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## THE NEUROBIOLOGY OF HUMAN WILL, SENSE OF AGENCY AND RESPONSIBILITY

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The majority of adult human beings have the feeling of being able to freely choose between several possible alternatives and to voluntarily control their actions. This is what philosophers and psychologists label free choice (*liberum arbitrium*) or free will. The development of neuroscience lately allowed for more precise explanations on the bodily phenomena related to free will and free action, namely to the impression one has that one has a choice to make and that one's conscious decision initiates one's actions.

### INTRODUCTION

The majority of adult human beings have the feeling of being able to freely choose between several possible alternatives and to voluntarily control their actions. This is what philosophers and psychologists label free choice (*liberum arbitrium*) or free will (Wegner, 2002).

The concept of free will thus generally refers to the capacity of rational agents to choose an action among several alternatives and, throughout history, it has also been closely related to both the concept of moral responsibility for one's own actions and the epistemic conditions of this responsibility such as being conscious of the possible alternative actions and of their moral significance. But, along the years, beyond rational deliberation and moral responsibility, free will has also involved other aspects such as free choice on the basis of desires and values, rightly ordered appetite, self-mastery, causation and control. Philosophers have also asserted possible differences between freedom of will and freedom of action as long as one can (or can-

not) attain one's goals not only due to the workings of free will, but also to external factors and constraints that are beyond one's control. Thus, it may happen that one can have free will, but not necessarily freedom of action as well. Without paying much attention to all these conceptual and practical differences, most scholars nowadays concentrate nonetheless on the question whether we "have" free will or not. And the main factors that are conceived as impeding our freedom of will are generally connected to physical, biological, psychological or theological deterministic views studied in detail by scholars doing research on compatibilism/incompatibilism, causal determinism, fatalism or divine foreknowledge.

Thus, the existence or absence of free will continued to be an important issue from the ancient period, when Democritus and the Stoics were denying the existence of free will on the basis of determinist philosophical positions until the contemporary period, when Albert Einstein quoted Schopenhauer's views: *Der Mensch kann was er will; er kann aber nicht wollen was er will* (The human being can do what he/she wants, but cannot will what he/she wants) (Epilogue, 1932). Both those who assert the existence of free will and those who deny it raise plausible arguments for their positions, but none of these manage to be compelling and the discussion on the existence or non-existence of free will continues (Geyer, 2016).

At any rate, despite the pessimism of the determinists regarding our free will, our capacity to act voluntarily is nevertheless fundamental for our existence. For this reason, social coercion under the form of prohibition or prison sentence must be rig-

ously justified and regulated. Defects of the capacity to act voluntarily appear in psychoses or abulia (the absence of willpower and the incapacity to proceed from idea to act) (Blakemore et al., 2002). But, even if the will is so important, it is nevertheless quite difficult to explain what is particularly characteristic for voluntary action. Our usual language suggests a dualist perspective of endogenous causality for voluntary action: "I" consciously choose to act and "my" choice causes the action in a certain manner. Especially for dualists who conceive mind and body as being separated, this language may be dual, involving the existence of a mental "I" that is different from the brain and the rest of the body, although it can generate events in the brain and movements of the body (actions). And here the development of neuroscience lately allowed for more precise explanations on the bodily phenomena related to free will and free action, namely to the impression one has that one has a choice to make and that one's conscious decision initiates one's actions.

### **VOLUNTARY ACTION VS. REFLEX**

Quite a satisfactory scientific approach defines voluntary action in opposition to the action generated by a stimulus. One can thus oppose voluntary action to a simple reflex. A reflex is an immediate motor response and its form is determined by its specific type of stimulus while the appearance and the form of a voluntary action is not directly determined by an external identifiable stimulus or is only indirectly determined by it (Haggard, 2008). Voluntary action is thus "free from immediacy", as Shadlen (2004) put it. Moreover, voluntary action involves the cerebral cortex while some of the reflexes involve exclusively the spinal cord. Finally, the will matures late in the development of the individual while the reflexes can be present at birth or even before that.

Furthermore, voluntary actions involve two types of subjective experiences that are generally absent in reflexes. First, there is the subjective experience of "intention" (to plan or nearly act) and the subjective experience of "agency" (the feeling one has that one's action produced an external event). For instance, when one presses a button to turn the light on and a bulb is lit, one attributes this

change to the action performed and receives confirmation that it generated a modification in the immediate environment. If a movement is generated by a reflex (e.g. the patellar reflex), the subjective experiences of intention and agency do not appear. But if we accept the idea of a continuum between reflexes and voluntary actions, we need to identify intermediary cases as well. For instance, both humans and animals easily learn to associate motor responses with arbitrary sensorial stimuli such as the red or green traffic lights that indicate "stop" and "go". The moment and the type of action are determined by the stimulus when a person crosses the street at the green light. But this action does not always happen when the green light appears. This depends on the person having a reason to cross the street or not. Thus, the response to the external stimuli generally has characteristics of both reflexes and voluntary actions. Associative cortex development in recent evolution allows not only for direct connection between the motor response and the stimuli, but also for conditioned, flexible connection to relevant stimuli for each individual (Haggard, 2008).

### **MEASUREMENTS AND EXPERIMENTS REGARDING HUMAN WILL**

Without a direct dependence of the voluntary action on the stimulus, the experimental study of this phenomenon is difficult. In order to avoid this difficulty, the experimental studies on human subjects are generally based on instructions that only partially determine what is required from the subjects. Thus, the subject can choose when to execute an action that was proposed to him/her, or he/she can choose a certain action out of a number of possible actions; he/she can also decide whether to act or not to act at all. In such experimental conditions, it can surely be objected that the subject is not motivated to choose one alternative or another. This situation can influence the subject, who can consider that the experimental requirement is to randomize the answer (namely, to answer at random).

Even nowadays the experimental research of voluntary action is dominated by the "Libet experiment" (1983). In this experiment, the participant was requested to do a simple voluntary action (e.g. to press a button) when he/she wanted to. Simultane-

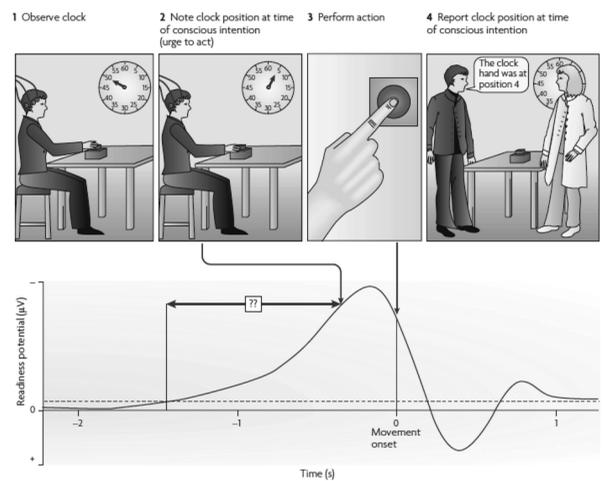
ously, his/her cerebral activity was measured through EEG or fMRI and the initiation of muscular contraction through electromyography (EMG). The subject had to follow the hand of a clock that rotated with a certain speed (one rotation in 2,56 seconds) and he/she had to report the position of the clock hand at the moment he/she felt the conscious intention to press the button. This temporal parameter was considered a marker of the will (W). The EEG activity measured in the frontal motor areas started one second or even earlier than the movement (the so-called readiness potential, with an amplitude of a few  $\mu\text{V}$ ) while the moment W appeared later (a few hundred ms before the movement started – Fig. 1). The maximum readiness potential could be registered at the level of the vertex point on the skull. The small amplitude when compared to the EEG waves required an EEG signal mediation. For this procedure, a synchroniser was needed in order to coordinate the zero moments from all the tracks registered. Libet used the moment when the EMG started for track synchronisation and the temporal sequence he discovered was: readiness potential, W, and EMG signal.

The results obtained lead to a few important questions regarding the cerebral events that initiate voluntary actions, the causal chain of neural activation, and the relationship between these phenomena and consciousness. Libet and his collaborators considered that subconscious cerebral processes initiated voluntary actions before the emergence of conscious attention. They also supposed that volitional conscious control did not operate in order to initiate the process of willing, but to control the realisation or, on the contrary, the suprimation of the final motor response initiated by subconscious processes. The conscious volitional control would thus express a "veto" regarding motor activation.

The experimental paradigm introduced by Libet was modernized by Haynes and his collaborators (Soon, 2013), who measured cerebral activation through fMRI, on the one hand, and through more complex and abstract tasks given to the subject, on the other hand. The subject could thus choose whether he/she added or deduced two given numbers. The percentage of successful predictions was 60% – not a very high one, but still beyond the 50% equal chances level. During this experiment, there were activations in the medial frontal cortex and

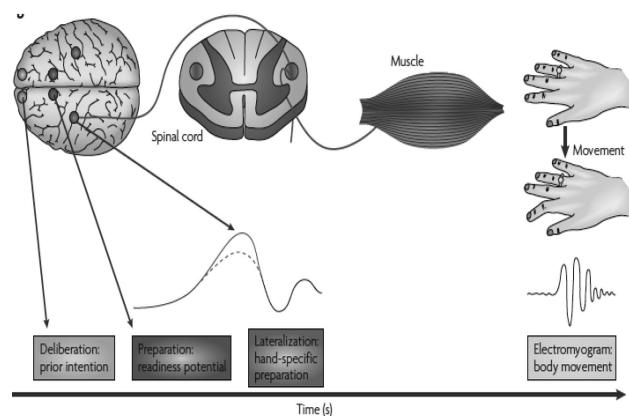
the posterior cingulate cortex before the choice having become conscious. After the choice, there were activations in the angular girus (Fig. 1).

A more precise and easily quantifiable construct that may be studied experimentally is the voluntary action that can be placed at the other end of the spectrum when compared to a simple reflex. Haggard (2008) emphasised the lateralization of the readiness potential, which is larger in the contralateral cerebral hemisphere that controls the movement of the ipsilateral hand. On the basis of this difference of amplitude of the readiness potential, one can predict which hand will be moved (Fig. 2).



**FIGURE 1.** Libet's experiment seems to disprove the existence of free conscious will. The participant looks at the hand of a clock while having his/her cerebral activity in the frontal motor areas recorded through EEG. He/she can move his/her finger when he/she chooses to. He/she is required to remember the position of the clock hand at the moment he/she felt the intention to act. On average, the participants reported the appearance of the conscious intention to act 206 ms before the beginning of the muscular contraction. However, the preparatory cerebral activity started one or more seconds before the beginning of movement. Thus, the preparation of the action in the brain starts before the moment in which the subject becomes conscious of his/her intention to act. Source: Haggard, 2008

Another category of studies on volitional action are the observations made during the marking of various functional areas which must be avoided in brain surgery of patients with epilepsy, that is not responsive to medication (Fried et al., 2011). The evaluation is done through the insertion of depth electrodes in the cortical tissue.



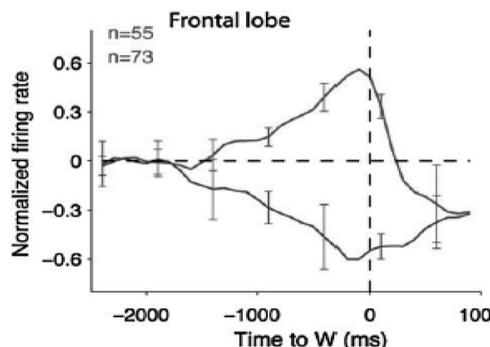
**FIGURE 2.** Cerebral activity preceding the movement of the right hand. Frontopolar cortex (green) initiates long-term plans and intentions and deliberates on them. The preSMA area (red) starts the preparation for action: together with the premotor area, it generates the readiness potential (red curve) that can be recorded through EEG. In the next phase of the readiness potential, the collateral hemisphere is more active than the ipsilateral one. This is reflected in the difference of amplitude between the readiness potentials registered on the two hemispheres (blue continuous and discontinuous curves). The motor area (blue) becomes active for a very short time before the execution of action. Then the neural signals are transmitted to the spinal cord and to the contralateral hand muscle. Muscular contraction can be registered as an electrical signal through electromyography (EMG).

Source: Haggard, 2008

On this occasion, one can register the activity of certain neurons in people who are awake and whose behaviour can also be monitored in parallel. The stimulation of the frontal medial area induces the need to move a certain part of the body without this movement being produced in each and every case. These neurons generate a potential that reproduces the readiness potential highlighted by Libet and these results suggest that conscious intention to act is the subjective corollary of an ongoing action. The explicative model shows that a voluntary act starts at the unconscious level and becomes conscious when the activity of the neurons from the medial frontal cortex reaches a certain level of activation. Fried's study (2011) evidenced a second interesting phenomenon: near the moment of decision making towards an action, two types of neural response appear in the supplementary motor area (SMA): either an increase of the neural activation or a decrease of it (Fig. 3).

The neurons with a decreased activation near the W moment could be involved in the inhibition of the volitional action. Libet also suggested the existence of "veto"-type decisions. The decision to

act or not can be an important component of the volitional act. The neurons with a decreasing activation could exercise tonic inhibition regarding the onset of an action until the moment it becomes useful and the same inhibitory neurons can contribute to the onset of voluntary action by reducing this tonic inhibition. Thus, a competitive interaction between activating and inhibiting neurons could create a circuit that could decide whether the action is to be done or not.

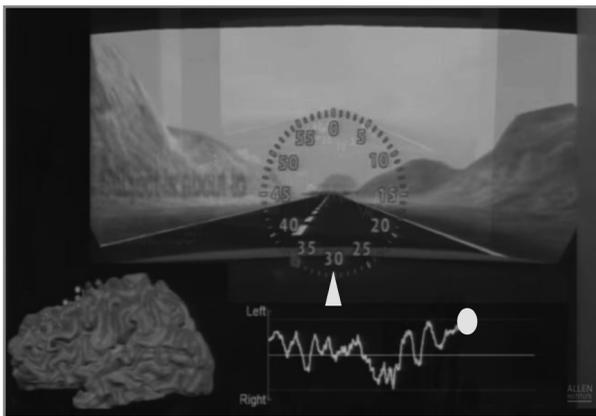


**FIGURE 3.** The response of the neurons in the frontal lobe before the W moment of becoming conscious of one's intention to act voluntarily. The activation of some neurons is higher when approaching the W moment (---), while the activation of other neurons is significantly lower when approaching the W moment (—). Source: Fried, 2011

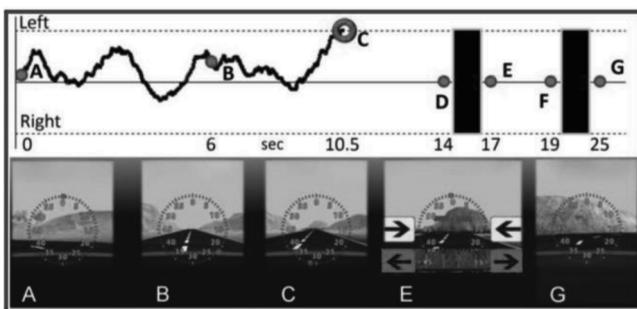
Another remarkable result of Fried's research is the fact that the mode of activation of a population of 256 neurons from the supplementary motor area turned out to be sufficient for the prediction of the moment in which the decision to move was made as well as the direction of this movement (right or left). Predictions can be made with 700 ms to a few seconds before the W moment (Soon et al., 2014). These results suggest that the subjective experience of will appears as a corollary of the pre-motor activity, an activity that begins a few hundred ms before one becoming conscious of his/her intention or will.

A more ecological experiment, that is, one that is nearer the real life, was done on a subject driving a virtual car (Perez et al. 2015). The goal of this experiment was to separate the act of decision-making from the motor plan which will realise the decided action. Through electrocortigraphy (EcoG) one can measure the gamma waves. When these go beyond a certain level, they allow for the prediction of the subject's decision before he/she is conscious of this decision (Fig. 4). Separating decision from the motor plan was achieved through instructions re-

garding the motor action that had to be done, which were given after the moment of decision content decoding (Fig. 5). Instructions were related to the hand that had to press the button corresponding to the chosen direction: if the congruent arrows (marked with pink in Fig. 5) appeared, the subject would press the right hand button with the right hand or the left hand button with the left hand; if the arrows indicating a reverse (marked with yellow in Fig. 5) appeared, the motor command was reversed – for instance, the left-hand button was pressed with the right hand.



**FIGURE 4.** An experiment done in more natural conditions allows for the prediction of the direction the driver will choose (right or left at the crossroads) and separates the content of the decision from the motor plan to press the button. On the panel placed on the wind-screen of the car, the yellow arrow indicates the moment in which the subject decodes the prediction and the red dot indicates the moment in which he/she becomes conscious of his/her decision. Source: Perez, 2015

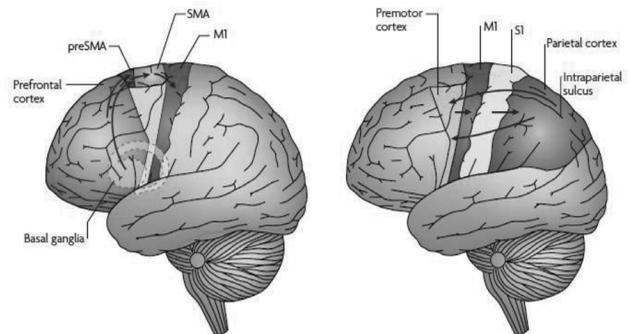


**FIGURE 5.** The experiment allows for the decoding of decision on the basis of the amplitude of the gamma waves. Thus, the different stages of the experiment allow for the decoding of the patient's decision by following the support vector classification on the basis of the gamma amplitude as registered by two electrodes placed in the frontal cortex (Brodmann 8 and 9 areas). Source: Perez, 2015

### Cerebral circuits involved in voluntary action

A few distinct motor circuits that contribute to volitional action have been highlighted both in the

human and in the primate brain. These circuits converge towards the primary motor cortex (M1), which has an executive function in motor commands through the transmission of commands to the spinal cord and then to the muscles. Out of this reason, the M1 area is considered a final common path for voluntary action. The M1 area receives impulses from the basal ganglia through the pre-supplementary motor area (preSMA) (Fig. 6).



**FIGURE 6.** The cerebral circuits involved in voluntary actions: a) Primary motor cortex (M1) receives two categories of input. The first circuit (left) starts in the basal ganglia and in the frontal area, from where the impulses get to the pre-supplementary motor area (preSMA) and then, through the SMA, to the M1. In the second cerebral circuit (right), information from the primary sensory areas (S1) reaches the parietal cortex and then the premotor cortex to finally get to the primary motor cortex (M1). By using sensory information, this parietal-premotor circuit, guides the actions that are oriented towards an object such as grasping something. Source: Haggard, 2008

But the preSMA is also included in a larger cognitive-motor circuit, which also includes the premotor cortex, the cingulate cortex and the frontopolar cortex. Through EEG, the source of the initial phase of the readiness potential was localised in the preSMA. This phase is continued with a cascade of neural events that propagate from the preSMA back to the SMA (supplementary motor area) and M1 and finally produce movement.

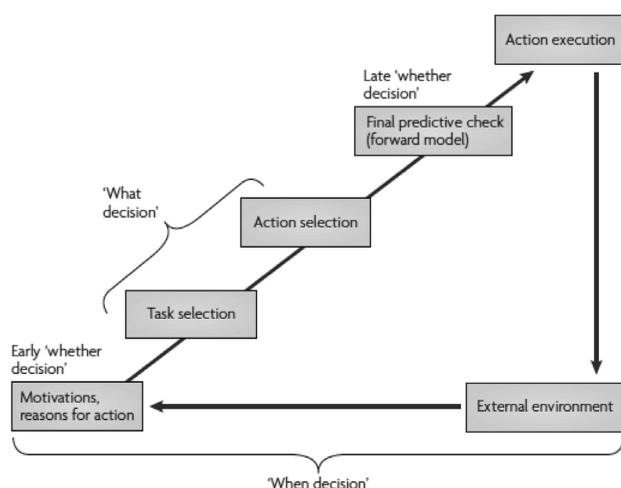
The subcortical loop that includes the basal ganglia integrates a series of cortical signals with dopaminergic signals that have their origins in the substantia nigra. This loop can modulate intention according to the reward signaling information. We can thus consider voluntary action rather as a flexible and intelligent interaction with the current and historical context of the body, than as an initiation of action without a neural cause.

A second cortical circuit converging towards the M1 motor area is involved in the sensory guidance

of actions. Within this circuit, the information in the primary sensory areas (S1) reaches the parietal cortex, then the premotor cortex and then the primary motor cortex (M1). While using sensory information, this parietal-premotor circuit, guides actions oriented towards a specific object such as grasping the respective object. Research done on neurons from the lateral intraparietal area (LIP) in primates indicate that these neurons encode the choice done by the animal when it is confronted with two alternatives that have the same reward value. Thus, when immediate action is necessary, the parieto-motor circuit arbitrates between alternative actions, but in the absence of emergency, the basal ganglia-preSMA circuit is primarily involved in the initiation of action. Thus, the two cerebral circuits seem to be involved in decisions of different types that are both relevant for human will (Haggard, 2008).

#### A functional model of volitional action

Volitional action can be described as a series of decision making processes that each determine the details of an action. The "if-decision", whether an action is to be pursued, has two components, an early, motivational one and a late one, with a role of final control. The "which-decision" establishes the goal or the task that needs to be done (the goal or task selection) and then the action that can help to attain the goal and do the task (action selection). The moment when the action will be done depends on environment circumstances and on internal motivation, but an explicit "when-decision" is not always necessary (Fig.7). We will describe these types of decision in what follows.



**FIGURA 7.** Functional model of the volitional action.  
Source: Haggard, 2008

#### The early "if-decision"

If the necessities of an individual are satisfied and the current stimuli are correctly processed, the responses will be routine ones. In this case, the person's behaviour can be described without any recourse to his/ her will. If new actions are nevertheless initiated or the routine type of action is modified, the brain generates information through a series of hierarchically organised decisions, as presented in Fig. 4. The needs, wishes and other reasons to act have an important role in this early decision. Voluntary actions appear when the routine processing of the stimuli does not furnish sufficient information in order to determine an answer; for instance, when an ambiguous stimulus does not permit the selection of an action out of two possible alternatives. Voluntary actions can also appear when new reasons for action appear: be it a manifested basal need such as hunger or a new wish – e.g. the wish to help somebody who suffers. In such situations, voluntary action will temporarily suspend the routine control, which is based on stimuli, and will shift this control of the motor apparatus from the sensorial entry to the volitional entry. A behavioural clue for the existence of this shift is the fact that the reaction time for a voluntarily prepared movement is longer than the one for a spontaneous movement of the same type (Obhi et al., 2004).

#### The "which-decision": selection of goal and action

Human beings generally have several simultaneous goals, but voluntary actions are done in a certain order. Thus, people have to plan the achievement of goals and select among them. The decision among different actions that can achieve the selected goal seems to involve the frontal cortex. This fact is suggested by the study of patients with frontal lesions who suffer from the syndrom of the anarchic hand (in which a unilateral frontal lesion produces the autonomous reaction of the contralateral hand when diverse stimuli appear, although the patient declares that he/she does not want to make that movement) (Della Sala et al., 1991). Lesions in the preSMA cortex produce hyperexcitability due to the fact that this area is involved in the suppression of the automatic responses to stimuli from the environment if these are somewhat irrelevant for the person. It is the case of patients with compul-

sive behaviour of using any kind of objects around them, whether they are useful for them or not.

A computational model suggests that the goal selection circuit and the action selection circuit are related (Koechlin et al., 2007). The frontopolar cortex implements the goal selection through the deviation of motor control towards the task with a higher reward value.

*The late "if-decision": A predictive final control and a possible veto*

The "which-decision" generates information that activates certain motor outputs. However, the details of these outputs are not predictable in the early phase of the "if-decision". Moreover, other cerebral circuits can independently generate information about the selected action; the synthesis of all the influences can be thus obtained later. The cost of the selected action can turn out to be too big, or it may be a weak means to attain the goal, or the outer context may have been modified in comparison to the moment of the early decision. Out of these reasons, it is advantageous to have a final control before the motor command is generated. In a model of visual guiding of a grasping movement, the control is achieved through the comparison between the result of a forward type predictive model and the description of the selected goal; the motor command is adjusted according to the difference between these two parameters. But the same control process can be used not only for adjusting an action, but also for completely suspending an action (veto). fMRI studies on participants in experiments in which the subjects are required to initiate or suspend some actions showed a more intense activation of the frontomedian anterior cortex (rostral in comparison to the preSMA) in the cases of action suppression (veto). This activation could be the neural correlate of the late "if-decision". Such decisions can have an important role in self-control. Moreover, the existence of these late decisions could allow for the preparation of some voluntary actions that could be simulated, but not also performed. The same study also showed an anterior insula activation, a fact that suggests the affective response to the intention that was not finalised through action (Brass et al., 2007).

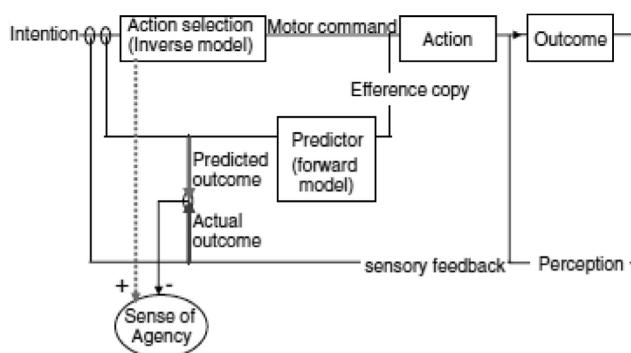
**Will, consciousness and the sense of agency**

Voluntary actions are accompanied by specific subjective experiences. The experience one has

when performing a voluntary action is different from the experience one has when passively moving a part of one's body when an external force is applied. Conscious intention to perform an action seems to be the very cause of the action. However, the majority of the neuroscientists doubt this idea, which derives from the fact that people first subjectively feel the intention to perform an action and then perform the movement. This idea involves the existence of the so-called „ghost in the machine" (Ryle, 2000).

Wegner (2013), for instance, considers that the human mind postulates a causal way from the conscious intention to act towards the action itself in order to explain the temporal correlation between the two events. But he thinks that the correlation appears due to the fact that both the conscious intention and the action have a common cause, which is the neural readiness for action. Thus, both events could rather be the consequences of the previous cerebral activity.

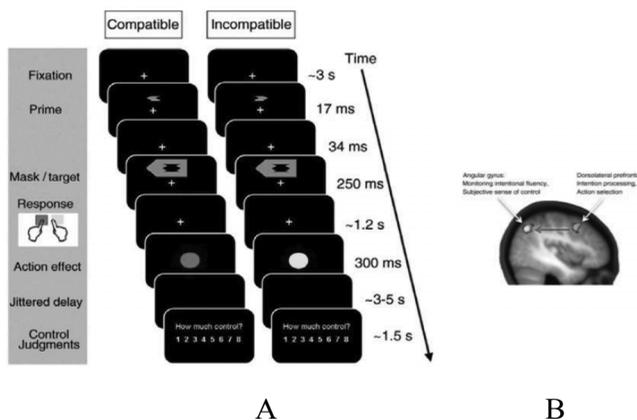
Alongside the subjective experience of intention, voluntary actions often generate the subjective experience of being an agent, namely the experience of the fact that a person's voluntary actions generate specific events in the outer world. One can speak of a sixth sense – the sense of agency (Haggard, 2012) – as we speak about the sense of sight, hearing, etc. The importance of the sense of agency, namely of being able to control one's actions, is obvious in cases in which abnormalities of this mental capacity appear. For instance, psychotic patients often report that their actions are not freely done by themselves, but are imposed or commanded by other real or imaginary beings. Depressive persons often feel helpless and unable to be agents, that is to control what they are doing (Haggard et al., 2012). The calculus made by the brain in order to generate the feeling of being an agent is made through the predictions of the consequences of the actions performed compared to the real results of the actions (Fig. 8). That means that a prospective signal (the intention to achieve a goal) is compared to a retrospective signal (the result of the action transmitted through a feed-back path). A feed-forward path uses a copy of the motor command (the efferent copy) in order to predict the result produced by the action. If the comparison between the prediction and the result does not generate an error, the sense of agency (I did this) appears.



**FIGURE 8.** Sense of agency. Computational model of the motor control and of the subjective experience of the subject. Manifesting one’s intention involves a motor command. The forward-path predicts the result of the motor command and this is compared to the result reported by the sensorial feedback. The prospective signal (red) is compared to the retrospective one (blue). A zero error given by the comparator corresponds to the sense of agency, that is of controlling one’s own actions. A second prospective signal generated during the selection of the action directly contributes to the sense of agency (the red discontinuous line). An easy and fluent selection of the suitable action generates a more intense sense of agency. Source: Haggard 2012.

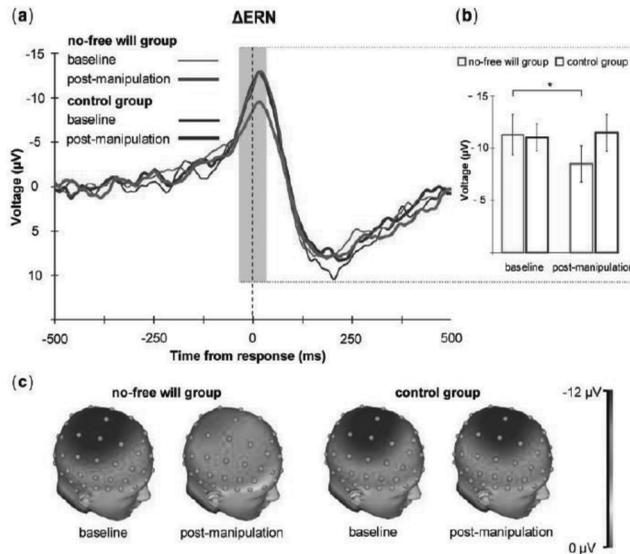
There are experimental data suggesting the fact that the sense of agency depends on prospective processes and does not represent a retrospective confabulation. The brain represents prospectively the result of an action before the action is produced. If the subjects are exposed to priming subliminal stimuli for a short time before the action is performed (Fig. 9) and these subliminal stimuli are either compatible or incompatible with the action (through the consequences produced by the action), it is observed that the subject reports a more intense sense of agency (namely to have control over the results of the action) in the first case, when there is a correspondence between the subliminal stimulus and the task stimulus presented (Chambon et al., 2013).

Studies of cerebral imagery done on subjects that perform the experiment described above indicate an activation of the angular gyrus in the parietal cortex when the subjects lack the sense of agency. The activation of the neurons in the angular gyrus raises proportionally with the decrease of the intensity in the sense of agency, that is of controlling the action. This result suggests that this area either functions as a comparator or receives the error signal generated in another area of the brain (Haggard et al., 2012). In this respect, it is interesting that the activation of the angular gyrus is negatively correlated with the sense of agency in the experimental priming alternative that is incompatible with the task ascribed to the participant in the experiment. In the priming alternative that is compatible with the task the angular gyrus is not activated. It can thus be supposed that the sense of agency, that is of controlling the action, reflects the basic state of the cerebral circuit in selecting the action while the lack of this sense of agency, that is of losing control, reflects the activity of the angular gyrus, which monitors the conflicts between the frontal mechanisms of action selection. When seeing things in this light, the experience of agency could be a form of “metacognition”, namely conscious experience that describes the efficacy of the action selection. The utility of this type of experience would be that the presence of the sense of agency, which corresponds to an effortless choice, guides human behaviour. On the contrary, the absence of the sense of agency can determine a slower cerebral activity and the shift towards a more attentive super-control strategy when the routine activity needs to be replaced with an innovating action.



**FIGURE 9.** A) Subliminal priming influences the sense of agency, that is the capacity of controlling the result of an action. The participant in the experiment has to press one of the two buttons (right/left) in order to answer the task request. If short subliminal stimuli are projected before the presentation of the task and these stimuli indicate either the task direction or the opposed one, the subject reports a more intense sense of agency, that is of controlling the result of the action, in the first case, when the direction of the subliminal stimulus coincides with that of the task. The result of the action is the appearance of a red or yellow circle, these colours corresponding to the direction indicated by the subliminal stimulus. B) A possible circuit that leads to the sense of agency. The dorsolateral prefrontal cortex selects among possible alternative actions. The angular gyrus in the parietal area monitors signals that indicate a conflict in the frontal area, which it interprets as a reduced sense of agency, that is of having reduced control of the action. Source: Chambon et al., 2013

Studies of social psychology emphasise that persons being exposed to the idea that free will does not exist are more predisposed to asocial behaviour such as cheating and aggressivity (Vohs et al., 2008) or their prosocial and altruistic behaviour is reduced (Baumeister et al., 2009). Their conclusion is generally that the weakening of the individual trust in free will reduces the capacity of the individual to activate his/her self-control. Self-control is demanding and energy-consuming and the denial of free will reduces the disponibility to invest this energy in an action that is thus considered ineffective.



**FIGURE 10.** a) The evoked potential of error detection – ERN (error related negativity) recorded through the electrodes Fz, FCz and Cz, before and after the manipulation of the belief in the existence of free will. b) Chart presenting the ERN amplitude, which significantly decreased in the intellectually manipulated group. c) 3D topographic map representing the distribution of ERN amplitude in the two groups before and after the manipulation of the belief in the existence of free will. Source: Rigoni et al., 2015.

These behavioural modifications can be partially explained through modifications of the cerebral activity involved in monitoring error. This cognitive capacity is essential in identifying whether an answer is correct or incorrect and in adjusting behaviour accordingly (Rigoni et al., 2015). It was emphasised that reducing the belief in free will alters the neurophysiological correlate of the behavioural errors monitoring function. Measurements of the evoked potential (ERP) in fronto-central electrodes indicate the appearance of a negative potential correlated with the detection of error (error-related negativity – ERN) just before the mechanical answer and lasting up to 100 ms. This ERN has its

origin in the medial prefrontal cortex or in the supplementary motor area (Bonini et al., 2014). Applying the go/no go test to subjects divided into two groups (1. the group in which the idea that there is no free will was induced through certain readings and 2. the control group in which neutral readings were offered), it became clear that the ERN amplitude decreased in group 1 after the intellectual manipulation they were subjected to (Fig. 10).

### Responsibility for action

Neurobiology inclines towards considering will, free will and voluntary action as results of a cerebral action of information processing and not as a transcendental mental capacity. This point of view has important ethical implications regarding individual responsibility for one's actions. All human cultures propagate the conception that the individual is responsible for his/her actions in front of the society and this idea relies on the concept of free will – that is, on the idea that the individual can control its actions – and on the fact that being conscious of the actions one performs allows one to choose between good and bad actions. Thus, in law systems originating in the Roman law, a crime is the consequence of a physical accountable action (*actus reus = accountable action*) and the conscious experience of performing the action (*mens rea = accountable thought*).

The connections between conscious intention, physical action and responsibility raise many problems of interpretation and fine-tuning. Intention without action is sometimes sufficient in order to declare the responsibility of a person and sometimes not. For instance, it is considered that thought is not a crime. Somebody who wants to hit somebody else and renounces at the last moment is not considered accountable. In other situations, mentally preparing a criminal action can be sufficient for accountability even if the planned action is finally stalled, as it is the case of the recent terrorist attacks in Europe and elsewhere. Likewise, people performing actions without intention can be considered accountable or, on the contrary, unaccountable. For instance, an attack during sleepwalking or psychotic states does not involve responsibility, but society must surely take preventive action to limit noxious actions even in such cases.

The results of the neurobiological research bring several contributions to the fine-tuning of judgment

declaring the responsibility and, thus, the guilt of a person. The early "if-decision", based on reasons and appreciations regarding the action as well as the final control before the action is performed, are the most relevant for decisions on the responsibility of a person. On the contrary, decisions referring to how and when the actions are performed are less relevant. The brain of a person may sometimes decide on the actions to be performed, but culture and education provide strong signals that can be learned by the motor-cognitive cerebral circuits. A neuroscientific approach of human responsibility involves not only neural processes generating the will, but also cerebral systems providing the individual with the cognitive capacity to understand how society constrains individual will and how the individual can adapt in an advantageous manner to these constraints. Learning how the social brain and the cognitive-motor brain work together is essential for the clarification of the concept of responsibility or accountability for a planned or performed action.

Accordingly, as Edward Wilson (2012) points out, „we cannot avoid the issue of free will or free choice, which, according to some philosophers, makes us unique. It may be the product of the subconscious decisional centre in the brain, which may generate the illusion of an independent action in the central cortex. And the more convincingly the physical processes behind the will are highlighted

in scientific research, the less remains related to any exclusively mental phenomenon that could be intuitively labeled as free will. We are free as independent beings, but our decisions are not free from all the organic processes that created the brain and the mind of each of us. Thus, free will or free choice seem to ultimately be of a biological nature”.

In the same line of thought, the more nuanced view of W. Newsome proposes more precise and quantifiable constructs for the study of free will such as autonomy and self-determinacy. Newsome considers that, at least partially, behaviour is influenced not only by organic processes, but also by beliefs, values, memories, goals, aspirations and rational thoughts – all of these being entities that allow for predictions and manipulations. The two great systems that can be modulated are thus the emotional system and the rational one. These allow for several degrees of freedom in choosing behaviour and controlling it, but this freedom is indeed not total. Any decision is influenced by the combination of bottom-up emotional impulses and top-down rational control. We become freer only if we become conscious of the bottom-up influences (such as hunger, thirst, hormonal states, fear, anxiety, tendencies, prejudices) and exercise top-down control in order to free ourselves from them or at least to better fine-tune them:

<https://www.youtube.com/watch?v=Jzn2msnmPso>

## REFERENCES

1. **Baumeister R.F., Masicampo E.J., DeWall C.N.**, Prosocial benefits of feeling free: disbelief in free will increases aggression and reduces helpfulness, *Personality and Social Psychology Bull.*, 35, 260 (2009)
2. **Blakemore S., Wolpert D., Frith C.** Abnormalities in the awareness of action. *Trends Cogn.Sci.* 6, 237-242, 2002
3. **Bonini F., Burle B., Liegeois-Chauvel C., Regis G., Chauvel P., Vidal F.** Action monitoring and medial frontal cortex: leading role of supplementary motor area, *Science*, 343, (6173), 888, 2014
4. **Brass M., Haggard P.** To do or not to do: the neural signature of self-control, *J. Neurosci.*, 27, 9141-9145, 2007
5. **Chambon V., Wenke D., Fleming S.M., Prinz W., Haggard P.** An online neural substrate for sense of agency. *Cerebr.Cortex*, 23, 1031-1037, 2013
6. **Della Sala S., Marchetti C., Spinnler H.** Right-sided anarchic (alien) hand: a longitudinal study, *Neuropsychologia*, 29, 1113-1127, 1991
7. **Epilogue: A Socratic Dialogue, Interlocutors Einstein and Murphy**, In: M.Planck, *Where is Science Going*, Norton, New York, p. 201-213, 1932.
8. **Fried I., Mukamel R., Kreiman G.** Internally generated preactivation of single neurons in human medial frontal cortex predicts volition. *Neuron*, 69, 548-562, 2011
9. **Geyer C.** *Hirnforschung und Willensfreiheit*, Ed. Shurkamp, 9. Auflage, 2016
10. **Haggard P. Chambon V.** Sense of agency, *Current Biol.*, 22,10, R390-R392, 2012
11. **Haggard P.** Human volition: towards a neuroscience of will, *Nature Rev. Neurosci.*, 9, 934-946, 2008
12. **Koechlin E., Hyafil A.** Anterior prefrontal function and the limits of human decision making. *Science*, 318, 594-598, 2007
13. **Libet B., Gleason C.A., Wright E.W., Pearl D.K.** Time of conscious intention to act in relation to onset of cerebral activity (readiness potential). The unconscious initiation of a freely voluntary act. *Brain*, 106, 623-642, 1983
14. **Obhi S.S., Haggard P.** Internally generated and externally triggered actions are physically distinct and independently controlled, *Exp.Brain. Res.* 156, 518-523, 2004
15. **Perez O., Mukamel R., Tankus A., Rosenblatt J.D., Yeshurun Y., Fried I.** Preconscious prediction of a driver's decision using intracranial recordings, *J.Cogn. Neurosci.*, 27,8, 1492-1502, 2015
16. **Rigoni D., Pourtois G., Brass M.** „Why should I care?“ Challenging free will attenuates neural reaction to errors, *Scan*, 10, 260, 2015
17. **Ryle G.** *The concept of mind*, Univ. Chicago Press, 2000

18. **Shadlen M.N., Gold J.I.** in *The Cognitive Neuroscience*, ed.3, Ed. Gazzaniga MS, 1229-1241, *MIT Press*, 2004
19. **Soon C.S., Heb A.H., Bodeb S., Haynes J.D.** Predicting free choices for abstract intentions, *PNAS*, 110, 15, 6217–6222, 2013
20. **Soon C.S., Allefeld C., Bogler C., Heinze J., Haynes J.D.** Predictive brain signals best predict upcoming and not previous choices, *Frontiers in Psychol.*, 5, 406, 2014
21. **Vohs K.D., Schooler J.W.** The value of believing in free will: encouraging a belief in determinism increases cheating, *Psychol.Sci.*, 19, 49, 2008
22. **Wegner D.M.** *The Illusion of Conscious Will*, MIT Press, 2002
23. **Wilson E.O.** *The Social Conquest of Earth*, Liveright, 2012.