Master Degree Project

UNIVERSITY OF SKÖVDE

THE ANTECEDENTS OF FREE WILL –
THE IMPORTANCE OF CONCEPT HETEROGENEITY IN RESEARCH INTERPRETATION AND DISCUSSION

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Abstract

Scientific research on free will was started by Libet et al. (1982). They detected that the readiness potential (RP) proceeded urges with up to 350ms. One interpretation of the RP was that it represented motor planning. The research progress of antecedent brain activity in relation to conscious urges is investigated by looking at contemporary studies. How different assumptions and definitions of the free will concept influences interpretation of these studies is also discussed. The evidence is in favor that the RP is not representing motor planning. Antecedent activity has been detected with numerous technologies, most notably fMRI-classifiers which have been used to predict decisions in advance. Scrutiny of these results reveals that the experimental setups are dependent on time-locking trials which may construe the results. It is shown that predictions based on probabilistic antecedents can be interpreted in numerous ways. The review shows that free will positions differ from each other on several factors, such as whether free will is either-or or exists on a spectrum. Some notable positions are not dependent on antecedent activity at all. The notion of control is one of the pivotal factors deciding if a subject experience free will, not if they are the causer *per se.* Future discussion will be improved by systematizing the differences between the free will positions and communicating them clearly. Convergent evidence points at the explanatory model of free will being a cognitive feeling – A feeling which reports ownership over actions but does not cause them.

Keywords: Libet, readiness potential, fMRI classifier, free will

"Man is a deterministic device thrown into a probabilistic universe.
In this match, surprises are expected."
— Michael Lewis

"There is no sin unless through a man's own will,
and hence the reward when we do right things also of our own will."
— Augustine of Hippo

"Life is like a game of cards. The hand you are dealt is determinism;
the way you play it is free will."
— Jawaharlal Nehru

"A puppet is free as long as he loves his strings."
— Sam Harris

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1.0 Introduction - The Scientific Investigation of Free Will

Free will, as a concept, has a rich history, which can be traced back to the ancient Greece (Bode et al., 2014). By means of feelings we experience that we are active agents that have the power to make free, deliberate choices. This feeling of ourselves as choice makers is manifested in a manner that informs us that we can do otherwise if we want to. Two of the criteria for the concept free will are control of choices and responsiveness to reason (Lavazza, 2016). In other words: free will is equal to the capacity to choose and execute a varying assortment of behavioral options for a specific situation (Brembs, 2011). Once the decision is made it is final and absolute, but this go against some physics concepts, where movement occurrences are determined by the prior and collective movements of the whole system. The *commonsense view*, which is described above, seems to subscribe an original causal power (*causa sui*) that has not been detected in nature. This view is called the libertarian view (Lavazza, 2016).

What is entailed by a 'free' decision is not as clear as one may first assume. An action can be free from being voluntary - either by coercion or due to automaticity. Intention entails the ability to do otherwise but does not necessitate execution (e.g. intent to drink can easily be forfeited by other factors such as a discovered fly in the glass). Intentions are specific to the action intended and are characterized by an absence of compulsion. An urge should occur before the action it is related to (e.g. urge to jump precede the physical jump). Many actions, however, are performed without a previously felt urge and urges are often related to actions where control is limited (e.g. sneezing). (Nachev & Hacker, 2014). In practice, evaluating free decisions are complicated.

1.1. Scientific Inquiry

Free will is a popular topic, stirring debates on i.a. child rearing, religious beliefs, and the judiciary system (Árnason, 2011; Parmigiani et al., 2017), which can cause communication difficulties due to underlying assumptions about the concept itself. The law is stipulated such that it requires an *ability to-do-otherwise* capacity of humans (or at least assumes it). Considering the possible grave consequences (e.g. life in prison), it is important to agree and come to terms with what individuals believe about free will.

Conducted experiments on free will resulted in substitutional explanatory models. Libet, Gleason, Wright, and Pearl (1983), found, in a groundbreaking experiment, that an electrophysiological marker, the readiness potential (RP), preceded decisional occurrence awareness. Subjects were tasked to move their right wrist whenever they felt the *urge* to do so, and importantly, report *when* this urge appeared. With the help of the data and reports from the subjects, the experimenters could identify brain activity that arose *before* the subjects reported that they had made a choice to move their wrist. Libet's original research was based on the electroencephalogram (EEG) technology. Recent years have introduced results from newer technologies (as well as replications of Libet's experiment) such as functional magnetic resonance imaging (fMRI). The hope of illuminating aspects of free will through the utilization of new technologies, as in other sciences, is that these technologies can converge on a common picture regarding the phenomenon in question (Roskies & Nahmias, 2016).

The commonsense view would state that a conscious decision is made in the brain from which follows brain activity which executes the action. If brain areas that execute the decision are activated prior to knowledge of even the urge to make that decision - the urge does not seem to have any *causal power* - which is distinctively associated with it. Libet's result spawned several replications (Gomes, 2002; Libet, 2002; Schultze-Kraft et al., 2016), which at the time seemed to cultivate and accumulate evidence for the theory of pre-conscious decisional brain activity. This theory started to show deficiencies when compared with contemporary and incompatible studies (e.g. Trevena & Miller, 2010), which produced novel approaches such as a computational model for the antecedent brain activity – spontaneous urge relation (Schurger, Mylopoulos, & Rosenthal, 2016). which seemingly divided the paradigm into two camps: a pre-conscious view of generating decisions and opposing views that were not ready to believe in those conclusions (Racine, 2017).

Why is free will something that is written about in prestigious journals, what are the motivational factors and where does the intrigue originate? Let's say that you are presented with a fruit platter. You can clearly observe an apple, an orange, and a banana and you are given the choice to choose one of the fruits. Abiding by your preferences, you chose the apple. Had you felt less hungry that day, you would probably have chosen the orange. A predicament that philosophy has grappled with is if you could have chosen otherwise, were you capable to choose another fruit, was is a realizable possibility**.** You know that the observed outcome can occur, but you do not know if *another* outcome was possible at that time point. The conclusion that only one outcome is possible seems to go against the feeling of free will – that you had the causal power to choose otherwise.

1.2. Libertarianism, Compatibilism and, Determinism

Determinism describes a worldview where everything happens now is caused by what happened in the past. The laws that govern nature (e.g. gravity) also governs us and our behavior. Free will can then be argued to be incompatible with determinism. In Quantum theory the *wave function* can be argued as support for determinism (Vaidman, 2014). The libertarian view does not believe that prior causes determine our present choices. A way to imagine determinism is to image domino bricks that knock each other over. None of the domino bricks have the causal power to tip itself over, but when the brick has tipped over, its own momentum and inertia is sufficient to knock over the following brick. Following the causal chain backwards in time will eventually reveal the original brick that tipped over, but what made the first brick tip over? Some claim the big bang and others claim a deity's intervention.

Many believe that free will is in fact compatible with determinism which is why this view is called compatibilism. Compatibilism is multifaceted, because it can be attained through rationalizing from distinct perspectives. Most come to this conclusion either by stating that determinism cannot determine everything (including free will) or by defining free will so that it does not have to include all the properties stated above, such as being a causal force. The most common presented compatibilists view of this type is to claim that free will exists if the cause, for the decision, is predominately observed in the brain. Quantum physics *spooky action*, where several phenomena have been measured and interpreted as occurring at random (Esfeld, 2017), is taken as evidence that the world is random or indeterministic (at least at some scales), and this makes the world indeterministic and hence compatible with the libertarian view. In the example of dominos, a compatibilist may claim that the whole row of dominos is the decision itself and what lies beyond it is not. In the fruit platter example, a compatibilist may claim that, as long as the person himself is making the decision, and not being coerced by an external force, his actions are not restricted and hence his free will is in action and operational. Compatibilism can also be related to desires and feelings. Wants and desires originate in the body, and free will is only hindered when obstacles block the path to achieve them (Racine, 2017). One is unlikely to be upset over the craving for ice cream compared to not having access to ice cream with which to quench the craving (i.e. realizations of intents are what matters).

If science could falsify determinism, it would increase the likelihood of libertarian free will. Or If antecedent brain activity can be shown to absolutely precede decisional awareness in a manner which is unavoidable (i.e. determined) (Pockett, 2009), the libertarian view would be falsified. Compatibilism is difficult to test, because the views have several definitions.

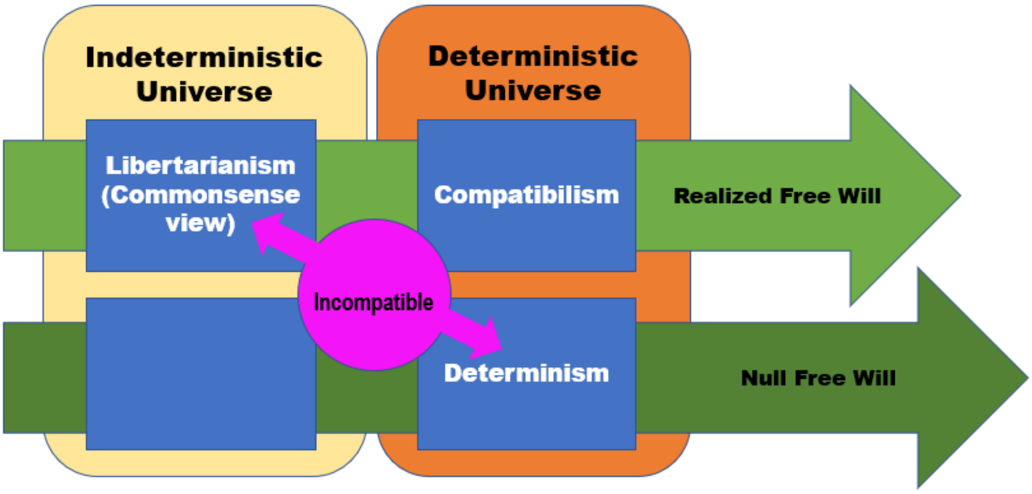

Figure 1. A diagram that frames the views of free will's relationship with a deterministic contra indeterministic universe.

1.3. Causality - Free Will in Other Contexts

Another concept that is related to free will is *fundamental causality* and our psychological relation to it. Wegner (2004) presented the example of a bowling ball speedily rolling down the lane and smashing into the pins. It overtly, looks like the bowling ball is causing the pins to fall over, that the ball is a causal force in this event. The ball is the *cause* and the pins are the *effect.* We cannot help but to infer a cause and effect relationship between the ball and the pins. Indeed, this is the point, we can *only* infer it. Causality can neither be located within the bowling ball itself nor can it be found between the bowling ball and the pins. Causality is fundamentally an event, which entails that it is not an attribute or characteristic. In a similar fashion, causality can be attributed to humans as well. If events are synchronized with thoughts, they are bound together, resulting in the agent perceiving causality over those events (Wegner, 2004).

The binding mechanism can be fooled (surprisingly easily), as has been shown in psychological experiments. Subjects were presented with two pictures of equally attractive women and were asked to choose which of the women they preferred. After the choice was made, the researchers swapped, using a slight of hand technique, the pictures, and presented the picture that was not previously chosen. The subjects were asked why they chose that woman. In most of the trials, the subjects began motivating why they chose the woman that they had just a few seconds earlier, dismissed in favor of the other picture. Only 27% of the trials resulted in the subjects noticing the picture change. This effect is called *choice blindness* (Johansson, Hall, Sikström, & Olsson, 2005). The brain seemingly has a system that attributes causality to the agent, extrapolated from thoughts and events. Ownership is created by this system when introspective mechanisms find a relationship between thoughts and actions (Wegner, 2004). Being the observer (i.e. the agent) of mental processes, does not necessarily entail any special knowledge of the involved mechanisms. Furthermore, the will can be dissociated, in healthy individuals, from voluntary actions after hypnosis induction. For those that are responders, after receiving a suggestion to perform an action (e.g. grabbing a glass of water) they conform with the experience of this action occurring to them, as opposed to experiencing that they caused the action (i.e. their will is not explicitly involved) (Wegner, 2004).

Situationism is the term used when studying decisional outcomes in social psychology. Attempts are made at measuring the degree to which outside environmental factors influence behaviors in the exposed/involved subjects. Several experiments have shown remarkable effects that can be attributed to the environment/situation: social roles (e.g. police officer), presence of authority figures (e.g. scientists), and the influence of *conformity* in order to fit in with the group (e.g. mirroring group behavior) (Asch, 1956; Darley & Latane, 1968; Haney, Banks, & Zimbardo, 1973; Milgram, 1963). If the likelihood of a subject drinking a glass of water was 30% if a clown was present and 95% if a doctor was present, it could then be argued that the subject's freedom to choose was affected by the social status of those people. If documented social factors make their behavior predictable, it can be argued that they then therefore have less freedom to choose (i.e. decreasing their free will) (Benjamin & Simpson, 2009).

1.4. Cognitive Neuroscience

In cognitive neuroscience, free will can be studied from a diverse selection of research hypotheses and aims. One method is to look at which brain areas are involved when the agent decides. fMRI allows for imaging during introspective state changes. These experiments measure a contrast between conditions where the subjects make internally free choices and performs externally guided actions (i.e. press whichever button you want or press the button that we instruct you to press) (Haggard, 2008). These experiments have shown that:

- The medial prefrontal cortex (mPFC) is linked to voluntary actions, such as the cancellation and inhibition of action plans
- The pre-supplementary motor areas/supplementary motor area (preSMA/SMA) have shown to be related to the *when-component* (timing of action execution)
- The rostral cingulate zone (RCZ) has shown to be related to the *what-component* (choice selection)
- The ventromedial prefrontal cortex (vmPFC) and dorsomedial prefrontal cortex (dmPFC) has shown to be related to the *whether-component* (IF the action will be executed)

The *what, when* and *whether* components of internal choices have therefore all been linked to different parts of the mPFC. A model has been constructed, named *WWW-model*, which stands for: *what*, *where*, and *whether*, that links brain areas with decisional components. The preSMA/SMA initiates the action, the RCZ selects the action, and the vmPFC/dmPFC aborts the action (Brass, Lynn, Demanet, & Rigoni, 2013). The contrast values of activity in different brain areas are used to specify correlates for free decisions. The WWW-model attempts to map where subjective aspects of free decisions lie (i.e. their neuronal correlates). Disappointment due to disengagement from a choice, has been associated with dmPFC activity, the feeling of making up your mind (i.e. selecting between choices) has shown activity in the RCZ, whilst urges have been correlated with preSMA/SMA activity. Zapparoli, Seghezzi, and Paulesu (2017), via hierarchical clustering corroborated the view of brain areas independent functioning in relation to decision making within the mPFC. Additionally, brain areas beyond the mPFC were included, namely: supramarginal gyrus (*what-component*), pallidum and thalamus (*when-component*), putamen and the insula (*whether component*). The independent brain patterns were also active during non-intentional motor actions, which was interpreted as compartmentalized intentionality (the distinct WWW-model regions) manifesting themselves (in fMRI) due to functional specialization of general-purpose systems.

Libet's experiment looked at the when-component of decision making, and conceptual replications have additionally looked at the what- and whether-components. Brain areas are also associated with the inference of who is the causer of an action - the temporal parietal junction (TPJ), and the anterior insula is active when the agent herself is judged the action's originator (Brass et al., 2013). Another approach has worked on a model based on episodic simulation of future events (imagining future possible events that have not occurred). The *constructive episodic simulation hypothesis* is based on evidence of shared BOLD activity between conditions where subjects remembered past events and imagined possible future events. Shared activity was observed in left hippocampus and right occipital gyrus. Additional activity, for prospective memory, was documented in the right frontal pole, hippocampus, bilateral premotor cortex, and left precuneus in a future imagining condition. These differences were attributed to the future simulation and manipulation aspects (Schacter & Addis, 2007; Schacter, Addis, & Buckner, 2007).

The *alien hand syndrome* is a neuropsychological disorder where one of the patient's hands operates without the will of the agent (independent of the subject's subjective experience). This syndrome can express itself by the anomalous hand tenaciously picking up and grabbing nearby objects or people. Overall motivation can be substantially diminished by a neurological condition called *abulia,* which results in patients seemingly not having the intrinsic will to do much of anything, such as eating. The documentations of both hypnosis and choice blindness hints at two systems being involved – one that causes events and the other which interprets the author/causer (Hallett, 2007; Wegner, 2004). Moreover, the prevalence of the alien hand syndrome indicates that the causality attribution system can malfunction.

Free will and volitional concepts have been coupled with executive functional systems. These executive systems are responsible for inhibition, planning, strategizing, attention control, working memory assisted problem solving, and creative/flexible environmental adaptiveness (Lavazza, 2016). All these functions revolve around some type of control and emphasize uniquely human associated abilities. Essentially the opposite of solely being a reactionary and automatic entity (i.e. automatism). An influential study tested children on their ability to postpone the consumption of a marshmallow candy. The children were asked to wait about 20 minutes and would, if they succeeded, be rewarded with an additional marshmallow. This is a difficult task where some children succeeded, and others failed. The informative part of this exercise is that it is generalizable to future outcomes, such as job success and health (Mischel, Ebbesen, & Zeiss, 1972). Freedom and control are examined through these functional systems (i.e. inhibiting the urge to eat). Though it is unclear if the ability to inhibit an urge is related to or substituted by these systems (i.e. free will necessitates control contra free will IS control).

1.5. Concept Discrepancies

The literature reveals tacit discrepancies in the free will concept. The ancient Greek stoics taught a deterministic view of free will - there existing no non-caused events, which enable free will due to the mind being the most proximal cause (Bobzien, 1998). Esfeld (2017) explains that physics principles utilize probabilities to estimate the future states of a system from where the initial conditions are unknown. Since the original state of the system (i.e. the starting value of the system's variables) is unknowable, the laws cannot be used for exact predictions. Vaidman (2014) states that if a theory can be proven within a small system, the results should be generalizable to a large system (if the theory is true) – thus making decisions deterministic. Brembs (2011) formulates an evolutionary and quantitative definition of free will which emphasizes controllable variability inhabited by organisms. The control of variability manifests itself in the form of creative generation of possible behaviors from which to choose from. A comparison is made between evolution's seemingly random mutations which are followed and acted on by a more deterministic selection process.

Bonn (2013) re-conceptualization combines both unconscious and conscious processes with an emphasis on individual differences stemming from memory formation and integration (i.a. *constructive episodic simulation hypothesis*). Ownership is proclaimed equally for planned behaviors and automatic motor programs. Roskies and Nahmias (2016) state that it is impossible to predict decisions by having access to present and prior brain activity (e.g. homologue brain activity can produce different outputs). Since decisions cannot be either causally explained (locate causal locus) or predicted (by behavior or brain activity), free will is inferred from no proven determinism. Lavazza (2016) operationalized (i.e. defines a measurement of a phenomenon) free will according to an executive function-based criterion, where free will, as a construct, can be measured by executive function index.

The divergent examples of free will definitions highlight an underlying problem. Reaching a conclusion of the nature of free will by utilizing ancient Stoic thinking, physics principles and neuroscience is valid, however, assumptions are different about what matters and what the conclusions mean. Probabilistic outcomes derived from deterministic laws, unpredictable brain activity, proximal causes of the mind, and control expressed as executive functions: all have unique *demarcation points* (i.e. differentiation factors). For example, the executive function position is intact if the system is functional, but this would not be the case of the proximal cause view. The free will concept is fundamentally philosophical, meaning that it is transferable into every research field, contrary to a concept such as cell division. Therefore, it is important to come to terms with the definitions of the free will positions so that authors can communicate their views without misinterpretations. The transparency would improve communication by contextualizing research findings - what Libet paradigm results would implicate about different positions.

1.6. Aims, Scope and, Research Questions

This essay has two aims and the first is to investigate the development of the Libet paradigm of free will. The influential experiment has seen considerable developments over the years since its introduction in 1982 (Libet, Wright, & Gleason, 1982) and is actively used in free will discourse. The goal is to show how this development relates to Libet's original findings and what form the paradigm now has taken (without Libet's involvement). Have any assumptions about free will, or how research should be conducted changed along the way?

The research questions: to what degree have new studies, aided by technological development, sorted out and uncovered the role antecedent brain activity serves in relation to conscious and free decision making? Do current literature, in the Libet paradigm, align with Libet's original conclusions of the properties of the RP (e.g. motor planning)? The scope will be to focus on empirical studies that replicate, by either highlighting limitations of the original experiment, or otherwise drive the research question on antecedent brain activity – spontaneous urge relation forward. The only type of decisions studied is free decisions based on spontaneous urges. This is a rather restricted view of free will decisions, but never the less, one that can be examined and from which conclusions can be drawn. The literature regarding imaging of brain activity whilst making decisions will be investigated (e.g. the WWW-model) (Brass et al., 2013) and how it relates to the antecedents. Psychological studies will be included if they support the research question (i.e. the relation between temporal brain activity and urges/conscious awareness).

The second aim is to explore the concept of free will and how it is related to the empirical results; to investigate why and how differing views of the same free will concept influence scientific discussion. How should a research field handle that the phenomena in question (free will) cannot be agreed upon? This is important because free will is something that most people, if they ponder it, care about a great deal. The concept is divided between differing views and this results in that empirical results are interpreted dependent on the held view and that communication is encumbered by the, sometimes unaware, differences between the involved parties. If the *explanandum* (description of phenomenon to be explained) is not shared between parties, naturally the *explanans* (the explanation of the phenomenon) is not either. The research question: how are the results from the empirical studies related to current views of free will? What are some of the factors that determine (i.e. demarcate) different views of free will? How can differing views of the explanandum influence how results and progress are viewed within the research field?

The free will concept will primarily be examined through relevant discussion and review articles that incorporate Libet-style studies in their assessment. Those that propose a novel perspective (original view) on the free will concept will be included as well. Additionally, illuminating, or contextualizing articles will be used if they aid the research question. The empirical articles are quite reserved regarding discourse of the free will concept, which is understandable since their studies are empirical and may not want to risk muddling their work with unnecessary discussion. Thus, discussion articles are necessary as means for providing this essay with adequate depth on the divergence of the free will concept.

This layout of the essay is as follows: Libet's experiment is introduced together with relevant background information. Then follows a detailed walkthrough of Libet's classical experiment, and an overview of the conceptual replications, a review of contemporary theoretical interpretations and models, then an analysis of the theories and current interpretations.

2.0 From the Classical Libet Study to Current Experiments: Evolution of the Field

2.1. Technical Background Information

Free will is typically operationalized as making a fast, conscious, and spontaneous decision to perform a simple motor act or to make a binary choice. Urges are perceived as a necessary antecedent for choices and as a reliable introspective measure (Nachev & Hacker, 2014). Researchers may use the term voluntary action or urge. Deciding to focus on the comparisons between voluntary actions (e.g. press button whenever you want) and forced/controlled actions (e.g. press the button when the light turns green). Thus, complex, and long-term decisions are not investigated. Free will is enabled in the sense that there are no instructions that state when an action must be performed (Bode et al., 2014).

The RP is a slow negative event-related potential waveform (i.e. an electrophysiological marker). It is captured from an EEG which uses scalp positioned electrodes which pick up fluctuations in scalp voltage. In this context, negativity means that the electrodes detect an overall shift in voltage away from the baseline electrical activity from which inferences can be made (i.e. why it occurred). The electrodes are designed to pick up signals through the skull-bone to get as much information about the underlying brain related electrical activity as possible (Kornhuber & Deecke, 1964). The RP wave is usually recorded from electrodes placed on the centerline of the scalp (e.g. Cz) and is formed by repeated trials (usually more than 40) which are averaged together. The trials are aligned to a specific time stamp (e.g. a stimulus). The EEG setup usually include electromyogram (EMG) equipment, where electrodes are positioned on the skin to measure electrical activity which emanates from underlying muscle activity (Alexander et al., 2016).

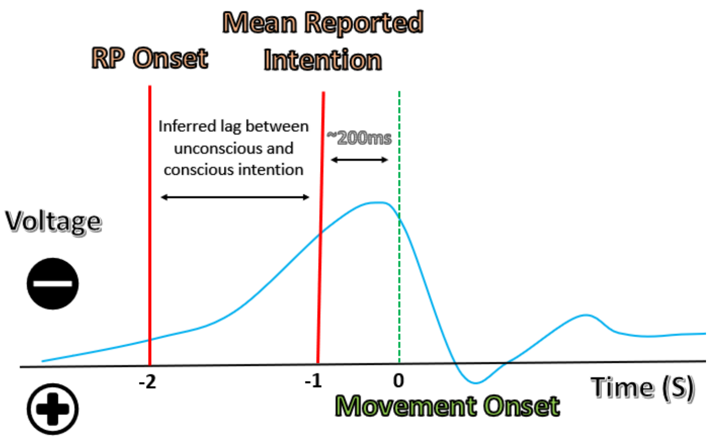

Figure 2. A schematic of Libet's original RP findings which illustrates the approximate 350ms precedence of the RP in relation to the intention reports. Modified from Haggard (2005).

fMRI (functional magnetic resonance imaging) is a technique which uses electromagnets to measure relative changes of blood oxygen level dependent (BOLD) in the brain. Working on the assumption that increased blood to brain areas equals that the brain areas are active and hence are performing their correlated functions. Multivariate pattern classification is a developed fMRI technique which uses classifiers (i.e. predictor variables) to reach an outcome (i.e. criterion variable). The classifiers need data from fMRI trials from which to base their outcome predictions. The principles of machine learning are used, which has been used to teach machines numerous skills (e.g. face recognition) (Pereira, Mitchell, & Botvinick, 2009).

2.2. Libet's Classical Experiment

Libet's original aim was to show that motor cortex activation proceeded after the intention to act. The evidence showed the contrary. Libet published three papers based on one experiment (Libet, Wright, & Gleason, 1982), two groups were tested on two different occasions. The papers looked at different aspects of the experiment. Subjects were instructed to look at a clock-face and report where a laser dot was positioned when they felt the conscious urge to move their right wrist. During the 40 trials, the 5 subjects were situated with both EEG and EMG sensors. The EEG measured the RP from the Cz electrode (At the top of the head), or in other conditions at the contralateral (opposite) motor cortex opposite to the subject's right hand (Cc). The EMG sensors were used to subtract the time for the motor movement of the hand, so that the remaining time more closely would mark the decision time. The subjects could freely choose when and if to move their hand, they also reported aborted urges to move their hand. If the subjects reported pre-planned movements, that trial was excluded from the experiment (Libet et al., 1983).

The averaged difference waves (the average waveform of several trials where one condition is subtracted from another) showed that the RP component can be observed 550ms prior to the button press, and 200ms prior to conscious awareness of the decision to act. This left the observed RP 350ms precedence over the conscious urge (see *figure* 2) (Libet et al., 1983). In the control condition, the subjects received a skin-stimulus which was difficult to notice, and its randomized administration occurred sometimes during each trial. The 5 subjects were instructed to report the clock position during the skin-stimuli as well. The noticed skin-stimuli reactions showed that awareness occurred 300ms after the skin-stimuli (Libet et al., 1982). This 300ms marker (P300) has been documented to occur in relation to uncertain events. Since the RP was NOT shown to rise in the control condition (react to stimuli) but solely in the conditions where decisions had to be made, conclusions were drawn that the RP had something to do with decision deliberation and/or planning. In the trials where the subjects reported pre-planned intentions to move their wrist's, a characteristic RP wave occurred (i.e. increased negativity), these trials were discarded (Libet et al., 1982).

In another condition, subjects were instructed to move at pre-determined times, but when a signal appeared, they should attempt to inhibit the wrist moment. Most subjects were able to stop the pre-planned movement up to 150-250ms prior to the pre-planned movement time. The RP-wave looked similar to the pre-planned movement condition but deviated from its trajectory when the successful abort command was executed (i.e. when successful abort was achieved). The absence of EMG recordings confirmed successful abortions. These findings led Libet to conclude that free will in the libertarian sense may not exist, but that a *Veto* function was available that could cancel out some latent actions that stemmed from uncontrolled brain processes. This veto function view of free will was subsequently coined *free won't* by Libet (Libet, 1985; Libet, 1999). Essentially, what Libet showed with his experiment is a temporal dissociation between the feeling of choice and correlated brain activity.

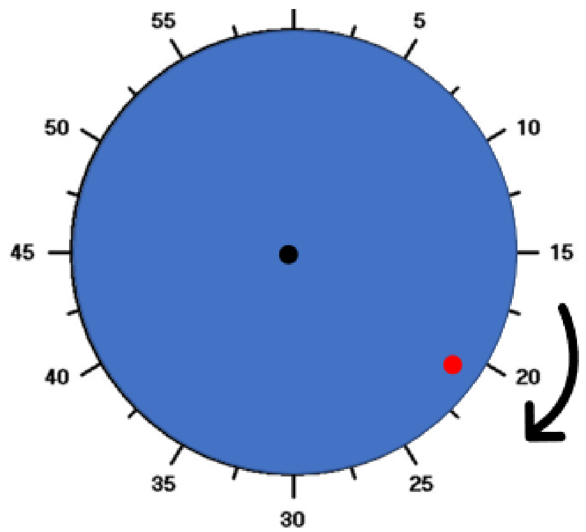

Figure 3. A depiction of a typical Libet-style clock. Subjects are tasked with following the movements of the circling red dot so that they can report its location when they feel an urge to press the button.

2.3. Critique of Libet's Experimental Design and Interpretations

- The unreliability of the subjects' own reports. Introspection can provide limited accuracy perhaps caused by distraction due to the subjects' having to concentrate on their internal state (if they feel the urge) and the position of the clock at the same time. Subject reports derived from introspection have shown to be erroneous (Bear & Bloom, 2016).
- Libet did not measure the time point of the actual decision (the urge) *per se*, but actually a metacognitive state, (metacognition is a term which denotes awareness of thinking and the mind) in this case awareness of the decision, which could have different brain correlates than the decision making itself. There is a difference between simply knowing a fact and checking via introspection that you know the fact. The metacognitive state would necessarily be available after the decision state (Nachev & Hacker, 2014; Strzyżyński, 2013).
- Libet's study only collected data when movement (EMG activity) was detected, which potentially give a misleading function for the RP, as trials without movement were not diligently documented. Studies show that the RP can occur without any registered movement (Roskies & Nahmias, 2016).
- Prior choice bias (i.e. previous brain activity swaying future brain activity – a problem if the trials are meant to be independent). Subjects could unconsciously plan their motor movements whilst trying to behave randomly/spontaneously (Lavazza, 2016).
- Demand characteristics are also problematic and hard to control for. The instruction to press the button whenever you feel like it does include implicit pressure to press the button sometimes during the trial. If the subject chose to never press the button, that subject would almost certainly be excluded from the final experimental results (Lavazza, 2016).

- Nachev and Hacker (2014) noted that Libet's conditions were task discriminative (task affordance) – meaning that they studied free will from the perspective of which task is performed (i.e. pressing the button). The timing with which the urge and the button press occur is what matters most. Timing discrimination (temporal affordance) should be prioritized.

Libet has responded to some of the critique points (Libet, 2002). Such as that the RP may be an artifact of smearing due the 40 trials averaging (e.g. individual differences may cause the RP pattern). Libet's response claims that this is not the case by detailing how 90% of trials closely follow the RP pattern and references other articles that have replicated his findings (Haggard & Eimer, 1999). Similarly, Libet et al. disputed the findings that other studies have found that the RP occurring *after* the urge (Gomes, 2002), as mainly evidence due to differences in the experimental design (e.g. subject reporting the decision to move contra awareness of this decision) (Libet, 2002).

2.4. Replications with TMS, Single cell recording and BCI

Lau, Rogers, Richard, and Passingham (2007) aimed to illuminate the properties of subjects' introspective urge reports. Therefore, they applied transcranial magnetic stimulation (TMS) (an instrument that can, via magnetic pulses, induce focal activity in the brain) to see how stimulation of the SMA influenced voluntary action perception. In accordance with previous Libet paradigm proceedings, 10 subjects focused on the center of a clock face which had a red dot cycling inside its parameter. After the subjects had observed a full rotation of the dot, they were tasked with clicking a computer mouse with their left finger – when they felt like it. Once the subjects had clicked the button, the red dot reappeared at the center of the clock, and the subjects were tasked with moving the dot, using a mouse in their right hand (like a cursor), to the location that the red dot presided at the moment when the subjects felt the spontaneous urge (to press the button).

In another condition, subjects were tasked to move the dot to where it resided once they managed to press the button (i.e. to differentiate between intention to act and the motor movement delay). TMS stimulation was applied at half the trials whilst the other half received sham-TMS (fake TMS stimulation to convince the subjects – useful for alleviating placebo effects), totaling 240 trials. The TMS stimulation was administered in the trials at either immediately following action execution (i.e. button presses) or 200ms following the action execution. Both task and whether TMS or sham-TMS were administered was randomized. The results showed that when TMS was applied immediately after action execution, in the trials where the subjects were tasked to mark the location on the clock when they felt the urge, occurred -9ms (i.e. their urge was perceived to have occurred 9ms prior), and -16ms for the condition where TMS stimulation was administered 200ms following action execution. For the trials where subjects had to mark when they actually pressed the button, The TMS administration immediately following action execution was reported at 14ms, and 9ms for the condition with 200ms delayed TMS administration. The results were calculated by subtracting the averaged times of the TMS condition from the sham-TMS condition (see *Table* 1).

The authors summarize that intention was shifted backwards in time and that motor movement was shifted forward in time by the TMS administration. They conclude by suggesting that neural activity occurring 200ms following an urge is involved in perceived intention of motor actions, since manipulating the motor cortex, at that time interval, apparently shifts time perception of urges.

Immediate Stimulation	200ms Delayed Stimulation	Estimate Of:
-9ms	-16ms	Urge to Press
14ms	9ms	Button Press

Table 1. The subjects' relative timing judgements of decision to press the button (urge) and the actual button press (ShamTMS - TMS)

Fried, Mukamel, and Kreiman (2011) implanted chronic depth electrodes (760 units) in 12 patients for a little over a week (primary reason was that all the subjects had seizure problems and the electrodes were used to localize the generator location of the seizure activity). The electrodes were inserted into several areas in the subjects' brains (both single- and multiunit). The subjects sat on a bed and performed a Libet clock experiment, where the subjects only had to press a button when they felt like it – and as usual – noting the position (i.e. time) of the clock handle. The electrodes recorded the ensuing electrical activity which was clustered by an algorithm and then manually sorted according to relevant activity (i.e. spike frequency = electrode measures of action potentials generated by neurons).

The results showed that electrodes located predominately in the SMA, preSMA, and anterior cingulate cortex displayed changed neuronal activity (firing rate) up to 1 second prior to awareness of the urge to press a button. However, some units within these brain structures showed the opposite pattern – e.g. a unit in the anterior cingulate cortex only deviated from baseline activity after the reported urge. After the experimental sessions the researchers attempted to calculate how well they could discriminate (i.e. predict) activity prior to the subjects urge to move compared to baseline activity. Their results showed that one unit, in the preSMA, could with 60% accuracy discriminate the subject's movements 500ms prior to their reported urge. Looking at ensembles of neuronal recordings (from each subject separately), they could discriminate up to 500ms with 73% accuracy. Pooling units from all the subjects, by constructing a pseudopopulation from 512 units, achieved a 90% accuracy, 500ms prior to urge, and 70% accuracy, 1000ms prior to urge.

Trevena and Miller (2010) investigated Libet's assumption that the RP is associated mainly with preparation for movement. 21 subjects were situated with EEG equipment and asked to make a spontaneous decision (feeling the urge) of pressing a button, once they heard a tone (which appeared in a non-predictive random fashion). A clock with a laser dot was used in accordance with the Libet's paradigm. Two conditions were included in the experiment. In the first: participants were instructed to always press either a left or a right button (which was indicated by the computer monitor), and in the second: the participants were instructed, once they saw the button indication, to decide whether to push the corresponding button or abstain from executing any action (i.e. do nothing). Instructions were also given to approximately distribute their spontaneous choices equally between the two alternatives. Since the timing of the tone was known by the researchers, they could compare the trials between when the subjects choose to press the button or abstained from doing so.

Instead of measuring the RP, as Libet did, they measured the lateralized readiness potential (LRP), which is associated with specific hand movement preparation, and was thus judged to better fit their experimental design. The LRP is very similar to the RP and shares the antecedent negativity pattern. The researchers specifically looked at whether the preceding LRP-related negativity influenced the decision outcome. If the LRP was already large, once the decision to act was made, then a decision to act should be more likely in comparison with if the negativity was smaller. The ANOVA analysis showed that the average reaction time between the *always-move* and *choose-to-move* conditions was significantly different (i.e. the reaction time was faster when the subject did not have to decide if they wanted to press the corresponding button). The temporal information from the reaction times made it possible to calculate the LRP size (negativity) in relation to the corresponding decision making. The results showed that during the *chose-to-move-condition*, the LRP amplitude did not differ between the trials between when the subject chose to move or to abstain. The authors conclude by suggesting that the LRP and the RP, instead of reflecting decision making or a specific motor action preparation, could instead reflect task-related sustained attention and effort.

Alexander et al. (2016) aimed to investigate if the RP was necessarily related to planning or preparation of movement. Therefore, they situated 17 subjects with EEG equipment for participation, in a modified Libet paradigm experiment, which incorporated and displayed four letters (one in each inner quarter of the Libet clock). The letters were all continually randomly updated to a different letter and color before it stopped at a predetermined time, thus allowing the subject to make a spontaneous choice of the four available alternatives (one of the quadrants). Once the choice was made, they had to report the position of the clock that matched their decision urge.

The experiment consisted of two types of trials. In the first, the subjects marked their choice by immediately pressing a button, and in the second, the subjects marked their choice without movement – just by verbally reporting the spatial location of the clock hand and the chosen letter. From the recorded EEG-data the researchers analyzed the difference between the movement and non-movement trials and found no significant difference from the RP waveform. From this information, the authors concluded that the RP is not responsible for unconscious motor decisions and/or motor preparation/planning. They speculated that the RP may encode anticipatory processes that lay outside the motor spectrum (e.g. general cognition).

Schultze-Kraft et al. (2016) conducted research on the intricacies on the Veto effect associated with the RP, to test the aspects that Libet himself did not manage to test (due to technological limitations) (Libet, 1985), namely confirming the temporal restrictions of the veto effect. Therefore, the authors conducted an experimental design where 12 subjects were EEG recorded during a Libet paradigm experiment. The subjects were instructed to rest their foot on a pedal button and press it whenever a light turned green. This alteration included the added element of the subjects being informed that they were not allowed to press the button once the presented led-light turned red – then the subjects had to attempt to inhibit any potential urge to press the button. A brain-computer-interface (BCI) was incorporated into the experimental design. The computer received real-time EEG data from the subjects (the RP wave) and subsequently sent back a representation of the RP to the subject. The magnitude of the RP is what determined if the light would turn red. Since the waveform can be observed prior to motor movement – it is difficult to inhibit the RP once it reaches a certain level/threshold. The subjects had the experience of playing a game against the computer and to attempt to win against it (where points were awarded for progress).

The results showed that when the stop-button turned red subjects were able to veto the motor movement up to 200ms prior to EMG activity. However, if the stop signal appeared later than 200ms the subjects could not stop their movement but could still abort the button press. The RP could be observed to appear more than 1000ms prior to EMG onset, thus the Authors concluded that subjects were able to intentionally override antecedent brain activity (RP) up to 200ms before EMG activity. This time point was deemed the point of no return.

2.5. fMRI-based Classifiers

Soon, Brass, Heinze, and Haynes (2008) wanted to know if the SMA is primarily responsible for decisions on movement or if other areas are as ostensibly involved. They scanned subjects, using fMRI whilst they observed a computer screen which showed a stream of letters. The subjects were instructed to either press a button with their right or left finger, whenever they felt the urge to do so. After the ensuing button press, a response-screen appeared which allowed the subjects to mark the letter that was shown on the screen during the exact time they felt to press a button (with either of their fingers) (See *figure 4*).

Utilizing statistical pattern recognition techniques, the researchers were able to discern that during motor movement execution – the primary motor cortex and the SMA were active. Furthermore, they found that frontopolar cortex activity showed predictive activity of which finger the subjects would choose to use to press the button - up to -9 seconds prior to reported decision urge (<60% prediction accuracy in the lateral frontopolar cortex). The precuneus and posterior cingulate cortex also showed predictive activity, but less so than the frontopolar cortex. Additionally, they were able to predict, with activity from the preSMA/SMA, when the subject would decide to move, with up to five seconds prior to motor movement. Measures were taken between the trials to ensure that carry-over information did not interfere (i.e. the predictive algorithm cannot use activity from prior trials that are still active during the next trial, meaning that the BOLD had the time to revert to baseline). A pre-test was put in place, which only allowed subjects to participate in the study if their behavior matched choice selection frequency (equal distribution of left and right button presses) and choice speed (make choice within the time limit of 15-50 seconds). The authors inferred a double dissociation between areas that control timing and outcome in early brain processing (regarding motor movement). From the evidence (early stage activity in frontopolar cortex), it is concluded that the SMA (from where the RP is measured) does not have ultimate decision authority and capability.

Bode et al. (2011) replicated the team's own experiment utilizing a high field fMRI (7 tesla) to scan 12 subjects during a similar experimental design – screen with stream of letters (see *figure 4*). The increased power (tesla units) allowed for increased resolution of the brain. Multivariate pattern classification was utilized with the emphasis solely on the frontopolar cortices BOLD activity prior to conscious decision making (the urge). The results showed that the BOLD signals from the frontopolar cortex were above chance at the -7.5 second mark (prior to spontaneous urge). The highest predictive chance was observed at the -1.5 second mark, at 57% accuracy (i.e. the likelihood that the subject would press either the left or right button). The authors concluded that motor intention could be encoded in the frontopolar cortex several seconds before a conscious decision can emerge.

Soon, He, Bode, and Haynes (2013) wanted to investigate if decisions beyond strictly motor decisions could be predicted in equal manner to their previous fMRI studied (Soon et al., 2008; Bode et al., 2011). Their Libet paradigm inspired experimental design was similar to their previous variant – screen of flowing letters. The screen still showed a stream of letters, but this time included numbers as well, one directly above the letter and four additional numbers, one in each corner of the screen (see *figure 4*, does not depict the additional numbers though). The 34 subjects were instructed to decide, spontaneously, whether they wanted to subtract or add. As in the previous experiment, after their decision (to either add or subtract) the subjects were told to note the letter on the current screens and then they had to immediately perform the chosen calculation (to either add or subtract) on the subsequent screens of numbers (the number above the letter). The participants were then tasked to mark the correct answer on the presented answer screen. The procedure was comparable to the earlier experiment, but instead of the classifier algorithm predicting left or right, it predicted subtraction or addition.

The resulting BOLD activity from the medial frontopolar region could predict with 59.5% accuracy -4 seconds prior to conscious awareness of spontaneous urge. A region between the precuneus and posterior cingulate cortex could predict with 59.0% accuracy -4 seconds prior to awareness of decision. The data also showed that the decision outcome could be detected in BOLD activity after the conscious decision – namely in the angular gyrus at +4 seconds post decision with 64% accuracy – which when adjusting for the BOLD response delay may provide information that the conscious decision is ‘felt’ in the angular gyrus. The preSMA activity could predict the timing of the decision (31.4% accuracy where 20% = chance). The default mode network relation to the predictive areas was also investigated, which turned out to significantly overlap (i.e. the activity of predictive regions showed corresponding activity with the default mode network). The authors noted that a slight functional dissociation between the timing (preSMA) and content (frontopolar) of the decision could be made, and additionally that simple (left and right) choices can be predicted earlier than complex choices. They concluded that unconscious precursor activity for more complex decisions than motor movement can be found and that this suggests that decisions are encoded at multiple scales in the brain.

Bode, Bogler, and Haynes (2013) investigated the hypothesis that guesses, and free decisions may share the same or similar networks. A hypothesis derived from previous evidence indicating that the medial parietal cortex activity was both active during perceptual choices and spontaneous decisions. 16 subjects were fMRI scanned whilst watching a screen that showed three briefly, clearly visible, images where the first and last pictures were masks (i.e. the pictures that did not resemble anything) and the third picture (in the middle) was the target picture. In the first condition, the subjects were instructed to identify if they saw a chair or a piano (the target picture). In the second condition, the images were very difficult to distinguish (low visibility), in fact, the target pictures were actually just like the masks images, but the subjects were not told that, instead they tried to identify if they saw a piano or chair. In the third and final condition, the subjects were tasked to make a spontaneous decision between a piano and a chair whilst at the same time ignoring the visual picture (that contained no information). The subjects did not know which condition they were going to participate in, but they did receive a cue from the screen that informed them if they had to identify an object category (red cross) or if they had to make a spontaneous decision (green cross). From these three conditions the researcher could compare guesses (second condition) with spontaneous decisions (third condition) and compare these to the baseline object category identification (first condition).

The results of the fMRI imaging (included pattern classification analyses) showed, in the first condition, bilateral visual cortex and lateral occipital complex activity (encoded 61%) and could be decoded (i.e. outcome estimated from the data) from the lateral occipital complex with 61% accuracy (right). The second condition showed decoding patterns in the medial posterior parietal cortex/precuneus, at 61% accuracy. The third condition showed decoding accuracy in the medial parietal cortex, at 57% accuracy, and in the anterior medial prefrontal cortex at 64% accuracy. The trained classifier found similar activity in both the second and third condition – guesses and free decisions activated some of the same networks, especially the precuneus. The similarity was structured so that it was possible to train the classifier to predict free choices when it had only been trained with data from guesses, at 57% accuracy (i.e. the second and third conditions showed similar patterns in the brain so that it was possible to use one to predict the other).

The authors concluded that under specific circumstances spontaneous decisions and guesses could use the same neural mechanisms. When the brain does not have access to external input in the form of clear information (the clear visible pictures in the first condition) the same internal mechanism could be used for guesses and difficult choices when the information value is very low (as is the case in the grainy second condition pictures). Basically, if information from the environment is very poor, regarding aiding with problem solving, more emphasis will be put on internal processes (e.g. to use creativity).

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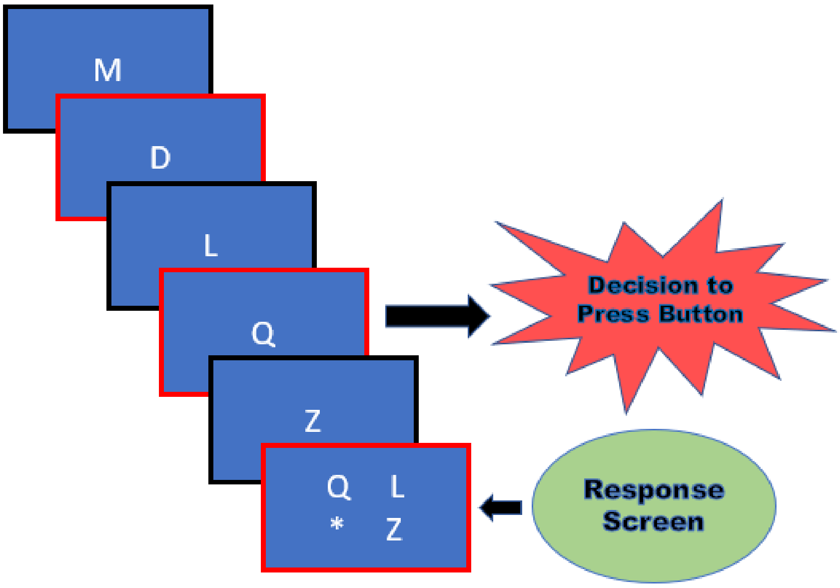

Figure 4. The stream of letters with accompanied response screen (bottom most rectangle). The subject selects the letter that was present when she made her spontaneous decision (in this case the letter Q). If the response screen did not contain the correct letter the subject was tasked to select the * symbol. The system used in the Soon et al. (2008), Bode et al. (2011) and Soon et al. (2013) studies. Figure is Based on Bode et al.

2.6. Stochastic-Decision Model

Schurger, Sitt, and Dehaene (2012) situated 16 subjects with EEG and instructed them to sit in front of a screen, in a Libet style paradigm setting. First the subjects performed the classical Libet experimental design and after that a novel condition was additionally introduced. This condition included an interruption element in the form of a random click sound. The subjects were thusly instructed to promptly press their allocated button. If a click sound was not administered, that trial would be identical to a classical Libet paradigm experiment (i.e. press the button when you feel the urge). The researchers analyzed the EEG data and reaction time of the urge to move via a constructed leaky stochastic-decision model (stochastic = includes random variables & leaky = incorporates). The authors postulated that the characteristics of the RP waveform could be attributed to the motor system's constant fluctuations and that these fluctuations would influence the reaction time in the interruption condition (with the click sound). The model followed the assumption that the brain uses similar areas during random/spontaneous decisions as well as for planned decisions. If the regular fluctuations were close to a threshold, then the reaction time would be swifter.

The results showed that the reaction times during the trials reflected this prediction (i.e. if the RP, prior to a random instruction to promptly press the button, showed negative amplitude – the motor action of pressing the button would be performed significantly faster). The stochastic-decision model displays the same pattern as the RP but gives another explanatory model for its shape (i.e. that prior RP negativity - instead of being attributed to antecedent unconscious decision making – illustrates random activity that is related to threshold values). The authors thus concluded that the RP should be dissociated from the decision aspects of spontaneous choices. They speculated that the experienced decision (the urge) to move may be closer in time with our perception – circa 150ms before EMG activity. Murakami, Vicente, Costa, and Mainen (2014) reported similar findings in rats.

One way to illustrate how the RP can give rise to a preceding wave pattern is to imagine a floodgate system. For ships (potential motor actions), to cross the floodgate, conditions must be fulfilled, e.g. adequate weather (no storm) and no extraneous blockades (debris or other ships). Once the conditions are fulfilled the ships can cross *IF* the floodgate gives permission. Ultimately, the floodgate operator decides if the ship may cross, but has no control over which ship will arrive or control external factors. The classical RP interpretation would state that the weather decides which ships are allowed through whilst in the stochastic-decision model the weather is only a prerequisite.

3.0 Theoretical Interpretations and Models of the Libet Experiments

Libet's inaugural experiment established a cognitive neuroscience paradigm based on free will research. Subsequent studies refined and expanded upon Libet's foundation. There are presently several ways of interpreting these findings. The empirical studies did not explicitly state their free will views. The antecedent brain activity – spontaneous urge relation was investigated, and the results were interpreted without discussion of free will *per se*. The discussion normally focused on the brain component investigated (e.g. p300 and the RP). Sometimes the empirical studies compared their results to the original study. Lau et al. (2007) compared their results to Wegner's account and Alexander et al. (2016) compared their results to Libet's. Therefore, to get a comprehensive perspective, discussion articles are included that indulge in the free will discussion.

3.1. Free Won't

Conclusions that are mostly agreed upon is that the notion of libertarian free will having the capacity to start a causal chain (*causa sui*), is highly unlikely (Rigato, Murakami, & Mainen, 2014; Lavazza, 2016), since the antecedent brain activity shows such high predictive accuracy. Libet did interpret that free will could co-exist with his results (i.e. that his evidence was not clear enough to warrant universal determinism). The veto effect was taken as evidence that free will was actually realized and exercised. The focus should instead lie on the choice of deciding whether to act out our dispositions - the free won't (Libet, 1999). Shared neural correlates for decisions to act and to inhibit actions has been argued in favor of inhibition being a sufficient model (Roskies, 2010). Libet deemed the possibility that the veto function was decided prior to our conscious awareness unacceptable, for the existence of free will, since it would render the agent with no free control at all. Libet instead considered the veto function as an executive top-down control mechanism (Libet, 1999).

Libet stated that the veto function could occur without antecedent brain activity and that this corresponds to the Christian belief of original sin and free will (original sin = antecedent brain activity & Free will = The veto effect). Libet presented Heisenberg's uncertainty principle and chaos theory as evidence against determinism, which left sufficient room for indeterminism and a causal veto effect. The non-deterministic position is based on the view that conscious will could act on a level below quantum mechanics (i.e. making consciousness and the free will operate independent of quantum physics) and that the *prima facie* (at first glance) experience of experiencing free will is still the strongest evidence of a correct world interpretation (Libet, 1999).

3.2. Compatibilism Views

Fischborn (2016) proposed *local determinism*. Determinism at one level does not necessitate determinism at another level (e.g. quantum physics contra planetary motions). The evidence, specifically from Libet (1985) and Soon et al. (2008) does not provide evidence that disproves libertarian free will – e.g. that 60% predictability is not enough accuracy. Though, higher predictability is theoretically possible. Fischborn summarized that Libet style experiments could disprove libertarian free will and that it is possible to increase the 60% prediction accuracy far higher and to generalize it to several types of behaviors. This would constitute a type of local determinism, where free will is still derived from the body proper. A conclusion that Roskies and Nahmias (2016) has issues with. They argued that neuroscience cannot, even in principle, show that a type of neural activity will cause a specified action in all subjects. The reasons given are: that the same neural activity can give rise to several behaviors (and vice versa) (Schurger & Uithol, 2015). Additionally, that the complexity and integrated nature of the brain’s neuronal connections renders it impossible to locate specific activity for specific actions (an average neuron has more than 10 000 connections). Furthermore, brain activity alone is insufficient for establishing causes (e.g. information held by muscle cells) (Schurger & Uithol, 2015). Decisions can be dependent on information held in external machinery (e.g. computers or phones) and can thus be considered an integral part of the decision itself. In practice, experiments cannot control for all the information requirements. Roskies and Nahmias are in unison with Fischborn in the sense that for libertarianism to be proven false, global determinism must be proven true (or conversely that indeterminism is not true). They are compatibilists because decisions cannot be causally explained and predicted from information pertained in the brain, whilst claiming the brain-body to be an adequate source of most decisions. This is essentially an epistemological claim which entails that the observed complexity is at a fundamental level undecipherable and that this property enables science-based free will to flourish.

3.3. Dynamical Systems Approach

Traditional methods of understanding how the motor cortex works attempts to calculate the outcome (i.e. motor action) based on fixed parameters. *The dynamical systems approach* instead focuses on patterns that shape the output (Shenoy, Sahani, & Churchland, 2013). The stochastic-decision model is compatible with the principles of the dynamical systems view (Schurger et al., 2012). The stochastic-decision model interprets the RP as randomness which has been distorted by the time-lock of the experimental trials. The trials always measure the moment before, during, and shortly after the stimulus. A restricted view of the antecedent brain activity – spontaneous urge relation.

The stochastic-decision models also explain, in the Libet experiment, why the RP rises (increased negativity), but does not always result in motor action. The background fluctuations can produce activity that nearly reaches the threshold for a motor action, but just nearly. If not randomness, the endogenous patterns could still encapsulate multiple action possibilities being calculated at the same time where the choice of one action equals the suppression of another. The BOLD effects that can be observed several seconds prior to the urge, shows that decisions do not appear from a vacuum and provides a time course for brain states with an eventual decision.

Schurger and Uithol (2015) reported that the same system is applicable on lesser creatures (phylogenetically older), such as the crayfish. The stochastic-decision model is also compatible with the discovery that activating specific neurons can yield several different behavioral responses on repeated activations (demonstrated in an optogenetically manipulated fruit fly larva). The neural circuits do not display a fixed response because they are dependent on the state of other neural circuits – this indicates that tracing a behavior/action back to specific neural activity is not generalizable/applicable between subjects. Furthermore, a dynamical system view is also compatible with the notion that action selection and action execution (i.e. *what* and *how*) may be processed simultaneously. This goes together with the observation that canonical neurons can respond to motor context sensitive cues, such as motion and perception (e.g. a grasping motion) – apparently computing the *what* and not the *when* of the motor action (i.e. the what is continuous and unconsciously processed without necessarily being executed). Similarly, somatic spindles can continuously send information into the background state (i.e. stochastic variables), creating a bi-directional process.

Schurger and Uithol (2015) summarized that their view indicates that the patterns are indefinite and probabilistic in nature – where only statistical approximation, which varies dependent on the temporal value, are realistically possible. Furthermore, that a conscious decision may originate from brain and bodily areas that are interlocked (Schurger & Uithol, 2015). The buildup, towards the threshold, is discussed as increasing dispositions towards certain actions (i.e. the likelihood) and once the threshold is crossed, a commitment to act is formed (Schurger et al., 2016). Their statements indicate that they subscribe to a type of random compatibilist indeterminism that show similarities with the free won't view that Libet put forth, but where the free won't have no causal powers.

3.4. Miscellaneous Views

An instrumentalist account is put forth by Racine (2017), where emphasis is on the subjective experience of free will from the first-person perspective together with discoveries from neuroscience from the third person perspective. The belief is that information derived from the collective of sciences (e.g. psychology, sociology biology etc.) will enrich our understanding of free will and subsequently lead to humans living better lives (e.g. believing that free will is an illusion may encourage cheating). Essentially, more effort should be put on answering epistemological questions (i.e. what we can know about free will) and less about ontological questions (i.e. if free will exists).

Lavazza (2016) proposes that free will should be measured and considered in relation to a cognitive capacity/executive functions index. Emphasis would be put on tasks that an agent has control over (e.g. inhibiting an act). This view also draws from several fields, but again, the findings from neuroscience serve more to put the experienced free will in a proper context instead of deciding its properties or ontological state. This view does entail that if executive functions were in some form damaged or reduced, free will would also diminish. This thinking is compatible with several psychiatric illnesses (Wegner, 2004) (e.g. OCD) and brain damage, such as damage to ventromedial prefrontal cortex (Bechara & Damasio, 2005).

Wegner and Wheatley (1999) popularized the view of free will as veritably being a feeling. This view has been echoed in the neuroscience field as well but is discussed in terms of free will as perception (Hallett, 2007). The antecedent brain activity – spontaneous urge relation is used as evidence, together with postdictive factors influence over decisional outcomes (Bear & Bloom, 2016). The notion of free will as a feeling is not as foreign as it might first appear, other cognitive aspects have been labeled as feelings as well, such as feelings of knowing, familiarity, and confusion (Wegner, 2004).

3.5. RP Status and fMRI-classifier Findings

The studies, and reviews, document some clear antecedent activity. The most prominent one is the RP-urge phenomenon, popularized by (Libet, 1985). Although, subsequent experiments replicated Libet's result (Fried et al., 2011), modifications to the experimental design highlighted discrepancies and other aspects of the RP. First, Schultze-Kraft et al. (2016) showed that the veto effect was real and provided a clear timepoint of 200ms. Alexander et al. (2016) dissociated the RP from motor planning, which is the environment the RP is usually measured in. Decoupling the RP from encapsulating decisional properties is a major blow to Libet's paradigm. Additionally, Schurger et al. (2012) work with the stochastic-decision model, shows that the RP phenomenon can be interpreted in a way that provides a different conclusion – that the RP reflects a background state that has no decisional power/properties and that subjects' reports could therefore reflect the emergence of a realized decision. From this data, Libet's conclusion can be seriously questioned, though his emphasis on the veto effect remain relevant. Lau et al. (2007), shows that TMS administration sheds light on the temporal dissociation of the feeling aspects of free will. Intentions being based, at least partly, on brain activity taking place after an action.

fMRI-based studies, using pattern classifier analysis, have shown neuronal correlates (e.g. medial prefrontal cortex and precuneus) as well as predictive activity in these areas (Soon et al., 2008; Bode et al., 2011; Soon et al., 2013; Bode et al., 2013), above chance predictions, up to 9s prior to awareness of an urge. These findings mainly show that there exists probabilistic activity up to 9s prior to the urge (Roskies & Nahmias, 2016). Data is used to construct possible functions for brain areas (i.e. their role in decision making) by looking at the flow of temporal activation. fMRI-classifier capability has been used to expand the observed perspective of the free will phenomenon. For example, Soon et al. (2013) utilized the technology to look at more abstract aspects of spontaneous decisions (subtraction/addition).

3.6. The WWW-Model

The preSMA area corresponds to the WWW-model in the Lau et al. (2007), Fried et al. (2011), and Soon et al. (2008,2013) studies (*when-component*), though the Trevena and Miller (2010) and Alexander et al. (2016) studies suggest anticipatory and sustained attention as functions related to the preSMA. The predictive activity in the posterior cingulate cortex also corresponds to the WWW-model (*what-component*). The predictive activity in the frontopolar cortex, precuneus/lateral occipital complex, however, does not (Soon et al., 2008; Bode et al., 2011; Soon et al., 2013; Bode et al., 2013). Additionally, Soon et al., (2013) reported a correlation with the angular gyrus (which is connected to the precuneus) and the moment when a decision was ‘felt’. There could be a relation between the increased spiking in the anterior cingulate cortex generated after the urge (Fried et al., 2011) and the BOLD-signal found in the angular gyrus.

Zapparoli et al. (2017) review of the WWW-model did include additional brain areas. The TPJ connects to the supramarginal gyrus and the insula with the posterior cingulate cortex. Though, this still leaves the frontopolar cortex and precuneus excluded from the expanded WWW-model. The frontopolar cortex has been related to delayed intentions which are notable because the experiments measured spontaneous decisions. The activity in the parietal areas could potentially be related to the proximal TPJ which has shown correlated bold activity with agency, especially the function of differentiating self-caused and other-caused actions (Brass et al., 2013). The feeling component of decision making may thus correspond to the moment when the causal system reaches an outcome of ownership. The precuneus association with imagining future events suggests that it may process long-term aspects of decisions (Schacter & Addis, 2007), and that parietal areas may be involved in the behavior of simulating random choices (Brass et al., 2013).

3.7. Antecedent Activity – Libertarianism, Compatibilism, and Determinism

Documented antecedent activity does not mean that conscious will cannot precede a decision. The contrary, is in fact most often reported. It is when the experiment is very restricted and controlled that the antecedents can be detected. The commonsense view can be considered an illusion, because this view entails a causal power that has not been detected (*causa sui*), although, evidence has not confirmed determinism either. The subjective feeling of agents having control over their non-restricted environment is taken as stronger evidence than that for determinism (Racine, 2017). The compatibilist view (some positions) would state that free will is still realized even if antecedent activity 100% predicted an action hours prior, as long as the causal locus is predominantly within the brain.

For determinism to be proven true, the antecedent activity must ‘determine’ the decision outcome (i.e. the outcome cannot be avoided) (Nachev & Hacker, 2014). This reveals a curios dilemma, namely that: If antecedent activity is observed that with 100% lead to a specified decisional outcome, can the researcher then, with the foresight bestowed by the brain measurement, sway the outcome? If the answer to this question is yes, is the conclusion then that determinacy is only valid for undisturbed or closed systems? In practice it is essentially impossible to test whether a decision is determined or not (i.e. infinite regress).

The veto is only operational up to 200ms, which can be interpreted as actions becoming determined 200ms before they occur (Schultze-Kraft et al., 2016).

Schurger et al. (2012) data can be interpreted as complexity formed by several variables (i.e. computationally unpredictable). The distinction is made between the activity before threshold crossing (intention) and after (commitment), where the commitment component is associated with finality of the action (i.e. where the veto function is not available anymore) (Schurger et al., 2016). The lines between determinism, libertarianism and compatibilism become less tangible when antecedent activity is included into the discussion.

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4.0 Scientific Designs and Analysis

4.1. Problematic Interpretations

Looking at brain activation with the goal of finding specific antecedent brain areas may construe the fact that several brain areas may contribute information at different times in a parallel system (hence looking at just the earliest antecedent poses the risk of neglecting vital information provided by latter antecedent activity) (Nachev & Hacker, 2014). If a fMRI-imaging session revealed 5s antecedent activity in the amygdala (related to fear) and 3s in the insula (related to disgust). Would you interpret that the subject only felt fear due to the amygdala being the earliest antecedent and, would increased insula activation eventually overrule the fear feeling?

Schurger et al. (2016) adds the distinction between prediction and forecasting, where prediction denotes a future commitment to act and forecasting denotes a probabilistic statement about future possible actions. Suggesting that intention can be associated with forecasting and prediction with deciding. Bode et al. (2013) results point out shared characteristics between guesses and free choices, which raises the question of what is being predicted in the fMRI-based classifier experiments. What is the significance of predicting a binary guess at 57% accuracy? Additionally, what is the statistical and epistemological significance of 57%? A doctor that could with 57% accuracy diagnose the likelihood of a disease, would not be credible.

Regarding the classical RP interpretation and time-locking trials, imagine that one would want to infer the ingredients used to bake a cake, and one could only investigate the pantry before, during and after the cake being baked. You have observed that there were fewer eggs in the pantry afterwards, compared to before and declare that eggs are an essential part of cakes - a precursor to the cake itself. What is neglected, is that the pantry is used throughout the day, besides the times it is used to supply ingredients for cakes. Eggs are used besides baking cakes. Restricting the time-window that you examine the ingredients in the pantry is comparable to how the RP is restrictively examined in the EEG-trials**.**

4.2. Methodological Issues in the Libet Paradigm

The experimental limitations severely restrict what conclusions you can draw from the results. The short trials (10-30 seconds) cannot be generalizable to long-term decisions. Long-term decisions, which require deliberation, could involve different brain mechanisms (Lavazza, 2016). Currently, all the experiments rely solely on spontaneous decisions. Spontaneity excludes planning (e.g. writing an academic essay), which exhibit similarities with guesses (Bode et al., 2013). Thus making it difficult to judge how spontaneous decisions based on urges generalize. The pre-test used in the fMRI-based classifiers studies (except, Bode et al., 2013, due to it not being reliant on choice distribution) could confound the results. Subjects were only allowed to participate if their choice behavior fulfilled the right frequency and temporal criteria. Similarly, Trevena and Miller (2010) gave instructions to the subjects to spontaneously choose one of the two alternatives an equal amount of times (50/50). There are potential demand characteristics of simulating random 50/50 choice behavior. Only one type of spontaneous choice is thus measured, the one fitted by the criteria. The models, in the fMRI experiments, are hence trained to solely predict patterns of this type. The classifiers would not be good at predicting outlier choice behavior (e.g. subject abstaining from choice).

Comparing an act with a brain state leaves the results vulnerable to confirmation bias. Schurger et al. (2016) discussed this through the lens of false- and true positive rate. Time-locking the trials only gather data on the true-positive rate. For false-positive rate data to be collected, the trials mustn't be time-locked. If you measure the RP's relation to free motor movements, you must calculate several conditions: RP + urge, RP + NO-urge, NO-RP +NO-urge, and NO-RP + NO-urge. Consider this in relation to whether older people are more likely to be run over at cross walks. For this hypothesis to be tested, you must gather data on driving accidents at cross-walks, but also collect data on the instances where no accidents occur (i.e. all the times elderly people pass cross-walks without an ensuing accident). It could simply be the case that elderly are more likely to use cross walks (i.e. younger people may drive more often or jaywalk). Most of the experiments analyzed the predictive accuracy after the trials were over (e.g. Soon et al., 2008), which makes using the word prediction somewhat misleading (prediction implicitly states that the event that is being predicted has not occurred already). Predicting a violent outburst is only useful/preventative if it is reported before the target behavior.

Individual differences between urges and movement onset have been reported. Averaging the urge reports of a sample can construe the result (averaging removes outliers). Averaging is only valuable if the average is a good representation of the measured phenomenon. If the average reported urge occurs before muscle activity, but a substantial percentage of subjects did not exhibit this pattern, a time average would *de facto* be telling a functional lie about the antecedent brain activity – spontaneous urge relation. Marked individual differences between the urge and movement onset has been reported, and Caspar and Cleeremans, (2015) showed that one of the deciding factors for these differences are personality traits, such as impulsiveness. Though not the norm, some subjects report that their urge arises after movement initiation (Trevena & Miller, 2010), and untrained subject display a higher tendency to report the urge after the motor movement has begun (Dominik et al., 2017). At best, this hints at that Libet paradigm experiments are difficult to execute or that some subjects are unskilled at introspection. At worst, judging arising urges of spontaneous muscle movements are a fruitless endeavor.

4.3. Experimental Lessons and Approaches

Uniquely, Schultze-Kraft et al. (2016), gamified their BCI experiment (Limit of the veto effect) and Lau et al. (2007) utilized TMS. These novel approaches illustrate the possibilities of designing an illuminating experiment. Identifying a problem is significantly easier than solving it, especially when a solution requires that several groups agrees. An experiment by Anderson et al. (2004), showed that it is possible to study monkeys' intentions (*Rhesus*) with implanted electrodes. The monkeys were trained to think of a movement pattern without performing any movement. A specific neuronal pattern (spikes) was discerned for each trained movement pattern and these could be used as markers for intention of performing that movement. This study shows that collecting data from conditions consisting of only planning and conditions consisting of planning together with action is feasible. A condition where only actions are recorded (i.e. spontaneous decisions) could be included as well. These three conditions could then be compared with each other and could potentially show if planning occurs prior to movement and if representations are necessary for the execution. However, it is impossible to collect reports from monkeys, since they cannot report about their introspection.

The decision should *matter* to the subjects, hence not being spontaneous. Apropos the fruit platter, the decision is only meaningful if the subject care about the outcome (i.e. consistent results in relation to a meaningless choice does not necessarily illuminate anything). Emphasizing the meaningfulness of decisions is an integral part of future experiments. Regarding the false-positive omissions, the experimental design must gather data that can be used to compare if the classifier patterns were active other times than before the predicted event.

The prospects of switching focus from short decisions to types of long-term decisions should be considered. Perhaps classifiers could be used to predict the second or third choice in a decision chain (instead of just the first). Classifiers could attempt to predict chess moves ahead of time. Additionally, classifiers could predict a subjects' forthcoming chess moves and then TMS-administration could be utilized to make the subject choose otherwise (e.g. moving the queen instead of the king), in the same fashion as when nerve stimulation induces muscle movements - then attitudes would change. Finally, perhaps predictive information could be used to train subjects. For instance, by influencing their brain activity so that it more closely resembles that of a field expert (e.g. professional painter).

4.4. Libet Criticism from a Contemporary Perspective

Comparisons between Libet's classical experiments and contemporary studies show that some of the criticism points are still valid and relevant. The reliability of the subject's own reports is still taken, to some degree, at face value. However, it has been shown that subjects vary significantly with their reports and may even interchange the felt urge and the onset of the motor movement (Dominik et al., 2017). The reviewed studies do not really control for this possibility. The subjects are still tasked with performing two different tasks simultaneously – making spontaneous choices and noting their temporal properties. The precision of the subjects' reports, however, have been increased, as can be seen with the stream of letters experimental setup (see *figure 4*) (Soon et al., 2008). All the data is still time-locked, by trials. Hence, only true-positive data is recorded (Fried et al., 2011; Schultze-Kraft et al., 2016). It is unclear how one should interpret the experiments utilizing fMRI-based classifier because time-locking also occurs in their designs (e.g. Bode et al., 2013).

Prior choice bias is reported as being amended in the fMRI-classifier studies (e.g. Bode et al., 2011), by waiting for the normalization of the BOLD-signal. Temporal affordance was calculated and measured in some of the presented studies (e.g. Soon et al., 2008; Fried et al., 2011). Though not as accurate as the task affordance calculations, the introduction of classifiers seems to have significantly alleviated this problem. It can be argued that temporal affordance should receive higher priority in the experimental designs. There are still reports on the RP not occurring before the urge report. Furthermore, some subjects don’t even show a general RP pattern. Schurger et al. (2012) excluded those subjects from his analysis and this could have altered the study’s results.

5.0 Conceptual Discrepancies in the Science of Free Will

5.1. Heterogeneous Landscape

The conclusion derived from the free will research is DEPENDENT on the pre-held position of the interpreters. If the body is not externally restricted, free will, in the way that matters, is realized and existing (Dennett, 1993). Demarcation points are placed at different places, i.a., the brain (Fischborn, 2016), the brain together with its bodily interactions (e.g. heart activity) (Schurger & Uithol, 2015), or psychological mechanisms (Lavazza, 2016), controllable variability (Brembs, 2011), and beyond (Roskies & Nahmias, 2016) (See *figure 5*). Generally, neuroscience looks at the brain (Brass et al., 2013), whilst psychology looks at behavior (Lavazza, 2016; Wegner, 2004), and philosophy (Kane, 2011) looks at introspection and logic. Perhaps the research field you inhabit shapes your view of free will. Due to the knowledge of one level being overcompensated. Knowing a lot of psychology compared to neuroscience would potentially shape your view of free will to be about executive functions (Bohm & Peat, 2010).

The ongoing debate about free will often takes one of the two following forms: either for or against a position (Brembs, 2011; Esfeld, 2017; Fischborn, 2016; Klemm, 2010; Lavazza, 2016; Libet, 1999; Pockett, 2013; Wegner, 2004). The veto-based view can only claim to provide a valid account of free will IF the definition used for it is accepted. Creating a new definition of a term as a means for understanding it carries risks of creating more discrepancies because the assumptions embedded are still there.

There are several demarcation factors besides emphasized level (e.g. the physics of the wave function and neural networks). Brembs (2011) and Lavazza (2016) free will propositions operate on a spectrum (i.e. they can decrease and increase in their respective magnitude). The free won't and libertarian positions are either-or in their structure, free will as perception and a feeling is also either-or, but the positions dissociate from the causal aspects, whilst the free won't and executive based positions greatly emphasizes the conscious part. Bonn (2013) re-conceptualization prioritizes the unconscious and underlying uniqueness between individuals, whilst the instrumentalist account operates on wellbeing-based imperatives. Furthermore, how the positions are operationalized and measured is an additional demarcation point. The executive function would be measured by the proficiency of the executive system (e.g. the marshmallow test) whilst the instrumentalist's account would measure wellbeing (e.g. positive and negative affect schedule) (Watson, Clark, & Tellegen, 1988).

This heterogeneous landscape of positions can be thought of in terms of levels of abstraction (i.e. a system can be described on several levels where lower levels include information of processes that higher levels only take at face value), where some of these views can describe different levels of the same system (e.g. behavior contra neuronal networks) (Shepherd, 2015). The free will positions place unevenly on the determinism/indeterminism diagram (see *figure 2*). This is an additional demarcation point besides proximity (see *figure 5*). If the root of the disagreement is holding different free will positions, this can be solved by systematizing and communicating these differences found between the positions (the demarcation points). If published articles stated their position, readers would understand how the evidence related to other positions.

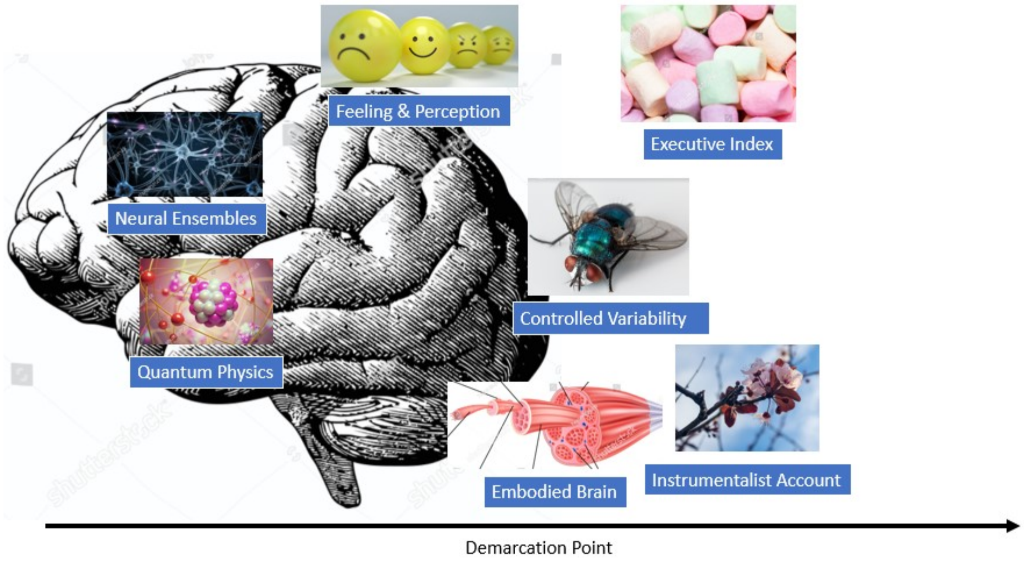

Figure 5. An illustration of different free will positions and their proximity to the brain. The pictures are symbolic of the positions (not official). Proximity is one of the variables between the positions that can serve as demarcation points. Which one of the positions are affected by the Libet style experiments (i.e. antecedent activity)?

5.2. Control and Defending What Matters

Through introspection, one can observe thoughts and feelings simply arise. There is no deliberation over what thoughts occupy the mind. What decides our attitudes and motivations spontaneously appear, and we can only consciously notice them – in this sense free will is an illusion independent of antecedent brain activity. A retort to this view is that: if free will is an illusion, then decisions and actions are meaningless. This has been defended by acknowledging that it is impossible to not make decisions and that the consequences have to be experienced none the less (Harris, 2012). The discovery of leptin and ghrelin, hormones that regulate appetite, does not make the prospects of eating something seize to matter. Perhaps, it is up to the individual to decide if the subjective experience matters and in what way. Similar to existential nihilism - cosmic uncertainty about the meaning of life, provides opportunity to find another meaning (Schiemann, 2016).

Nahmias, Shepard, and Reuter (2014) reports that subjects don't feel that their free will is being compromised by predictive brain activity. What matters is whether someone uses the predicative data to manipulate them. However, it has been shown that swaying a subject's free will belief can alter the preceding RP-wave (lower early amplitude) (Rigoni, Kühn, Sartori, & Brass, 2011) and affect attitudes towards retributive punishments (Shariff et al., 2014). Perchance, no amount of predictive activity would matter, in regard to the subjects, as long as the feeling of ownership is intact, making that feeling the imperative factor.

Thought experiments (e.g. metaphors) and empirical experiments highlights where peoples' views lie, by leveraging their intuitions towards a specific issue. Thought experiments allow for the simulation of an ideal context where all the confounding variables are controlled for (e.g. for or against the death penalty) (Brendel, 2004). Thought experiments can be utilized when formulating the free will positions. In moral philosophy, there are several positions from which to interpret moral questions, such as utilitarianism and deontology. Hopefully, the same could be the case for free will discourse eventually.

Some of the articles give the impression of 'defending' something precious, even using the word *rescue* in the title (Hameroff, 2012). The belief is that something of great importance is lost if the commonsense view is declared illusory or even different. This goes against the fundamental values of science, where evidence should be given precedence over beliefs. Scientific consensus reports that a perceived lack of control over the environment can lead to psychological distress (e.g. social anxiety disorder) (Keeton, Perry-Jenkins, & Sayer, 2008), whilst making choices induces positive emotions (Brass et al., 2013).

Studies have shown that the brain actively synchronizes our experience of touch together with other senses, such as vision, which can give us the false perception of both occurring simultaneously. For example, the brain actively synchronizes the voice to the speaker's lip movements, a mechanism which can cease to work (Murray & Wallace, 2011;

Park, Kayser, Thut, & Gross, 2016). However, facts of perceptual temporal illusions do not induce any feeling of something being lost (the notion of living in the presence) and it does not induce an instinctual defensive response. The antecedent part itself is not what compels people to defend *causa sui* types of free will *per se*. When the brain synchronizes the different senses into perception the slowest sense determines when the percept is available as qualia. A consequence of the brain computing perception in this manner is that the human perception experience is perceptually approximately 80ms in the past (Eagleman, 2008). Essentially there is no such thing as experiencing the presence. Although our brain tells us, in several ways, that we live in the present in a similar manner to the way it tells us that we author decisions. In the synchronizing process, if the input from two senses is separated by more than 80ms, they are experienced separately (i.e. as two distinct percepts) (Eagleman, 2008). This can be interpreted as the brain outputting percepts in an either-or format, despite the original source not consisting of those properties. Thus, we know that the brain does not depict the world as accurate as might *prima facie* be the case.

Defining the free will concept scientifically, so that it is measurable (e.g. degrees of variability), is only a solution if what people care about IS measured, which is the feeling of being the causer. Most would not equate less inhibition or decreased creativity to less freedom. There is a clear distinction between defining free will as what one wants it to be, motivated by, just deserts, child rearing, and what it veritably is (i.e. infer from evidence). The reason free will is defended is because the very notion of control is threatened. Control is a fundamental psychological need (Maslow's hierarchy of needs) (Koltko-Rivera, 2006). Leotti, Lyengar, and Ochsner (2010) argues that control is imperative for survival, hence there exists and an adaptive behavior to restore it if its compromised. Panic and epileptic disorders are negatively correlated with the belief in free will, as well as the need to urinate (Ent & Baumeister, 2014). Thus, the free will positions are demonstrably flexible. Should the definition of a concept change based on physical needs? It has been shown that when there is an emotional attachment to a position which is dependent on facts – facts pointing at different conclusions are often ignored. This is one form of *confirmation bias* (e.g. climate change) (Kaplan, Gimbel, & Harris, 2016; Peter & Koch, 2016).

5.3. Future of Antecedent Research

The knowledge gained whilst elucidating the age-old enigma of the will's relation to its environment can be utilized within several sectors. Putting emphasis on the feeling aspect of free will can be useful for treating and identifying disorders where that feeling is compromised (e.g. alien hand syndrome, dissociative personality disorder and schizophrenia) (Sass, 2011), with potential earlier diagnosis. In relation to dementia diseases, measures of agency could be used in relation to caregivers (i.e. if and to what degree a caregiver should be implemented into the patient's life). The compatibilist position that emphasizes brain activity can be used as a model for whether the volitional system is damaged by applying executive function tests that measure working memory, attention, and inhibition.

Increased emphasis on interdisciplinary research would serve the scientific community. The degree of interdisciplinary communication is hard to decipher due to journal restriction on the format (e.g. a neuroscience-based journal may not want to publish an article discussing philosophy). Terms will be used for a concept which has traditionally been applied within that research program, therefore accelerating assumption heterogeneity. Research fields can also benefit from a philosophical approach, such as applying conceptual analysis (Nachev & Hacker, 2014). This would hopefully lessen the degree to which scientists misunderstand each other. Perhaps lessons can be learned from other research fields. For instance: intelligence has several definitions and the evidence is only relevant for some of the definitions. Discovering new genes that correlate highly with IQ, might be negatively correlated with other aspects of intelligence (e.g. social aptitude). A practiced approach is to divide intelligence into categories such as multiple intelligences and general intelligence (IQ) (Gaikwad & Bharathi, 2018).

The current research that works on models where the RP is not time locked (Schurger & Uithol, 2015; Schurger et al., 2016) can be viewed as a change in fundamental assumptions (i.e. a paradigm shift) with regard to the research program. From the kuhnean perspective, the Libet paradigm accumulated too many anomalies. Instead of discovering the false assumptions, a research program is motivated, due to false assumptions, to invent ad-hoc solutions. Research field integration would dissuade false assumptions by forcing transparency (Kuhn, 1970).

5.4. Free Will as a Metacognitive Feeling

The antecedent evidence against libertarianism and determinism has put these viewpoints in a precarious position. The essence seems to either lie with control, which leads to some type of compatibilism, or causal force, either ultimate (libertarian free will) or none (determinism). Ceasing and deciding upon generated options (veto-effect) is a type of time-restricted compatibilism, where the free won't occupy the domain wherein an action can be inhibited. These views are incoherent because free decisions necessitate that we have control of our thoughts and feelings, which we conclusively do not (Harris, 2012). Leaving free will to be an illusion by either considering it as a cognitive feeling or a type of perception.

No one doubts that a healthy person feels that she is the owner and causer of her actions. The evidence supports a two systems view of decision making, where one system is responsible for making decisions and the other interprets ownership over actions. The metacognitive concept (thinking about thinking), has already established this division. The feeling only interprets ownership. The individual differences found in hypnosis and choice blindness (Johansson et al., 2005; Wegner, 2004) shows that the mental interpretation system is expressed as a skill, meaning that it can be expressed on a normal distribution curve (i.e. non-binary). Individual differences have also been reported in Libet style experiments in relation to urges and spontaneous movements. Some subjects (outliers) reported that their urge arose after the movement initiation (Trevena & Miller, 2010), which has been correlated with impulsiveness (Caspar & Cleeremans, 2015). Additionally, impulsivity has been negatively correlated with time perception ability (Vasile, 2015), which is a cognitive feeling (Wegner, 2004). Libet style experiments may thus measure the mental interpretation system – a metacognitive skill, which explains why performance varies (the same as impulsiveness). Similar neural correlates have been found for metacognition (prospective judgments) and spontaneous choices - parts of the mPFC (Fleming & Dolan, 2012). The post-decision angular gyrus activity could correspond to the feeling of ownership (Soon et al., 2013), the final report from the mental interpretation system. Regarding the alien hand syndrome, it seems more likely that the mental interpretation system has dissociated from one of the arms, then that the arm suddenly received a free will of its own. A criticism towards the metacognitive perspective is that it only shifts the focus towards mechanisms we don't understand - areas that are separated from the metacognitive system (i.e. since we cannot find free will's origin it is defined as free) (Bode et al., 2014). Perhaps this relationship can be clarified by comparing metacognitive judgments of time perception to the urge for motor movements (in a Libet trial). Free will as a causal factor is an illusion, but as a feeling, it reports the state of our agency as organisms. Further research will clarify if the metacognitive approach has the most explanatory power.

Psychologically, free will makes sense precisely because it is a feeling. It is important for wellbeing and life success. In sports psychology, it is known that confidence is a deciding factor when it comes to athletic endeavors (Gill, Williams, & Reifsteck, 2017). Confidence ensures that you reach your actual capability, whereas doubt will diminish your performance. This aligns with the belief in free will altering subjects' behavior (Vohs & Schooler, 2008). This description of free will resembles Wegner (2004) and shares characteristics with the metacognitive definition (Fleming & Lau, 2014). In conclusion, when choosing the fruit from the plate, what matters is not that we are causal entities, but that our intentions are sufficiently fulfilled, which leads to overall wellbeing and contentment - a feeling that is undeniable.

6.0 Conclusion

The first aim, the investigation of the Libet paradigm, shows that research on the antecedent brain activity – spontaneous urge relation is generalizable and transferable to additional technologies (EEG, fMRI, ERPs & neuronal spiking) and experimental setups (e.g. spontaneous choice selection of abstract concepts). Libet's interpretation of the RP as representing motor planning has seen considerable resistance by falsifications (e.g. Alexander et al., 2016) and alternative interpretations (Schurger et al., 2012). How results from contemporary Libet style studies should be interpreted, epistemological significance of probability, is the pivotal issue.

The second aim is concerned with the constitution and application of the free will concept in relation to free will research. The review shows that empirical studies often avoid communicating their position, whilst various discussion articles attempt to justify a specific position or compose arguments against another. This pattern suggests that antecedent activity research serves to upregulate alternative views of free will, that are not dependent on antecedent activity at all. Or a position is defined so that it is only falsified and refuted by documenting 100% predictability.

Experimental limitations illustrate how a theory can be corroborated dependent on the study design (e.g. time-locked trials). Progress could be improved by facilitating interdisciplinary research and change focus towards researching long-term decisions.
The diverse interpretations are one of the factors enabling the heterogeneous landscape of free will positions. The positions are separated by demarcation points which largely revolve around proximity and indeterminacy requirements, as well as more philosophical departures. It is discussed how the systematizing of these demarcation points can amend communication issues.

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