact hand and turn the page of a book with one hand while they go back to the previous page with the other hand. Another patient with the same syndrome was accompanying one of the authors (JG) down a laboratory hallway and reached up with one hand to pull a cord to turn on a hall decontaminant shower while the other hand grabbed at the alien hand to prevent it from pulling the cord.

In summary, either because of brain lesions or by non-invasive brain stimulation, we can observe a double dissociation between what we do and what we feel we have done. There are examples of *actions without agency*, as in the alien hand syndrome or during hypnotic experiences, and examples of *illusionary agency*, i.e., situations in which people have the feeling that they are doing something when they are not as in asomatognosia. Based on this double dissociation, one can argue that the brain has networks distinguishing between the will to do something and the action itself. Accordingly, the separation of the neural substrate that allows conscious will and action can also be present in the everyday life of people without brain lesions. This is the foundation of the theory of *apparent mental causation* [7, 47], which suggests that conscious will is experienced whenever we can draw the inference that our thought has caused our action, whether this inference is correct or not. This can occur in accordance with the principles of priority, consistency, and exclusivity. Then, we experience conscious will and ascribe authorship to ourselves for an action when the thought of an act appears in consciousness just before an action (*priority*) is *consistent* with the action and is not accompanied by conspicuous alternative causes of the action (*exclusivity*).

Some authors [9, 10] have interpreted the theory of apparent mental causation as suggesting that the sense of ourselves as agents and authors of our actions is an illusion that concerns and permeates all our actions in the world so that we are not free and morally responsible in the way we think we are. Nahmias [48] refuted this interpretation on strictly logical-philosophical grounds. Daniel Wegner, the major proponent of it, says that he did not intend that conscious thought cannot cause actions (Wegner [47], page 68), and indeed, it is different to propose that some actions are done automatically, with little or no conscious control, or that the illusion of self-agency concerns every human decision; thereby, we are not morally responsible of what we do or what we think. Kihlstrom [49] noted that Wegner's many examples of illusory involuntariness do not warrant the conclusion that the experience of voluntariness is also an illusion.

We should be careful to distinguish between the cause of an action and its reason. A decision is the deed the fills the gap between a possible reason and the consequent action. The distinction between reason and cause is inextricably linked to the distinction between voluntary action and a mere event. All voluntary actions are also events, but the reverse is not true. There is a difference between falling asleep and letting sleep motivate you to go to sleep [50]. A motivated action can be deliberate or not: we can distinguish between *impulsive actions*, like running away in fear; *spontaneous actions*, such as avoiding an obstacle when walking; routine actions, such as washing and dressing in the morning before going to work; actions that involve an *implicit decision*, when we interrupt what we were doing because of being attracted by something or someone else; and finally those involving an *explicit decision*, sometimes deliberations, like when we decide the amount to save for the education of our children. The role of consciousness can vary according to the type of voluntary actions. Yet, nothing demonstrates that if we could control a given set of factors that shapes one's personality, we could predict people's decision. In this probabilistic domain, there is a place for human will even if it would be a misnomer to claim this will is completely free, as what we can want depends also on our sensory-motor limits, our personality, and on the environment.

However, take the example of the driver queuing on the highway, who applies the brake to avoid hitting the car in front of his car that suddenly and unexpectedly slows down. Stepping on the brake pedal is an automatic movement, but the efficacy of applying the brake depends on habits and decisions that characterize the driving style of the driver. Such habits include a general attitude to drive with caution or recklessness, procedures like devoting most attentional resources to driving while refraining from texting over the cell phone or avoid to engaging in an argument during driving. In this context, there is no firm boundary between automatic and effortful actions.

One can argue that both habits and decisions are influenced by an individual's personality traits that in turn are biased by genetics and environment (a broad term that includes education, social background, and personal experiences). Do we think that despite all the multiple factors that might influence the driver's behavior there is space for his responsibility in hitting or not hitting the car in front of him? In real life, we all believe that yes, the driver is at least partly responsible. Indeed, even in this case, in which the ultimate cause was definitively an automatic movement, we would be hesitant to accept the lack of freedom of choice as a plausible reason for what happened. Is there empirical evidence that a person cannot change his disposition and hence, for example, his driving style? And how could he take the responsibility for the effect of his driving if he were not at least in part free? We think that Free Will and personal responsibility, in this, as in similar cases, cannot be denied

but should be evaluated in relationship with all the factors that might have influenced the person's behavior.

In sum, there is no evidence that our will is fully determined by the laws of nature. Also, there is no evidence against the will linking the reason of an action with its deed. Therefore, the theory of the apparent mental causation operates in a restricted space: that of actions requiring only a limited integrative role of consciousness (e.g., automatic, impulsive, spontaneous, and habitual actions).

Consciousness

Given that Free Will usually involves a conscious decision, understanding the boundaries of conscious information processing becomes important for characterizing Free Will. Consciousness is a word that encompasses a wide range of seemingly related meanings, from the basic "awareness of environment," which would include unicellular organisms, to the more complex "awareness of awareness" that would leave out great apes and human infants. Consciousness provides the window in which we make intentional and willed decisions. For the sake of simplicity, we use consciousness when information is accessible to us for reasoning and controlling behavior. However, if we consider all the different situations that we undergo in everyday life (e.g., sleep and dreaming) and those conditions in which consciousness is impaired or disrupted (e.g., coma, general anesthesia, seizures, disorientation, loss of movements to painful stimuli), we can conclude that consciousness varies along a continuum according to at least two dimensions: wakefulness and awareness.

Theories that view consciousness as an emerging property of the brain usually assume that local states of consciousness may involve different degrees of integration and different impact on the processes of decision-making (i.e., spatio-temporal, multisensory, semantic integration, and integration of novel information). Usually, the more complex or novel the stimuli, the more likely consciousness will be needed for integration to occur, but there is no absolute dependency of integration on consciousness [51]. Indeed, there can be consciousness without Free Will, but it is generally recognized that Free Will requires consciousness. But consciousness is not enough: a Free Will scenario requires the possibility to envisage alternative courses of events (*freedom of imagination*), the ability to weigh reasons to choose among alternatives (*freedom of evaluation*), the possibility to decide and intend an action (*freedom of decision or will*), and the freedom to cause, control, and execute an action to carry through the decision (*freedom of execution*) [52]. The examination of consciousness in the context of Free Will is simply describing the workspace within which "free" will operates.

Freedom and its limits

Freedom of imagination and its limits

Imagine that you are driving the usual path from your office to home. You know that before getting home, you have planned to stop by your friend's home to discuss with her a common project. You have driven the road between your house and hers many times, and you do not consider that you might take a more direct route. In this case, you have not consciously envisioned an alternative course of action, so freedom does not come into play. This conclusion would apply whenever you are told to behave in a certain way without considering that you might have done otherwise. To have freedom of imagination is to be conscious that you had a choice. A positive example of freedom of imagination is human creativity. One of the most complex and intriguing forms of creativity is musical improvisation where new music is produced in real-time as in improvisation. A recent study [53] explored whole-brain functional network connectivity from fMRI data during jazz music improvisation compared with a pre-learned score performance. Results demonstrated that a state of *weak* connectivity is associated with a feeling of "flow" allowing unhindered musical creation. In other words, human creativity, i.e., freedom of imagination, is enhanced with attenuated executive control.

Freedom of evaluation and unconscious bias

Mudrik et al. [54] have provided an extensive review of the typology of threats to Free Will due to unconscious influences on decision making. They include the effects of *framing information* on a subsequent decision, the *nudging effect* by which components of the decision process (the alternatives, the outcomes, or the correspondence between them) can be presented in ways that favor a specific choice, the racial, gender and facial appearance stereotypes, and the *physiological and psychological state* of who is deciding (e.g., fatigue, hunger, sleep deprivation, and mood). Unconscious biases are instantiated in our brains at an early age and influence how we make choices, particularly in ambiguous circumstances when rapid responses are required.

If a person never considers the reason why he should choose one action over others, he has lost the capacity for freely evaluating a subsequent choice. As both control and reason-responsiveness vary in degree from person to person and in different contexts, we can posit that the apparent freedom of our will can also vary. Thus, the notion that Free Will has constraints that may or not be overcome by conscious deliberation helps to shape further research on what determines our moral responsibility as agents.

Freedom of decisions and constraints that limit it

Our freedom is dependent upon personal, environmental, and social constraints. In turn, constraints can be absolute or relative. Absolute personal constraints are those dependent on our body's physiology. Relative personal constraints depend on the role of the genomic influences on our personality and character, our social skills, learned beliefs, and the culture we find ourselves in.

There is abundant evidence that personality traits are substantially influenced by genes. Current models propose that personality is instantiated in the brain, distally caused by genes and environment. Human personality is 30–60% heritable according to twin and adoption studies [55], confirmed by the Genome Wide Association Study (GWAS) of the Finnish population and replicated in Korean and German samples [56]. The effects of genetic constitution on behavior have been recognized as extenuating factors in sentencing homicide cases. In the USA, a case that caused quite a stir was that of the sentence concerning the case of Mr. Davis Bradley Waldroup, who, on the 26th of October 2006, had repeatedly attempted to kill his wife and had killed a female friend who was trying to defend her. Davis was charged with premeditated murder (first degree under American law) and attempted premeditated murder. The charges could have carried the death penalty (then in effect in the state of Tennessee). The ruling dropped the initial charge to non-premeditated murder (second degree) and attempted non-premeditated murder, sentencing Davis to 32 years in prison. This judgment acknowledged the expertise of Professor William Bernet, a forensic psychiatrist who had just published a paper on behavioral genetics in crime cases [57]. The murderer carried a mutation in the monoamine oxidase A (MAO-A) gene. MAO-A is the main enzyme involved in the metabolism of serotonin and norepinephrine. The Low MAO-A mutation causes a reduced expression of the enzyme and therefore higher concentrations of neurotransmitters that predispose a person not only to adventure and exploration but also to aggression. As a matter of fact, the tendency to develop violent behavior is relatively low in carriers of Low MAO-A mutation and does not differ from that of individuals who have high enzyme activity (High MAO-A), provided that the carriers grow up in a healthy and protective psychosocial environment. It is only when the environment is characterized by abuse and by serious situations of family and social hardship that the tendency to develop aggressive behaviors manifests itself more frequently (up to 85%) in Low MAO-A carriers [58]. That was the argument in the case of Davis Bradley Waldroup. Similarly, in 2009, an Italian court cut the sentence given to a convicted murderer by 1 year because he had the same gene mutation linked to violent behavior. This was the first time that behavioral genetics affected a sentence passed by a European court [59].

An individual's belief system is another kind of personal constraint that contributes to shaping our decisions. It includes political, religious, philosophical, and ideological attitudes or a combination of these. Typically, beliefs are not required to be true or false and do not exist in isolation in the mind of the believer. They belong to a system in the sense that they are related to each other.

As to political choices, conspiracy belief systems often have an outsized influence. A recent example is the QAnon movement that originated in the American far-right political sphere in 2017. The core QAnon theory is that a plot of satanic cannibalistic sexual abusers of children operating a global child sex trafficking ring conspired against former U.S. President Donald Trump during his term in office. QAnon conspiracy believers have named democratic politicians, Hollywood actors, high-ranking government officials, business tycoons, and medical experts as members of the plot. Without going into further details, QAnon followers have perpetrated acts of violence on numerous occasions, including their active participation in the attack to the US Capitol on January 6, 2021. Although some people articulating QAnon beliefs may have been cynically coopting them for their own political purposes, many people accepted them at face value. But by accepting the QAnon theory uncritically, it would not be surprising that a person would be pushed to make political choices congruent with this belief system, even if irrational. In all these cases, internal or external circumstances influence the person's choice limiting his choices and thus his will.

Freedom of execution

Executing an action does not depend only on our will. It depends also on the rules and laws of the society we live in. However, even the more strict and threatening rules of war can be overwhelmed by human will. "Ich schieße nicht, I don't shoot," said Josef Schulz, a German soldier who, during World War II, served as a corporal in the 714 Infantry Division of the Wehrmacht. He had been a capable artist and a member of an underground opposition to Hitler. On 20 July 1941, he refused to take part in the execution of 16 Yugoslav partisans and was shot himself [60]. Similar events have been reported elsewhere and testify to the freedom of the will even in the presence of the absolute obligation of obedience characteristic of military laws. However, these extreme examples can be also taken as a demonstration of the power of circumstances to prevent the execution of what has been called Free Will.

Conclusions

We summarize our thinking about the decision-making process required in willed decisions in the context of a journey in Fig. 1.

The question of Free Will does not refer to the possibility of acting without constraints, but to the scope of the human will, the nature of human decisions and choices. In real-life situations, we navigate between both personal and environmental constraints, including rules, laws, and dangers of different origins. This means that there is no absolute Free Will. Instead, freedom has limits based on genetic, physical, personal, environmental, and social constraints. It is freedom within a ring of constraints. However, this does not threaten the concept of choice, which is strongly dependent on the possibility to decide among alternatives even with constraints. Only in our imagination can absolute freedom potentially exist but again within the constraints of our imagination.

From a more general philosophical viewpoint, we have Free Will if we have alternative choices, no matter how numerous and persuasive the constraints. The sense of freedom in making choices is something that humans seem to have acquired during the development of human society. In Homer's time, during the Trojan War, the fighters made their decisions based on the suggestions of the gods. Then, gradually we built societies more and more based on individual freedom and personal responsibility.

In recent decades, an increasing number of neuroscientists have argued that Free Will is just an illusion, and that instead of being intentional authors of our life, we are simply pushed around by past events and by the unconscious working of our brain. We think that this position is due to the articulation of a strong version of determinism and reductionism. The task of explaining the functions of the mind naturally leads us to look for the neural basis that makes them possible. Groups of neurons, connections between different brain regions, synapses, and chemical neuromediators can be examined for their relevance to choosing. The basic idea behind rejecting the notion of Free Will is that if we can explain every action through a series of causal precedents, there is no space for Free Will, and indeed of our will tout court. But why we should reduce the search for causation to low-level neural or even atomic explanations? Higher-level forms of causation are just as real and as important [61]. Suppose that we wanted to explain the rules governing car traffic. We would not have an answer looking at the characteristics of the engines that propel the cars, but rather to the day of the week, the opening hours of offices and factories, weather conditions, the possibility of using alternative means of transport, and so on.

In conclusion, we do not know for sure whether determinism or indeterminism is true. Neuroscience, like any other human scientific effort, is looking for causes of the phenomena in its study domain. But causes do not need to be always searched for at the low level, and we do not need to abandon a deterministic standing if we look for them elsewhere. In behavioral sciences, we must deal with randomness and with human decisions. When studying human behavior and the interrelations of the nervous system and behavior, we can only count on probabilistic knowledge, not on compelling laws. This is often enough to build theories that can guide neurologists and neurosurgeons that get close to predicting the results of ablating a specific part of the brain or the effect of levodopa on a patient with Parkinson disease.

As we have seen, there are many constraints that can shape our decisions, but the role of our will in determining our future cannot be disregarded. The Free Will that we need is what gives us the political freedom to move about in a state governed by law and do what we want to do [61]. People who believe that there are "laws of nature" which

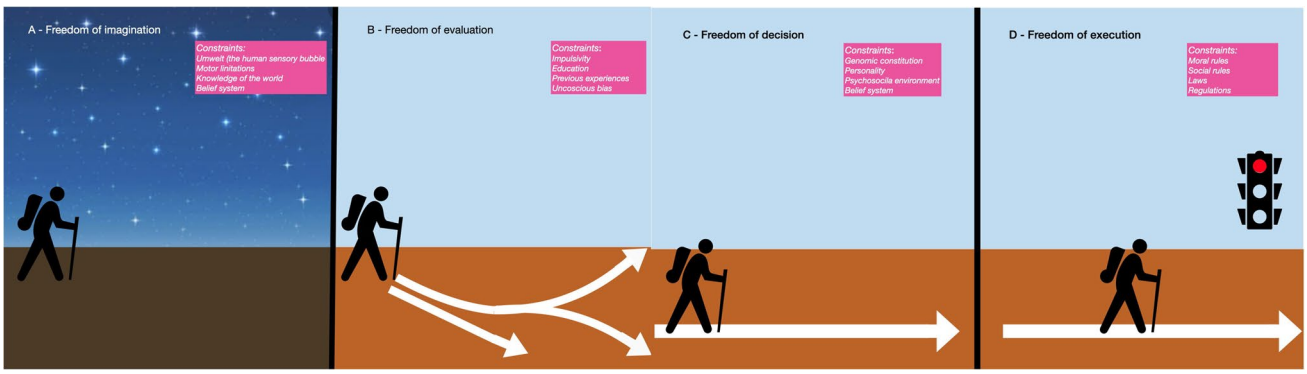

Fig. 1 The figure shows in four stages the limits to one's Free Will that a person who wants to start a long journey encounters from the moment she thinks of planning it: (**A**) freedom of imagination through the phase of evaluation (**B**) and decision (**C**) up to its execution (**D**)

cause every single human action should reflect that if this were true, it would apply to each preceding event, going back to the birth of the universe: the Big Bang. That logic appears a bit silly to us.

Free Will without constraints is an illusion. Yet, we are born to choose. And we do. The desire of control through choice and agency is an essential component of what it means to be human [62]. The freedom to choose when there are several constrained is an essential component of personal responsibility, that in turn is the foundation of human society. These choices become stored and strengthened in our brains over our lifetime and guides our behavioral responses denying complete Free Will but allowing us to make decisions even when the choices appear quite varied. Yet, these choices never approach the range of decisions and actions that can be created in our imagination or in a fictional or artificial world that is limited only by our creativity but not by the real-world constraints articulated above. So Free Will may be possible in fantasies whose narratives and images find a place in our brain but are rarely instantiated, even, when possible, in real life. Instead, in real life, our wills are corralled, and we move about within these boundaries, obeying the constraints that are imposed upon our will. Our will, even if corralled, retains the freedom of choice and, hence, the personal responsibility for our deeds and the individual merits of our achievements.

In conclusion, neuroscience cannot disprove the philosophical claim of Free Will, but it can have an important role in highlighting the factors that can push our choices in one or another direction.

Author contribution The authors contributed equally to this work.

Declarations

Ethical approval The paper reflects the authors' own research and analysis in a truthful and complete manner.

Conflict of interest The authors declare no competing interests.

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