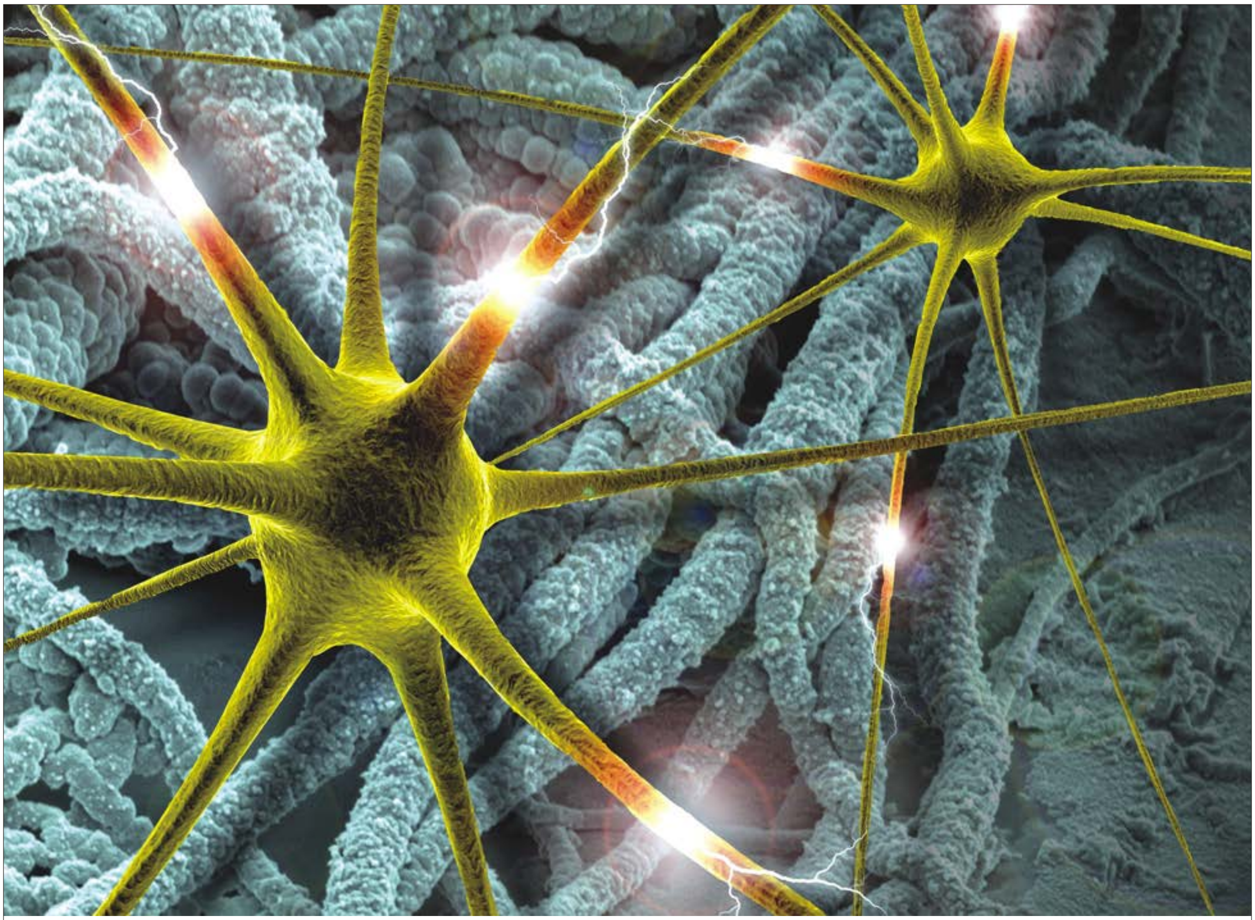

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Review Article
Understanding the Neural Basis of Intention

Andrew Ewanlen Aigbedion

University of Ibadan, Oyo State, Nigeria

Abstract

We execute millions of actions in our daily activities. Little attention is paid to them because they are mostly carried out unconsciously. We take for granted that they are mostly generated with in the neural circuit in form of intention. In other words, intention has been central to describing and explaining human goal directed behaviour. The neural mechanisms and basis of forming, maintaining/deactivation, execution/implementing remains a fundamental issue unresolved which is the focus of this review. However, the available experimental evidence casts doubts on simulation theory and alternative interpreted accounts. This review introduce the level of intensity of stimuli, previous experience as the rational encompassing the totality of human intention with no particular defined neural circuit for the above unresolved issues. These scenarios are describe with vary examples from experimental evidences available. Finally, this study discusses the need for more descriptive and "life-like" experimental models not yet attempted to be simulated. This could provide more neurological explanation involving more brain areas and connections.

Key words: Emotion, action, mirror neurons, motor cognition, intention, neural circuit

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Corresponding Author: Andrew Ewanlen Aigbedion, University of Ibadan, Oyo State, Nigeria

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INTRODUCTION

The conception to the facts surrounding intentions have been a key to explaining the ultimate behavior of human goal. The brain carries out interacting steps, which are modulated by external influences, which affect how we plan, store and implement intentions. Such implementations are immediate, other cases delayed. In cognitive neuroscience from Libet[1], it is believed that there is a relation between conscious intentions and actions. Although, several experiment work has concerned the use of brain imaging to identify human intention[2,3] and those involving non-human primates have identified frontal, parietal areas and sensorimotor control of intentions[4]. In addition, executing intended actions is related to volitional processes. Thus, describing and explaining the processes involved with building intentions to implementing them is a complex conceptual and empirical challenge that is, so far, studied by rarely cross-talking fields of study.

However, in spite of the advances of recent neurophysiological techniques and imaging techniques and their important contribution to the clarification of the basic mechanisms underlying intentional actions, there are still some fundamental issues that remain unresolved.

Therefore, understanding the neural pathway of intentions is a crucial part of building neural prosthetics to aid paralyzed patients[5].

Examples are:

- How are intention formed (e.g., the role of episodic future thinking in the formation of intentions)?
- How are intention maintained (e.g., the role of episodic and working memory)?
- How are intentions executed and later deactivated in the face of competing goals?
- What are the mechanisms and the neural basis of forming and implementing intentions and are those for immediate versus delayed intentions differ?

The main goal of the present review is to provide possible connections on the mechanisms and neural basis of forming and implementing intentions.

How intentions are formed: Intentions are formed from the stimulation of physical features of the current environment, processed primarily through the visual areas of the brain and the tactile, auditory and olfactory areas. The neural anatomy representing the formation of intention in the brain includes sensory cortex, Pre-Frontal Cortex (PFC), the basal ganglia, the amygdala, Anterior Cingulate Cortex (ACC) and the Supplementary Motor Area (SMA). The formation of intention receives input entirely through the sensory cortex, which triggers patterns of firing for the different stimuli (visual, auditory, tactile and olfactory) and the output signal often is the Supplementary Motor Area (SMA) which upon activation; measured with EEG correlates with the urge to start an action[1,6]. Although, we continually monitor others behaviours and interprets them as intentions to their ultimate action, the functional mechanisms and neural circuits involved remain highly controversial[7,8]. The formation of intentions can be attributed to two postulated theories:

- Simulation theory which assumes that we build our observed behaviour through a direct matching process that activates the mirror- neuron circuit[9,10]
- The alternative interpretative account assumes intention build up is based on specialized inferential process activating brain areas with no mirror properties[11,12]

According to the simulation theory finding: mirror neurons are in the premotor cortex of the macaque monkey[13,14]. Mirror neuron is active when the monkey observes or executes the same action; it provides the neural basis for action understanding through motor simulation[15,16]. Recent FMRI and TMS study indicates that areas assumed to contribute to the human mirror system (Inferior frontal gyrus and inferior parietal cortex) are involved in it[17,18]. More recently, it has proposed that the premotor mirror-neuron areas are sensitive to context effects on intention recognition and are also involved in understanding the (global) intentions of others in which intention is interpreted to indicate the way of an action[17,19].

However, the other theory assumes that intention formation is at its core an inferential process that assigns intention to an action by evaluating its efficiency as an optimal means of obtaining the goal within the specific constraints of the situation[11,12,20]. This model assumes that the neural mechanisms of action understanding involve context-sensitive inferential processes of rationalization or metalizing that are based on the visual processing of the stimuli[6,10,21]. Such mechanisms have been consistently related to regions along the Superior Temporal Sulcus (STS), the temporoparietal junction (TPJ), the anterior fronto-median cortex and the posterior cingulate cortex[21-24] which are brain areas lacking mirror properties. From the theories above, we can say, stimuli coming in relation to the world constituted by relations to perceptual, motor and emotional information form intentions. These, when bound together can cause action through routing this information to the motor system. The pattern of spikes from these phenomena binds together neural representations of situations and their evaluations to produce actions. The spiking activities of these phenomena rely on neural pattern transitions embedded between the respective populations of neurons. The combination of these phenomena to form a unified program of activity can thus be regarded as intention. Therefore, the tenets in intention formation include the physical features of the current environment which are comprehended through the visual areas of the brain and sometimes by olfactory, auditory and tactile areas. Importantly, the emotional system of the brain constantly evaluates situations which scientifically can be proven to be an important building block of intentions. The part of the brain associated with the emotion system (but are not limited to) the amygdala, insula, ventromedial prefrontal cortex and the nucleus accumbens. The emotional system is a reflection of the state of emotions like fear, aggression; guilt and shame which is the product of sensorimotor experience play a major role in intention priming. For example, an individual may want to help a drowning child but may be held back due to his inability to swim. There are other ways situations are represented as the choice of behaviours in situations is equally strongly constrained by culturally shared knowledge about identities and social institutions[25]. Neuroscientific evidence corroborates the notion of a non-verbal "action vocabulary" in pre-motor cortex, consisting of abstract representations of underlying motor programs in relation to goals[10,26,27]. Also, there is an ample verifiable evidence for verbal concepts to facilitate mental simulations of movements as well as the action itself[28]. The stimuli from the environment serve as an input to the sensory cortex. This channel the information gathered to the amygdala. Basically, the action potential from the ACC terminate at the SMA, which has been experimentally proven upon activation, measured with EEG correlates with participants reporting a felt "urge" to start an action.

How intentions are maintained: Still based on the intensity of the stimuli being released, normally when a stimuli transmit an impulse, it passes through automatic pathway e.g., if an individual is offered a gift such as the "cigarette", automatic pathway will perform it's default action to accept "take" and triggers exactly the same activity in the Anterior Cingulate Cortex (ACC) which is then passed to the working memory [Pre Frontal Cortex (PFC)]. However, the basal ganglia have a conversion command that smoking is unhealthy (representing explicit knowledge). Also, there is a conversion rule between [Pre-Frontal Cortex (PFC)] and the amygdala that anything unhealthy is bad, thus overriding the initial pathway of taking the gift (cigarette) as good. The presence of this negative judgement or abstraction stops the acceptance ("Take") action from being passed from the Anterior Cingulate Cortex (ACC) to the Supplementary Motor Area (SMA), invariably preventing the action from occurring. This can be attributed to an instance of successful self-control[29]. This is in accordance with the proposed theory by Norman and Shallice[30] that actions under conscious control involve a competition mechanism in addition to those used in automatic actions.

How are intentions executed and later deactivated in the face of competing goals: In an attempt to understand the phenomenon, studies in the brain imaging paradigm investigated in adult human subjects whether action understanding in novel situations involves the mirror network or the inferential reasoning network. In this context, participants saw unusual actions (e.g., operating a light switch with the knee) in three different contexts. In the "plausible-constraint" context (hands plausibly occupied), the model's hand were occupied (she was carrying a stack of heavy folders), thus making it plausible why she had to use her knee to operate the switch. In the "implausible-constraint" context (hands implausibly occupied), the model's hands were also occupied but in a way that provided no plausible reason for why she used her knee instead of her hands (carrying only one light folder she could have easily liberated one hand to operate the switch). In the "no-constraint" context (hands free), the model's hands were unoccupied (so she was free to use them to switch on the light). However, the outcome of these findings showed that in individuals with vary plausibility had to execute the action with their knee due to her trying to ensure the heavy folders taken is not damaged in the process, while in the hands free individual, because there was no competing goal, the initial intention of switching on the light with the hands was done. In an attempt to answer this question, the simulation theory of Cunnington and Schroder when compared to show a neural difference between a free choice and a forced response; more neural activity is seen in the Pre Frontal Cortex (PFC) and Basal Ganglia (BG) when making a free choice than in the forced condition while the PFC is only strongly active when making a free choice[31]. Furthermore, using the analogy given above, an intention can later be deactivated in the face of a competing goal. This is possible where there is a heavy cognitive load that stops the deliberative pathway from overriding the automatic pathway[32]. For example, when individual is under pressure to work and meet up with a target, the PFC contains the pattern for work and will continue thinking about work. Therefore when offered a gift (cigarette) and the information (stimuli) is presented to the sensory cortex, the spiking activity for "Take and smoke" is weakly transferred to the PFC due to the pressure on the spiking neurons for work. Thus, deliberative pathway will not pass it's assessment on to the amygdala and ACC, hence the automatic "Take" action will occur. Thus, an individual distracted by thinking about other things (high cognitive) will not follow through on the intention to avoid smoking. Finally, the basal ganglia area allows the individual to choose one action out of a list of possible actions.

CONCLUSION

Although, intention has been traced to the theories stated above, from the experimental study stated above, the mirror network seems to play a role only in situations in which no active inferential processing is required to identify the goal of the observed behaviour because with the action and its stereotypic context are highly familiar and map onto corresponding motor schemes already represented in the observer's action repertoire. This can potentiate as a foundation for the understanding that the neural basis for the formation and execution/implementing of immediate intention can be likened to the mirror neuron circuit which differ from the delayed intention believed to be carried out by other brain areas other than the mirror neurons.

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