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### Sculpting the space of actions: explaining human action by integrating intentions and mechanisms

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## 2 MOTOR INTENTIONS: THE FIRST STEP IN THE HIERARCHY, OR NOT?

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Building up our account of intentional action by starting from motor intentions and gradually developing it into a more complex and dynamic account, may raise some questions. Why, indeed, aren't we adopting the order of the cascade of intentions and don't we start with the distal – future directed – intentions? Shouldn't we agree with Bratman, who denies such priority of motor intentions by contending: “not that there are no present-directed intentions, but that to understand what intentions are we should begin by concentrating on the future-directed case. This is the methodological priority of future-directed intention” (Bratman 1984 379)? If an opera singer is to perform a particular role at a particular time and place at all, this intentional action can only occur if his distal intentions have priority over his proximal and motor intentions.

The nature or role of intentions is manifold, as was mentioned above. For Bratman and other philosophers of action, however, intentions are foremost ‘terminators of practical reasoning’, when reasoning has culminated in the formulation of an intention to act sometime in the future – near or distant. Another important role intentions play is as ‘prompters of practical reasoning’ when decisions about means-end relations have to be made, pertaining to a current situation. Third, they also contribute to the coordination and organization of action (Pacherie 2006). All three roles depend upon their being future-directed, rather than being directed only at a present situation. To the extent that intentions are necessary for coordination and organization of an agent's many intentions and actions, their distal versions are even more crucial. Proximal and motor intentions do not explicitly integrate information about moments and situations that transcend a current situation, diminishing their role in such coordination. For that reason mainly they're not given the methodological priority that is lent to distal intentions.

However, this apparent simplicity of especially motor intentions is precisely our reason for taking these as a starter. Given the importance in our account of learning and development and our interest in the increase of complexity of the mechanisms that can be used to explain action, starting with distal intentions would be odd. Indeed, when we follow the order of intentions as they emerge during ontogenetic or phylogenetic development, we can better explain why we can expect this development of a hierarchical structure and the differential generative entrenchment of intentions to occur. For with the increase of capabilities for actions, there is also an increasing demand for saving the cognitive resources required for their performance and for avoiding the performance of incoherent or even contraproductive actions. By starting

at the lower end of the intentional cascade, therefore, we aim to show that its increasing complexity and dynamics – including inter-level interactions – is not surprising, as soon as some form of learning and development is taking place.

To be sure, this set-up of an argument about development or increasing complexity is not new – not even in philosophy. Aristotle, for example, presented in his *De Anima* an analysis of different kinds of ‘souls’ or their functions, which are related such that the analysis of the most complex – human – soul can build upon the analyses of the more simple vegetative, sensory, and locomotive souls, as their capabilities are integrated in the former one.<sup>307</sup> Although driven by very different ambitions, Hegel followed Aristotle when providing a comparable trajectory by starting his *Phenomenology of Spirit* with an analysis of perceptual certainty (*sinnliche Gewissheit*) that included no explicitly articulated contents (Hegel 1988). Belonging to another tradition, we can find arguments for such a set-up that to some extent hold for the present one, as well.

In his discussion of method in philosophical psychology, Grice defends what he calls: ‘creature construction.’ Employed as a heuristic, he engages in this creature construction by describing stages of a creature that is capable of having increasingly complex mental states. Applying psychological concepts in this way, one allegedly can: “compare what one thus generates with the psychological concepts we apply to suitably related actual creatures, and when inadequacies appear, to go back to the drawing-board to extend or emend the construction” (Grice 1974 37). Inspired by this heuristic, Bratman follows suit by constructing even eight different creatures with increasingly hierarchical planning structures, contending that Creature 1 is moved merely by the strongest of his first order desires and can therefore hardly be called an agent, while Creature 8’s coherent and consistent planning is facilitated by hierarchical and feed back structures (Bratman 2006b, ch. 3). Although Creature 8 does not lack Creature 1’s strong desires, the former has meanwhile reached such complexity that these strong desires can be put to work while being coordinated with other constraints. Something alike will be described in the present context.

Our approach does not involve the construction of hypothetical creatures, but is in nature more akin to the dynamical or developmental approaches mentioned earlier. In terms of our returning example, we will not start with the analysis of the opera’s singer comprehensive interpretation of a role but devote this first analysis to the intentional control of ongoing motor actions. The analysis will especially focus on the increasing complexity and automaticity with which such actions can be performed. Based upon

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<sup>307</sup> Aristotle’s psychology exemplifies how a materialist – or mechanical – explanatory strategy can be combined with a teleological one, by underlining how simple bodily functions are reorganized and take up new roles when integrated with more complex cognitive functions (cf. (van der Eijk 1997).

these properties, an opera singer can increasingly expand his repertory of complex performances and adjust these to a current stage setting at will. As a result of dynamic properties of motor intentions, therefore, the agent is capable of further sculpting the space of actions such that proximal and distal intentions are facilitated, if they somehow build upon the emerging properties of this sculpted space.

In the next two sections we will look more closely at these motor intentions, observing whether the four characteristics listed in the previous section - section III.1.3. - figure in philosophical and cognitive scientific accounts respectively as we would expect them to, based upon our previous analyses. For our expectation is that an agent should be able to produce ever more complex behavior as a result of some sort of kludge formation which also affects the action representations involved.

## 2.1 A philosophical analysis of motor intentions and guidance

When for our first analysis we aim to separate motor intentions from the kinds of choices or decisions that are the contents of proximal and distal intentions, are we not left with mere physical movements? Are goals and criteria for satisfaction of an action not set before an action unfolds in a cognitive process that is separate from that action itself? Such considerations have partly motivated the development of causal theories of action. Davidson, for example, did compare the action to a causal event with the difference being the fact that in our description of an action we refer to an agent's reason for action as its cause, leaving the nature of the subsequent action relatively untouched by its preceding intention (Davidson 1963).<sup>308</sup>

Such theories have drawn several lines of critique which we must leave aside, since this is not the place for a detailed discussion of this debate.<sup>309</sup> Based upon philosophical

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<sup>308</sup> Even though Davidson compares his approach to Aristotle's comparison of actions and events in the Physics, there is reason to reject that comparison. Aristotle is more liberal in admitting different kinds of determining factors and also clearly acknowledges that such a factor must not always precede its effect, making Aristotle not vulnerable to a criticism that has been raised against the causal theory of action. (cf. Sorabji 1980 ch. 2).

<sup>309</sup> Although our focus is on Frankfurt's and Bratman's analysis, other authors have contributed to the debate. Searle, for example, has introduced the helpful notions of prior intention and intention-in-action in order to account for the distinction between an intention that precedes and causes an action, and an intention in action that has been caused by this prior intention and is itself more responsible for determining appropriate bodily movements (Searle 1980). Nonetheless, Pacherie writes critically of such 'dual-intention theories' that "they tend to assume that the role of the first of these two intentions is over once the second is in place" and "that action guidance and monitoring are the sole responsibility of the second intentions" (Pacherie 2008 181). This is not correct. Searle, for instance, has agreed to have made that mistake and accordingly later added to the causal relation of a prior intention to action also a constitutive relation (see Searle 2001 51, n. 5). Bratman's future-directed intentions are explicitly meant to retain their coordinating role once they've become present-directed intentions (Bratman 1992b). Finally, Mele states explicitly that he'll argue that "the moving role of proximal intention extends beyond triggering to the causal sustaining of the functioning of actual mechanisms" (Mele 1992 173).

and empirical considerations our aim is to convince the reader that such a separation between an agent's intentions and his corresponding action is implausible. If we can observe experienced agents engage in complex and flexible motor actions that are carefully planned and exercised, than it seems plausible that the momentary motor movements can be deeply shaped and influenced by intentions – even if they operate at different temporal scales and are determined in terms different from the 'metrics' of those movements. If this is the case, however, then we need to show that motor movements are intentional not only in the sense of unfolding under the ongoing influence of intentions. On top of that, we must ask if and how these 'motor intentions' can be shaped under the influence of those other - proximal and distal – intentions. In short, in contrast to a causal theory of action, our aim is to show that the apparent simplicity of an unfolding action hides a complex and dynamic intentional nature.

Responding to the causal theory of action of Davidson and others, Frankfurt has emphasized how both the phenomenology of action and its analysis betray that an action remains determined by agent's intentions until the very end. His approach was taken up by Pacherie when developing her notion of motor intentions, as she agrees with Frankfurt's insights, who: "argues that what distinguishes an action from a mere bodily movement is the fact that the person is in some particular relation to the movements of his body during the time in which he's performing them and that this relation is one of guidance" (Pacherie 2008 190). She then goes on to interpret Frankfurt's insights in terms of motor control at the lowest level of the intentional cascade.<sup>310</sup> Let us look whether their combined account does include the necessary complexity of motor intentions, being not only responsible for ongoing control but also being capable of modifiability via processes that are under the control of those other intentions – proximal and distal intentions. Moreover, let us notice whether the account includes also a form of differential generative entrenchment of the motor intentions, allowing some a greater role than others in complex motor actions.

Taking up the alleged separation between an action and its preceding intentional cause, Frankfurt clearly defines what is at stake: "[t]he problem of action is to explicate the contrast between what an agent does and what merely happens to him, or between the bodily movements that he makes and those that occur without his making them" (Frankfurt 1988 69). Admittedly, most specific bodily movements are not intended in detail by an agent, yet it is problematic to maintain that they are only happening to him

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<sup>310</sup> In fact, Pacherie correctly notes that philosophers have not always clearly distinguished between two forms of guidance, which she aims to correct: she distinguishes between higher- and lower-level guidance and monitoring, corresponding to proximal and motor intentions and having correspondingly different properties (Pacherie 2006). Frankfurt does also not distinguish between different levels of guidance but we'll focus here on those properties of guidance that are more strongly related to motor intentions.

and not guided by him.<sup>311</sup> On the contrary, we usually assume that if an agent is acting, he: “must be in some particular relation to the movements of his body *during* the period of time in which he is presumed to be performing an action” (Frankfurt 1988 70, italics in original). This relation is not identical with the kinds of intentionality that are located at higher levels of the intentional cascade while it seems to be lacking completely in cases when the agent’s pupil dilates in response to incoming light or when he suffers from a muscular spasm. Instead, for the guidance that is involved in action we can better consider cases when ongoing movements that appear to be made automatically still demonstrate coherently many complex and meaningful patterns, as when a musician is guiding his body parts (Frankfurt 1988 72).

Such ongoing guidance of action is not usually dependent upon an agent’s conscious decision making, which forces us to ascribe guidance to a drug addict’s behavior both when he is taking his drugs because of his addiction or upon his free choice (Frankfurt 1988 76). Indeed, guidance is often necessitated by mere changes in movement or in the environment that threaten to impede successful completion of the behavior. Frankfurt suggests that mechanisms responsible for guidance may linger in the background when an action is performed, being prepared to intervene if necessary. He compares this with a driver who only then intervenes when the speed or direction of his vehicle no longer satisfy goals or criteria that have been set previously. In such a case, the guidance mechanisms may remain passive when: “no negative feedback of the sort that would trigger their compensatory activity may occur” (Frankfurt 1988 75). Let us first look closer at the relation between an agent and his guided action, realizing that the nature the guidance relation is partly dependent upon the information or contents involved. Indeed, purposive guidance can only occur after some contents of behavior have become particularly relevant to the agent.

Take again the case of the musician, whose movements do not simply ‘happen’ to him as they are meaningful and coherent patterns that result from extended periods of intentional practice (Frankfurt 1988 72). Due to such practice, he is so familiar with the patterns that should be performed and the sounds that result from these, that negative feedback may occur when the comparison of these patterns with the actually performed body movements or musical sounds yields incompatible results. Such situations arise, for example, when the musician strikes a dissonance or when his tempo is not in sync with the orchestra. Often in such cases, as experienced musicians

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<sup>311</sup> It seems to me that Aristotle has already put an elaborate conceptual apparatus in place to account for several phenomena that require nuanced explanations. For example, Aristotle could make a difference between cases in which the cause of a movement is ‘in the agent’ but is still not ‘upto him’ implying that he has no cognitive control over the movement, as is the case with certain pathologies or intoxication. Cf. (Sorabji 1980).

know, it is often hard to resist repeating the failed note or adjust automatically one's tempo in order to correct the mistake. So guidance is activated in cases when a complex and purposive behavioral pattern is either inappropriately or incorrectly performed or not in harmony with relevant environmental conditions and then issues in interrupting and perhaps repeating the attempted behavior.<sup>312</sup> Similar to the high way being a car driver's environment, we may perhaps consider the music score – remembered, or not – as an environmental condition for a musician that presents conditions for the activation of guidance mechanisms in order to adjust his dynamics or tempo. However, not all behavioral responses to environmental stimuli should be considered as involving guidance.

Naturally, it is not to be denied that pupil dilation is a purposive movement of some body part. However, if we refer to guidance at all in such a case, this guidance: “is attributable only to the operation of some mechanism with which he cannot be identified” (Frankfurt 1988 73). Identifiability with the guidance mechanism is apparently an important characteristic for guidance to be not just purposive but genuinely intentional. Perhaps, so we may ask, this identifiability is associated with the long-term processes that allow the modification of motor intentions that we expect to find in the account? At least we have learnt that according to Frankfurt, first, many behaviors are accompanied by some distinct mechanism that is responsible for an agent's guidance of it. Second, such a guidance mechanism can be more or less connected to an agent's identity. The examples of the driver, the drug addict and the musician suggest that we can observe guidance mechanisms with which an agent is identifiable at work in their actions and not in pupil dilation, the difference being that the latter is a motor reflex while the former examples refer to habitual and long-term intentional actions. Those actions which gradually develop under the influence of proximal and distal intentions and are characterized by the richness of their contents, compared to pupil dilation movements.

The richness of intentional action is discernible from the goals, relevant environmental information and criteria that are relevant for its guidance. This same richness is related to the identifiability of the agent with such action. Several years after his earlier account of action, Frankfurt further embeds his notion of guided behavior in the context of the agent's overall constitution.<sup>313</sup> For then he argues that

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<sup>312</sup> Although approaching Pacherie's model of agency from a rather phenomenological perspective, Gallagher concurs that for adjusting our motor intentions we do not always need to rely on higher level intentions (Gallagher 2012).

<sup>313</sup> Nonetheless, it has been argued that Frankfurt's overall position can be characterized by his emphasis on the phenomenon of guidance. Indeed, it is this notion that is crucial in his opposition to the causal theory of action, according to (Di Nucci 2011). Di Nucci stresses that guidance is relevant for all forms of skilled, habitual and routine activities, which concurs with our view here.

the performance of an action depends upon the agent's wholeheartedness with respect to that action, in which case his intention to act has co-determined: "his cognitive, affective, attitudinal, and behavioral processes" (Frankfurt 1999 103).<sup>314</sup> Such a wide range of processes that involve various kinds of information, we may note, are obviously not involved in pupil dilation nor in the purely physical event that an action was deemed to be according to the causal theory of action.

Given both the informational richness and the multiplicity of the processes involved in the development of this kind of guidance, it seems plausible that it needs more time and attention to arise than motor reflexes do. Indeed, such guidance is usually an effect of an agent having gained experience with or deliberately learnt a particular meaningful pattern of movements.<sup>315</sup> Such guidance is not involved in the movements – complicated as they are – that an epileptic patient makes, for it is: "unlikely that a person would have created such an incoherently complicated pattern if he had been guiding his body through its movements" (Frankfurt 1988 72). In contrast to such a patient, we can observe in guided behavior that is a result of practise and experience a relation between someone's – or an animal's – persistence and the consistency of his performance that results from it, as guidance does entail: "a certain consistency or steadiness of behavior; and this presupposes some degree of persistence" (Frankfurt 1988 84). Again, the musician's consistent performance of a complex piece of music after having practiced the score for many times is exemplary.

In sum, according to Frankfurt's analysis guidance is at stake whenever an agent is performing a complicated and meaningful pattern of movements, during which his enduring intentions play a certain role. Relying on separate mechanisms – being different from the mechanisms that produce ongoing movements – and employing relevant information about aim, meaning and context of the action, these mechanisms only intervene when it is necessary to adjust the action, while remaining passively in the background for the rest of the time. The analysis does not offer detailed insight about the information that is used for guidance but only contends that guidance

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<sup>314</sup> In his analysis of the problem of action, a similar view was already announced when Frankfurt wrote that: "[t]he facts that we are rational and self-conscious substantially affect the character of our behavior and the ways in which our actions are integrated into our lives" (Frankfurt 1988 77). Behavior being guided is an important aspect of its character in this context.

<sup>315</sup> Guidance is different for instrumental actions directed at a goal-state and for actions that are performed for their own sake. For example, Aristotle explicitly ascribes to music such an intrinsic value and distinguishes music making from actions that have an external goal, even though music education can have beneficial effects on the pupil's character (Politics, VIII, 5-7). In the next chapter we will take note of the fact that in cognitive scientific investigations of intentional action, such action is usually defined in terms of its goal-directedness, often with the involvement of an associated external object. Nonetheless, musical processing is being studied precisely because it is possible to investigate the role of meaningful patterns in the absence of a specific (end) goal of the behavior, comparable to language processing (Levitin and Menon 2003).



stems from consistent practice of patterns of movements during an extended period of time. In any case, guidance appears for its interventions to not necessarily require information about the goal of an action or about higher levels of intention regarding the action.

Given our previous analyses of dynamical modifications of underlying mechanisms, of kludge formation and the role of modifiable – redescrivable – representations in these, let us note a couple of issues that merit further analysis. To begin with, it seems that the analysis distinguishes between guidance of intentionally initiated behavior and bodily movements that merely happen to him without including a third option: highly automatized actions that are guided but the initiation of which may at times not be under the agent's control, as when a musical attack is triggered by the environmental stimulus provided by the accompaniment.<sup>316</sup> We can only suggest at this point that these options probably differ more in degree than in kind, sharing properties and underlying processes with each other. Deciding about that suggestion would require further clarification of how the patterns involved in guidance are stored and retrieved, as would be an answer to the question whether the representations involved are somehow redescrived during learning – an algorithmic theory in Marr's sense (Marr 1982) remains to be formulated. Finally and related to this, it merits further discussion how experience with practiced patterns of movements may enhance the agent's consistency in his performances, as has been suggested. Is practice affecting the representation of these complex patterns and is it more specifically thanks to a hierarchical structure that an agent's actions increase in coherence and consistency – as we will learn from other analyses?<sup>317</sup> Although we've suggested that some of these issues are relevant in the context of Frankfurt's analyses, turning to a more empirical perspective on motor intentions will perhaps provide more detailed insights – concurring hopefully with some results of our earlier analyses.

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<sup>316</sup> In his analysis of 'identification and externality', Frankfurt also distinguishes between passions that are internal or external to a person. There, however, he points out that a person may come to recognize a certain passion as his own, even though he regrets having that passion (cf. Frankfurt 1988 64). Could we assume that similar to this situation, an agent may observe that some of his automatized actions are no longer under his comprehensive control even though they are clearly attributable to him? Frankfurt seems to deny this, when he elsewhere protests against Aristotle's view on a person's responsibility for his own character and argues that Aristotle overemphasizes causal responsibility for his character instead of considering rational identification with his character as (cf. Frankfurt 1988 171). Frankfurt appears to overlook, however, the fundamental place of action in Aristotle's ethics in general, including his view on character. Indeed, this view on character implies that one is in a position to influence it – perhaps after having identified with some rather than other characteristics – by acting repeatedly in line with those preferred characteristics and by trying to increase control over others through practice as well. See also (Audi 1991) on this issue.

## 2.2 Motor intentions and chunks: evidence about developing complexity at the bottom of the hierarchy

Looking for motor intentions in the analysis of action according to the philosophical hierarchical account that provided a basis of Pacherie's intentional cascade, we learnt that these were particularly implied in the phenomenon of behavioral guidance. This parallel notwithstanding, we looked in vain for some aspects of motor intentions that we did expect to find on the basis of our previous analyses of modifications of complex and dynamic mechanisms, of kludge formation and of the redescription of representations involved in development and learning, as is the case when babbling babies grow into expert singers. Let us consider whether empirical research does provide evidence for these aspects of motor intentions. In order to do so, let us first consider what empirical research Pacherie's model refers to.

Pacherie explicitly notes that motor intentions differ from the other two kinds - proximal and distal - of intentions. The contents of motor intentions are not propositional, for example, and they conform to some features of modularity, as they are to some extent informationally encapsulated and cognitively impenetrable (Pacherie 2008 187 ff.).<sup>318</sup> Notwithstanding these differences in information processing, motor intentions are an integral component of the intentional cascade that is further elaborated as a complex model of action control. Indeed, it is suggested: "that the information-processing model of action control in terms of internal models be explicitly combined with the threefold distinction among levels of intentions [...], thus yielding a richer theoretical framework for thinking about action" (Pacherie 2008 193). Allegedly, action control relies on the use of models of action that are employed by the processes involved. What representations and what kinds of information processing are implied here?

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<sup>317</sup> Sharing the interest in a hierarchical account of agency with Frankfurt, Bratman has barely touched upon the topic of motor intentions in Pacherie's or guidance in Frankfurt's sense. He seems content to note that the specific motor movements that are 'necessary constitutive means' of an intended action belong to the motivational potential of that intention, while they need not be articulated by that intention. For example, the intention of shooting a jump shot may well imply as a means to that end that the agent must stop on his left foot, even though the latter motor intention - in our terms - is not included in the intention: "motivational potential can be extended by means-end beliefs, even when what is intended is not thereby extended" (Bratman 1984 401). Indeed, other beliefs and desires may play a role in this motor movement with his left foot, for example the agent's necessity to spare his hurt right foot. Clearly, this does not yet present a role for independent guidance mechanisms that somehow adjust those constitutive motor movements by employing a representation of meaningful and coherent patterns of movements that have been gathered by the agent.

<sup>318</sup> The non-conceptual nature of the representations involved in motor intentions does not preclude their having properties usually ascribed to conceptual representations. For example, non-conceptual representations have conditions for their satisfaction; there are misrepresentations possible; non-conceptual representations can be composed and have a hierarchical structure, too. See (Bermúdez and Cahen 2012 ; Bermúdez 1995) for a discussion of non-conceptual content in cognitive functions.

From the available accounts of internal models of action involved in intending, monitoring, guiding and adjusting motor actions, Pacherie's framework leans in particular upon the account of motor representations presented by Jeannerod and others (Pacherie 2000 ; Pacherie 2008). Drawing together research on motor action, motor imagery and observation of motor action, Jeannerod had earlier argued that the cognitive processes involved in these tasks make use of largely overlapping 'motor representations' which are not limited to representations of motor contractions.<sup>319</sup> On the contrary, these representations merit independent attention when studying overt action because these: "representations are likely to be endowed with properties (partly built on experience from previous actions) which may not be apparent in their eventual motor counterpart. They seem to be structured with different levels of organization; they use cognitive rules for establishing the serial order of action parts, for assembling programs, etc." (Jeannerod 1994 201). It is the complexity of representations and their associated modifiability that will be found especially important for motor intentions and deeply involved in the process of kludge formation that is observable with regard to motor intentions, too.<sup>320</sup>

Just like Frankfurt did notice that experience and practice have an impact on guidance, so did he note that guidance does not require language. Jeannerod does ascribe to that position, as well. Although he does not assign to motor intentions all characteristics of modularity as presented by Fodor nor its characteristic of informational encapsulation alone (cf. (Fodor 1983)), Jeannerod does make a distinction between semantic and pragmatic modes of knowledge regarding actions and motor movements. In his account, these modes correspond largely with the two different streams of visual processing, which he distinguishes as semantic and pragmatic. However, he does acknowledge that there are still interactions between those streams (Jeannerod 1997 ; Jeannerod 2006).<sup>321</sup> Notwithstanding these interactions, this pragmatic mode of knowledge is in itself non-conceptual and is accessible for explicitly articulated and

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<sup>319</sup> Theoretically, sensory representations could have occupied a similar central role as the motor representations in this framework. However, evidence from different lines of research shows that the representations involved in a wide range of tasks related to motor behavior, like its perception, imagination, performance and verbal expression, are subject to modifications as a result of experience with their performance and not as a result of perceptual experience with them (de Vignemont and Haggard 2008). Similarly, the shared representations of action that play a role in the activities of mirror neuron systems which are activated when subjects try to understand, imitate or perceive an action appear to be primarily sensitive to motor experiences a subject has gained. Indeed, representation of perceptual information about an action only would provide little for understanding that action, it is argued (Rizzolatti and Sinigaglia 2008).

<sup>320</sup> Jeannerod and others confirm the modifiability and complexity of both perceptual and motor schemas when they observe: "that new schemas often arise as modulators of existing schemas rather than as new systems with independent functional roles" (Jeannerod, Arbib et al. 1995 361).

<sup>321</sup> About the number and interpretation of visual streams, discussion is still going on – see footnote 50.

conscious modification only indirectly, for instance via motor imagery (Jeannerod 1997).<sup>322</sup> Apart from this limitation, motor representations are complex, flexible and dynamic and subject to indirect adjustments via other cognitive processes and under the influence of experience. Kludge formation, therefore, can possibly involve these motor intentions, too. We will come back to that later, but must first mention an important role that these motor representations play in Pacherie's framework.

That framework integrates the motor representations with other components that together are responsible for the specification of motor actions and the multiple forms of control involved in these. For, corresponding to the framework's different levels of intentions it includes also different levels of motor representations. Moreover, during the processes involved, such representations are used both for the representation of the desired, predicted and actual states of the relevant behavior and include representations of relevant properties of the objects and the situation for action. In fact, it is the complex process of comparison between those states at the three different levels of specification that facilitates control of the action and also contributes to the agent's sense of control. For example, when a motor intention that specifies the movements to grasp a certain object leads to movements that eventually miss the object, comparison between the relevant representations may result in a sense of lacking motor control – and usually in a correction of movement (Pacherie 2008).<sup>323</sup>

Given this elaborate structure of a hierarchy that includes the intentional cascade, multiple representations and several relations between those, the question presents itself whether this structure also allows for the four characteristics of a comprehensive framework for the explanation of action in which a sculpted space of actions plays a role, as formulated in section III.1.3? Remember, these characteristics were formulated in line with our interest in the explanation of action and its potential modifications under the influence of development, learning and expertise. They referred to potential

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<sup>322</sup> Jeannerod also elsewhere refers to the fact that both experiments and patient studies confirm that automatic and implicit processing of motor action usually functions in relative isolation from conscious and explicit – verbal – processing of the representations involved in such motor actions. The former is also often spared in patients who have difficulty with conscious and explicit processing of information related to motor action, with the reverse occurring more seldomly (Jeannerod 1997; Jeannerod 1999). Other evidence of the distinction of the two modes of processing comes from experiments like those with subjects who automatically adjust their grasping movements to a changing objects, before being aware of any changes (Jeannerod 1997).

<sup>323</sup> The comparator aspects of the framework build upon Wolpert's a.o. work on the contribution of forward and inverse models on neural processes, responsible for planning, control and learning (Wolpert, Ghahramani et al. 1995; Wolpert and Ghahramani 2000). Jeannerod has similarly used Wolpert's work to develop his theory of motor simulation, which explains how similar motor representations are used in different cognitive functions – like action, imagination, observation, verbal expression – and also contribute to many different cognitive phenomena, including pathologies or other surprising phenomena (Jeannerod 2001; Jeannerod 2006).

changes in the underlying mechanism that leads to an action and the mechanism's employment of different representations, to the differential generative entrenchment of some representations and the involvement of these in new actions, and finally to the demands for coherence and consistency in action which should be fulfilled partly by the structure's hierarchy. Did the philosophical analysis of motor intentions and guidance present limited confirmation of these characteristics, let us now look for further confirmation in this section on empirical research on motor intentions and focus particularly on the role of expertise in that context. Doing so, we will devote separate sections to the connection between expertise and motor intentions, to modifying mechanisms, to the differential generative entrenchment of motor intentions and finally to the coherence and consistency between actions.

### **2.2.1 Motor intentions, representations and the role of expertise**

Even though motor intentions are ascribed a relative autonomy from the other intentions, they should enable an agent to act appropriately in a particular situation.<sup>324</sup> Motor intentions as contained in the framework enable an agent to do this by establishing associations between perceived environmental conditions and an appropriate motor response to these. Motor intentions are said to be involved in the 'pragmatical organization' of a perceived situation by an agent, who can demonstrate how: "affordances of an object or situation are automatically detected even in the absence of any intention to act." As mentioned, it indeed is not just a matter of the detection of such an affordance, though, as this is directly connected to potential actions, since: "[t]hese affordances automatically prepotentiate corresponding motor programs" (Pacherie 2008: 186).<sup>325</sup> So even though the term suggests otherwise, motor intentions involve not just representations of potential motor actions but also of relevant environmental properties that are associated with these actions.<sup>326</sup> A related issue that will be discussed in the next section on potential mechanism modifications

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<sup>324</sup> In utilization behavior, agents act inappropriately as upon the perception of a specific object an agent is unable to inhibit an action afforded by it, even if the result of the action is undesirable – as is the case when a second set of glasses is put on (Lhermitte 1983). This pathology is associated with lesions in the frontal lobes (Lhermitte, Pillon et al. 1986). It underlines the complexity of expertise, which is more than just stimulus driven, reflex-like action as that would oftentimes be inappropriate or ineffective.

<sup>325</sup> Jeannerod explicitly remarks that affordances are among other things those properties of objects that afford specific motor patterns, without necessarily offering cues for a perceptual category (Jeannerod 1994). The fact that many event codes or features – like those of spatial orientation - involved in the representation of perceived information and in motor control are shared implies that not for all affordance features a comprehensive cognitive transformation is necessary in order to get from scene perception to motor action (Hommel, Musseler et al. 2001). Particularly neurons in cortical association areas are involved in coding for features pertaining to both perceptual, and cognitive and motor functions related to a single task (Cisek and Kalaska 2010).

associated with motor intentions and expertise is how motor intentions are learnt and stored at all. For now, we can expect that the automatic detection of action options in a specific situation and the automatic prepotentiation of associated motor programs is subject to change through expertise.

Given that any situation affords many options for action and that there are usually multiple motor movements available in order to realize a single option, the potential space of actions is large and expertise may be expected to play a role in sculpting that space. A domain of action that allows researchers investigation of this expertise-dependency, as it allows the calculation of the number of options or the outcomes of different options, is chess. Indeed, the best researched domain of expertise and associated cognitive functions is perhaps the domain of chess. Much cognitive psychological research has been conducted on the acquisition of skill or expertise in chess since De Groot's seminal studies (de Groot 1946).<sup>327</sup> Even though different explanations have been offered, researchers agree that expertise in chess is associated with a broad – and connected – variety of improved capabilities like enhanced perception, recognition, and storage of patterns or board positions, improved envisioning of potential responses and finally better results in acting (Chase and Simon 1973 ; Dreyfus 2004 ; Ericsson and Roring 2007).

Nonetheless, it may be contended that since chess involves rather limited motor activities, its generalizability is perhaps limited. However, the generalizability of chess is supported by the fact that even though cognitive and perceptual-motor skills are usually investigated separately, there are several arguments not to treat them strictly separate. For there is considerable overlap in their acquisition and in brain activations activated with them, and it appears that in all cases a distinction can be made between explicit and implicit knowledge involved in these skills (Rosenbaum, Carlson et al. 2001). Moreover, studies of expertise in domains in which physical action is required

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<sup>326</sup> A related but still different issue is whether intentional motor action does always imply a specified goal. Humans appear in general to be 'obsessed with goals' as some investigators concluding and associating it with the prevalence of a teleological stance in action observation (Csibra and Gergely 2007). Indeed, scientists who investigate intentional action appear to share that obsession, as most actions studied include them having clear goals. However, action goals can be various and include an agent's end state, both postural and motivational – for example one's goal for running may be to lose weight, which refers to a desirable end state. Nonetheless, defining such distinct actions goal may also be a matter of different levels of specification, since a runner must in any case specify the direction and goal for running in order to implicitly determine the necessary motor intentions. Simplified to the extreme, observers can also imitate meaningless actions by encoding only the spatiotemporal layout of the necessary movements (Decety, Grèzes et al. 1997). It is a matter of definition, if one wants to call the latter goal-directed behavior, too.

<sup>327</sup> Gobet lists nine reasons why chess is such a profitable domain for the study of expertise, among which are its ecological validity, its offering the ELO ratings of players as a quantification of expertise, its use in artificial intelligence experiments, and of course the complexity of the tasks involved (Gobet 1998).

show improvements that are comparable to those that have been found in studies of chess expertise, as demonstrate studies in nursing (Benner 2004), in fire fighting (Klein, Calderwood et al. 1986), or in sports (Janelle and Hillman 2003). Moreover, it is also commonly acknowledged that these improved capabilities do in real situations not rely on conceptual or declarative knowledge, but rely instead on a different type of knowledge, often referred to in the literature as ‘intuition.’ Supported by these arguments, let us therefore take a closer look to how chess experts deal with the contents of their domain of expertise and how this is different from novices and let us do so by focusing upon an explanatory approach that aims to combine insights of several other approaches: template theory (Gobet and Chassy 2009 ; Gobet and Simon 1996).

Building upon De Groot’s findings, research of perceptual and memory skills and their interaction in chess experts showed that they are capable of processing much more information than novices do and recognize relevant information much easier, doing this also faster and more reliable. Experiments in which players have been exposed to complex positions for a limited amount of time, after which the players had to reproduce from memory these positions, for example, demonstrated significant differences in accuracy and completeness between experts and novices. As experts face cognitive and memory limitations identical with those that novices face, the differences have been explained by hypothesizing that experts automatically enlarge the amount of information that can be processed at a time by chunking and thus condensing it (Chase and Simon 1973). Indeed, it appears that where novices have difficulty in recognizing and processing meaningful patterns, experts easily group stimuli in meaningful groups also called chunks, a chunk being defined as: “a collection of elements having strong associations with one another, but weak associations with elements within other chunks” (Gobet, Lane et al. 2001 236).<sup>328</sup> For example, a series of letters is difficult to memorize unless one can chunk that information with the use of memorized words: the letter series “andramoienepe” can be chunked as an ancient Greek sentence of three words.<sup>329</sup> Indeed, it is the exhortation from the start of the *Odyssey*, which is followed by some 12.000 verses that have many times been

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<sup>328</sup> This definition of a chunk resonates somewhat with the definition of a module, of which the internal relations or interactions between its elements are strong, while relations to other system components is weaker (Mitchell 2006).

<sup>329</sup> Parry was one of the first to draw attention to this accomplishment, pointing out that such oral traditions still existed in modernity. Moreover, he also referred to the role of returning formulas, descriptions and the like – chunks of information, as we may now call them - as ‘singer’s rests’ in these challenging songs (Parry 1930). Bloch argues for the importance of recognizing that much cultural expertise is stored in ‘chunked and non-sentential knowledge’ and therefore challenging to anthropologists who aim to render it in linguistic form (Bloch 1991).



recited by heart by illiterate persons – a task that equally relies on their ability to chunk information at several levels of grain: as words, as sentences, as scene descriptions, and so on.<sup>330</sup>

Having improved capabilities of perceiving, recognizing and memorizing relevant situational conditions, experts have in addition gathered many associated, appropriate behavioral responses to each of these chunks of information.<sup>331</sup> An early account of such associations was in terms of the ‘production’ of an action in response to the perception and recognition of a specific pattern which happens to satisfy certain conditions (Newell and Simon 1972).<sup>332</sup> To begin with, an expert must discover at an early stage relevant situational conditions, as chess experts do who are quicker to recognize the relevant strategic patterns present in a certain board position (Ferrari, Didierjean et al. 2008).<sup>333</sup> Subsequently, experts generate or activate proper options for action upon the recognition of such patterns without requiring time-consuming, intermediate deliberation.<sup>334</sup> Indeed, this process of the generation of an appropriate action option is already initiated during the perception of the scene. For in sports as diverse as chess and basketball, expert perception is shown to be partly anticipatory in character as experts tend to focus their attention on positions that are particularly

<sup>330</sup> It is now estimated that expert chess players can memorize ca. 300.000 configurations of chess positions, ranging from complete boards to smaller configurations (Gobet and Simon 2000).

<sup>331</sup> Reviewing the literature on expertise, the authors list among the benefits of having expertise: having better perceptual and recognition skills, a larger set of routines, better ability of mental simulation and detection of problems and opportunities, more declarative knowledge about the skill and metacognition about his own capabilities and limitations (Phillips, Klein et al. 2008).

<sup>332</sup> In his ACT theory, Anderson posits that the interaction of production rules and chunks of declarative knowledge can together account for cognition. Perhaps, the declarative stage distinguished as the first stage of skill acquisition by Anderson applies to cognitive skills more than to motor skills (Anderson 1982).

<sup>333</sup> As reviewed in (Didierjean and Marmèche 2005), during perception unexpected – a drum in the kitchen – or un-anticipated – a change of direction of a moving object – scenes attract observers’ attention, testifying to the fact that perception is not the passive process it is often made out to be. In line with research of such effects of familiarity, a review of expert effects in memory recall in many different domains of expertise – ranging from chess and computer programming via medical expertise to sports – is concluded with a theory in which the authors propose that experts become attuned to the specific constraints that are relevant to the domain of expertise. They explicitly note the affinity of their theory to the ecological theory of perception with its emphasis on situational affordances (Vicente and Wang 1998).

<sup>334</sup> This is not to deny that deliberate practice plays an important role in the process of skill acquisition for experts, too. However, over time important physiological and functional adaptations have taken place that are associated with modified mechanisms if compared with novices (Ericsson and Roring 2007).

<sup>335</sup> Such an interaction between expertise, recognition of domain relevant situation features and expert’s attention to these has been shown not just with memory recall but also with eye tracking experiments, for example in pilots (Bellenkes, Wickens et al. 1997). In a review of behavioral and neural correlates with decision making in response to external cues or rewards and to internal preferences respectively, the authors draw two conclusions. First, the two neural networks that are associated with externally and internally guided decision-making are not completely distinct but activations differ rather gradually from each other. Second, there is a large overlap between the internally guided decision-making network and the so-called resting state or default mode network, suggesting that internally guided decision making relies more on agents’ internal preferences or criteria that are established over a longer period of time (Nakao, Ohira et al. 2012). Expertise, one may surmise, has lasting effects on such preference or criteria, too.



relevant for future moves (Didierjean and Marmèche 2005).<sup>335</sup> Assisted by that focus, the generation of appropriate action options is a less demanding task than if no such pre-selection of relevant situational features had occurred. Nonetheless, even with these constraints in place there are still several action options being generated in parallel, as several behavioral and computational studies suggest. From these, eventually a single option is being selected for execution, the selection of which is usually done implicitly (Cisek 2007). Expert accounts of their performance appear to concur with this account. For example, fire fighters who have been operating in real emergency situations and under time constraints, report afterwards that they did not compare in evaluative terms several options for action but instead experienced that one option simply stood out or presented itself as the most viable one in the current situation (Klein, Calderwood et al. 1986).<sup>336</sup>

What we've learnt from the above and will be confirmed more below, is that an expert's sculpted space of actions influences several components of the mechanisms involved in his performance. Based upon his many previous experiences, he has an enhanced capacity of perceiving, recognizing and focusing upon patterns of relevant situational features.<sup>337</sup> Moreover, the representations involved in these processes have become strongly associated with options for action, which in turn also influence the expert's focus of attention and subsequent perception of the situation. In that sense, the expert's sculpted space of action is affecting all processes involved. A matter of concern is to what extent this sculpting process may not only be enhancing the expert's performance but may also be limiting it, as it is perhaps inflexibly constrained by the specifics of the representations involved: does expertise only contribute to a facilitated repetition of the expert's previous experiences? Several lines of evidence and theories suggest otherwise, as we'll argue below. In this section we will focus on how the representations that are involved in expertise are structured such that they offer the kind of flexibility and adaptivity that we expect from an expert.

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<sup>336</sup> Based upon an analysis of Conan Doyle's texts, it is stipulated that Sherlock Holmes relies upon similar mechanisms facilitating his expertise as described here. The authors point out that Holmes' case suggests some issues to be taken seriously in the study of expertise, among which the role of emotion in expertise (Didierjean and Gobet 2008).

<sup>337</sup> Research with dance experts has shown that a 'specific configural perceptual mechanism' that helps the perception of a familiar action configuration can be enhanced by both visual and motor familiarity with that specific action. However, expertise turned out not to make a difference for the perception of inverted stimuli, with inversion being rather uncommon in dance (Calvo-Merino, Ehrenberg et al. 2010). Below, we will learn more about the involvement of mirror neuron systems in both recognition of an action and in the simultaneous preparation of motor responses. Cf. reviews in (Casile, Caggiano et al. 2011 ; Iacoboni 2009). Mirror neuron activations during both observation and performance of action has suggested that they are responsible for shared motor representations, associated with the motor intentions under discussion or Searle's intentions-in-action (de Vignemont and Haggard 2008).

This flexibility and adaptivity stems from two aspects of the representations that are implied in the expert's sculpted space of actions and less so in novices. Before mentioning these two aspects, let us refer to our discussion of the process of representational redescription in chapter II.2, which takes place during development and learning (Clark and Karmiloff-Smith 1993; Cleeremans 1997 ; Karmiloff-Smith 1992 ; Mareschal, Johnson et al. 2007). For example, investigating children's drawings, Karmiloff-Smith observed that initially children would draw houses and figures in a rigid sequential order and with fixed components. With increasing experience, however, children demonstrate employment of redescription and increasingly structured representations which grant them more flexibility and creativity in drawing. Being asked to draw a house or man 'that does not exist', for example, they had to retain the informational core of the object while modifying some important feature of it (Karmiloff-Smith 1990). Similar modification processes also affect the motor intentions that support experts' extraordinary performances.

First, the representations that experts' cognitive processes employ tend to have more structure than in novices, with hierarchy being a central feature of that structure. Second, this hierarchical structure is such that it leaves some room for variety, allowing experts the necessary flexibility and adaptivity. These aspects were added to the chunking theory as research showed that chess experts are also better than novices in recognizing and memorizing board positions that deviate somewhat from familiar positions, while still being not much better with random positions (Gobet 1998).<sup>338</sup> Apparently, representations tend not to be chunked or compressed in an indiscriminate or unstructured manner. Instead, apart from chunks that represent bits of complex and specific information experts also develop templates. Templates are more complex information representations with a hierarchical structure that contain both a core pattern of information and some free slots for fine details that can be filled in according to a specific situation. With this extension, the 'template theory' can both account for enhanced expert capabilities and for the flexibility that are associated with these could (Gobet and Simon 1996).<sup>339</sup> In addition, template theory can explain why

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<sup>338</sup> The template theory can better account for expert's complex pattern recognition and response generation than the preceding chunking theory. As such it can counter some of the objections made by the Dreyfus's alternative account of intuition (Dreyfus 2004), more based upon phenomenology than associated with mechanistic explanation (Gobet and Chassy 2009).

<sup>339</sup> Acquisition of templates is similar to chunk acquisition, with templates being established when there is enough overlap in information between perceived patterns with some variety in components (open slots) that are associated to the overlapping pattern through particular similarity links (Gobet, Lane et al. 2001). Research of recall and problem solving with chess masters with different specializations demonstrated that their responses correlated with their having such highly differentiated and complex knowledge structures, correlating with their domain of specialization and was not dependent on general mastery of chess (Bilalić, McLeod et al. 2009)

experts still perform better than novices in a kindred domain, even though they have little personal experience with it. For example, baseball experts can still benefit from their expertise when asked to memorize cricket events, presumably because several templates concerning these competitive ball team sports are valid in both sports (Jessup 2009). Moreover, even when experts actively perform in a domain in which they have no motor experience they appear to benefit from their expertise, transferring the assembled templates and having to only fill the slots in with the specifics of muscular information (Keele, Jennings et al. 1995)t.

In sum, this section has discussed how expertise is associated with the modification of motor intentions, affecting not just motor processes but also cognitive processes like perception, recognition and memory. This is in line with an account of theory of representations which are being shared between multiple processes involved in motor action and which are undergoing changes due to learning. Corresponding to these representational changes, we might expect the mechanisms underlying these motor intentions to change as well. It is to this aspect of motor intentions that we will now turn.

### ***2.2.2 Motor intentions and mechanisms that change with growing expertise***

In previous Parts we discussed various lines of evidence of the phenomenon that complex and dynamical systems tend to develop hierarchical (heterarchical) structures. Such developments are facilitated by the formation of generative entrenchments or kludges, as was discussed in Part II: the formation of a distinct component mechanism – often from already available components - as can be especially observed from functional differences or differences in performance of a cognitive function. Apart from the functional consequences of such kludge formation, we must usually also infer a change in the algorithmic theory which accounts for the performance, including the representations involved. It is to be expected that these processes of kludge formation and changes in representations can be observed also in the present context, where we are considering the interaction between a hierarchically - or rather: heterarchically - structured intentional cascade and the sculpted space of actions that is the result of growing expertise for a particular domain. What modifications obtain in with regard to the motor intentions that contribute to the effects of expertise?

Learning, memorizing and employing motor representations are complex processes carried out by complex mechanisms with components being distributed in the brain. Underlying every form of acquisition of expertise or skill learning are the various forms of neural plasticity that affect synaptic processes involved in interactions between

neurons. Based upon such modifiable neuronal interactions, learning a particular skill depends upon the crafting of cell assemblies, as is evident from modified motor representations in primary motor cortex upon relatively simple skill learning which last at least several days (Nudo, Milliken et al. 1996).<sup>340</sup> Hebbian learning allows further development of different types of such cell assemblies in the form of simple chunks and more complex templates, which are involved in complex and flexible motor skills as we learnt in the previous section (Chassy and Gobet 2011). The complex and distributed nature of the mechanism involved in such skill learning is evident from the study of apraxias and other deficits. For example, some patients cannot perform complex actions while being able to complete the simple components actions, others can perform complex actions as long as they are automatically initiated, still others have difficulty acquiring new action skills, and so on (Jeannerod 1997).<sup>341</sup> Such effects show how an agent's space of actions is sculpted partly under the influence of mechanism components that are difficult to explicitly control.

Indeed, skill learning does not always require complex mechanisms that involve higher levels of intentional control. Both computational and empirical studies have demonstrated that rather simple processes that derive statistical information from the observation and performance of actions do automatically lead over time to a hierarchically structured network, which is fit to represent appropriately the hierarchical structure of behavior and includes chunks of behavior (Botvinick 2008).<sup>342</sup> Nonetheless and in line with the expected mechanism modification, learning such complex and structured motor representations involved in motor intentions appears to be a complex process. Indeed, even in simple skill learning at least two phases can be distinguished which may even be considered as two different processes.

The phases to be discussed are to a large extent responsible for the two aspects that we distinguished earlier with regard to motor intentions: these involved both the recognition of affordances in the environments and the preparation of appropriate

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<sup>340</sup> Research suggests that a change in motor representations is less dependent upon mere frequency of use but occurs in particular when a new motor skill is being learnt (Plautz, Milliken et al. 2000).

<sup>341</sup> Related to though different from the discussion here of motor intentions and expertise is the research in habits or habituated responses. Chunks of behavior are in that case automatically performed upon the perception of a particular stimulus even though the reward with which these habits earlier were associated may have become devaluated (Graybiel 2008). It is the fixed nature of habits and the lack of competition between potential action responses in a given situation that allows distinguishing them from the more functional and adaptive forms of expertise discussed here, although that distinction may be gradual rather than strict.

<sup>342</sup> Several lines of evidence confirm that subjects typically encode observed actions in a hierarchical fashion. Indeed, the better they hierarchically encode behavior, the better they are capable of learning and reproducing it. Hierarchical encoding can partly rely on the observation of (statistical) changes in speed and direction of movements, which allows the first stage of segmentation of behavior (Hard, Lozano et al. 2006). Research suggests that infants but also adults use statistical processes for segmentation, which subsequently facilitates further understanding of intentional and hierarchical action (Baldwin, Andersson et al. 2008 ; Baldwin and Baird 2001).

motor programs. Interestingly, a first indication that expertise affects neural processing in several ways was obtained with fMRI investigations of verbal and motor expertise in which subjects would gain experience with tasks that required them to read and generate words or to complete maze tasks of varying complexity. Results have led to the distinction of an early phase in which repeated behavior lead to an increasing efficiency of corresponding neural activations. This was followed by a second phase, characterized by additional activations in different neural areas, which has been associated with an increased and more comprehensive access to sets of stored associations or programs related to the initial task. Based upon these findings, the authors conclude that experts can be said to perform 'different tasks' than novices do (Petersen, van Mier et al. 1998): novices cannot rely on the structured representations and associated response options that make up an experts' sculpted space.

Concurring with the distinction of two aspects of expertise and specifying the finding of two phases of increasing expertise is the distinction of an early phase of improved pattern recognition and a subsequent - though partly parallel - phase in which response options are becoming associated with such patterns. Pattern recognition being reliant upon long term memory, these processes unwind largely automatically and therefore require hardly any short term memory (Chassy and Gobet 2011).<sup>343</sup> Otherwise put, during the first phase and thanks to the establishment of chunks a decrease in working memory involvement and consequently an increased efficiency can be observed. During the second phase - in which additional activations were found by Petersen and colleagues (Petersen, van Mier et al. 1998) - a functional reorganization takes place, in which more complex and fine-tuned knowledge structures (chunks and also templates) from long term memory are activated in experts, in association with working memory contents of an ongoing task (Guida, Gobet et al. 2012).<sup>344</sup> In sum, kludges are established with increasing expertise, affecting expert performance in at least two ways which are observable even at the level of relatively simple motor intentions: these

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<sup>343</sup> Focusing on the role of memory in expert performance, the LTWM framework explains this as based upon 'long-term working memory' in which long term memorized information is used in interaction with rapidly accessed short term memory (Ericsson and Roring 2007). The difference between this framework and template theory is perhaps less than stated, as the latter as well includes an interaction between long and short term memory (Gobet, Lane et al. 2001).

<sup>344</sup> Corresponding with such a transition is the observation of a shift occurring during successful learning of motor representations or schemas with activations tending to rely less on anterior frontal regions but instead more on posterior regions (Tracy, Flanders et al. 2003). Investigation of tennis players with different levels of expertise shows that expert players were better capable of grasping and long-term storing the hierarchical structure of the tennis serve, which correlated with the quality of their reproducing it (Schack and Mechsner 2006). Research with judo experts suggest that the study of memorized cognitive hierarchical representations of throwing techniques in individuals can enhance effects of their training these. The authors note that it is striking that experts across different sports use comparable hierarchical representations (Weigelt, Ahlmeyer et al. 2011). In music, experts are shown to equally have enhanced processing and memorizing of hierarchical structures which facilitate retrieval and practice of difficult parts (Williamson and Valentine 2002).

neural assemblies process information with greater efficiency and have undergone some functional reorganization as well that also affect motor responses.<sup>345</sup>

Now it may well be contended that the modifications of mechanisms that are involved in expertise are not unlike the shift that occurs in modes of processing according to the dual-process accounts that we've discussed in the previous Part.<sup>346</sup> In that context, we've noted that not only are representations modified but underlying mechanisms do not remain the same, as well. Indeed, dual-processing may be generally involved in expertise, as experts do employ both automatic processing after expert intuition has been formed, and also engage in controlled, deliberate search for solutions when necessary (Campitelli and Gobet 2010).<sup>347</sup> In a more restricted fashion, dual-processing theory can be applied to the chunking process itself, which is so important for the acquisition of expertise. In that case, we can distinguish between automatic and deliberate chunking processes (Gobet, Lane et al. 2001).<sup>348</sup> In the latter case, the characteristics of the more comprehensive templates and the chunks that are formed during learning are determined partly by deliberate choice – which confirms that indeed some top-down influence is effective, concurring with the intentional cascade framework. More below in this Part we will consider to what extent agents are capable of deliberately determining how to represent complex information and in doing so are also determining the corresponding neural processes. For now it suffices to point out that informational encapsulation of these chunking processes appears not to be at stake.<sup>349</sup>

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<sup>345</sup> Such kludge formation and the corresponding increase of connectivity that is responsible for activations in related, associated areas can be explained in terms of modularity, as was suggested in the previous Part. Indeed, a recent computational study which compared the evolution of networks under conditions of selection pressures for both performance and connection costs demonstrated that modular networks fared better with regard to both conditions. The authors point out that when a system develops a modular structure this also implies that there are fewer parameters to optimize, fewer nodes to connect and hence smaller connection costs, smaller effects of mutations on the overall system – all contributing to fast and cost-effective adaptability (Clune, Mouret et al. 2013). Expertise, when considered in terms of kludge formation, yields the same benefits, so we would argue.

<sup>346</sup> Automatic processing, so we found, is considered to be intuitive, fast and parallel, involving implicit and non-verbal knowledge and requiring no conscious attention. Controlled processing, on the other hand, is considered to require consciousness, to be slow and sequential and to rely on explicit knowledge. Behavioral and computational differences are furthermore associated with different underlying mechanisms (cf. (Frankish and Evans 2009)).

<sup>347</sup> Somewhat differently put is the distinction between intuitive and analytic processing inspired by dual-processing theories (Hodgkinson, Langan-Fox et al. 2008). These authors point out that emotion plays an important part in intuition. Others agree with the importance of emotion in expert intuition (Chassy and Gobet 2011), understanding emotion according to Frijda's notion of emotion as action tendency (Frijda 1986).

<sup>348</sup> Studies of music and sport experts show that deliberate practice has a strong effect on expert performance. Such experts deliberately practice specific components or features of their performance, like difficult runs on the piano or take-offs in sports or the tempo changes in the piece as a whole, thus further elaborating the hierarchy of the representations underlying their performance (Ericsson, Krampe et al. 1993 ; Meinz and Hambrick 2010).

In any case, we have argued in this section that corresponding to the modifications of the representations involved in motor intentions, underlying mechanisms are changing – for example due to kludge formation. The establishment and memorizing of complex and fine-tuned knowledge structures and their association with one or more appropriate response options leads to both increased efficiency and reconfiguration of the relevant processes and the mechanisms responsible for them (Guida, Gobet et al. 2012 ; Petersen, van Mier et al. 1998).<sup>338</sup> In sum, this repertory of knowledge structures and associated response options in a sculpted space of actions allows an agent usually to respond appropriately without requiring the agent to pass through the entire intentional cascade. Instead, he can rely on the expertise he has gathered over years of practice – practice which at the time did rely on the necessary distal and proximal intentions.

### ***2.2.3 Motor intentions and differential generative entrenchment of components***

From previous Parts we learnt how mechanism modifications underly changes in cognitive functioning. More specifically, we learnt about the associations between kludge formation and the changes or redescrptions of the representations involved in cognitive processes. In those contexts we also learnt that not all mechanisms components or representational components will equally be involved in future developments, as some are more generatively entrenched than others. When expert learning sculpts the expert's space of actions, therefore, we may expect that some dimensions or areas of that space will figure more prominently in further developments, than others. As we will see in this Part, such generative entrenchment obtains at all levels of the intentional cascade.

Generally, it has been observed that developing or learning new actions does often not imply the formation of completely new action representations but instead builds on previously learnt action representations, modifying these in some respects (Jeannerod, Arbib et al. 1995). In the present context of motor intentions, we did learn how experts demonstrate with their cognitive responses increased efficiency in processing and greater availability of appropriate responses after having established

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<sup>349</sup> This distinction between automatic and deliberate chunking processes would explain why the template theory of expertise in itself does not contradict the fact that deliberate practice can contribute to acquisition of expertise, the latter being defended by (Ericsson and Roring 2007). Deliberate practice has been shown to be effective in many artistic and scientific and sports activities, among which chess (Ericsson, Roring et al. 2007).

<sup>350</sup> The basal ganglia are important for chunking action sequences as several studies show. Patients with lesions in these structures are impeded in developing novel chunks, contributing to their lagging behind in responses to repeated tasks compared to healthy subjects (Boyd, Edwards et al. 2009).



knowledge structures like chunks and templates (Guida, Gobet et al. 2012 ; Petersen, van Mier et al. 1998). These templates, we noticed, contain empty slots which allow them more flexibility than if they would have been completely specified. Granted with this flexibility and with the set of response options associated with them, they are applicable in a wide range of situations and thus likely to become more generatively entrenched (Gobet and Simon 1996).<sup>351</sup>

Such differential entrenchment of chunks and templates is confirmed by much research that focuses specifically on the influence of hierarchical structure in representations that are employed in learning and imitation. Obviously, this holds when subjects are explicitly articulating hierarchical relations in an object assembly task, in which case subjects who developed more elaborated hierarchical representations of action were not only better in understanding and recalling an action but also in performing it (Hard, Lozano et al. 2006). However, similar consequences of differential generative entrenchment have also been observed in studies that focused on implicit motor intentions and in non-human animals.

For example, young children automatically develop hierarchical representations of an action they are required to imitate. Indeed, the phenomenon of ‘overimitation’ demonstrates that they have a greater capacity to represent quite elaborate hierarchies than animals do even though language is not directly involved (Lyons, Damrosch et al. 2011).<sup>352</sup> More specifically demonstrating differential entrenchment of knowledge structures in animals is research in which great apes demonstrate their capability of learning hierarchically structured actions for which they employ representations at both the level of action sequences and at a higher level of action ‘programs’. These program level representations allow greater flexibility and can be applied in a wider range of situations, for example when a nettle leaf eating program can be further specified when a specific plant is targeted (Byrne and Russon 1998). Particularly the program level representations at stake here are comparable to templates and similarly allow greater flexibility and adaptivity as they allow further specification of components that are left open.

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<sup>351</sup> To the extent that the brain prepares in parallel several options for action while interacting with the environment and internal - personal - conditions it is plausible that knowledge structures which bring along such properties will influence the ‘saliency maps’ associated with this parallel processing positively for more entrenched options (Cisek and Kalaska 2010). Several authors subscribe to this phenomenon of a competition between response options, e.g. (Brass and Haggard 2008 ; Botvinick 2001);

<sup>352</sup> The authors suggest that overimitation in children can be explained by referring to the ‘teleological stance’ that they often appear to take. This stance implies that - especially - children interpret action as aimed to realizing a particular goal rather than fulfilling a mental intention (Gergely and Csibra 2003). Overimitation being not restricted to western cultures, it may be especially important for the transmission of complex forms of tool-use, which is as much prevalent in humans in contrast to animals as overimitation is (Nielsen and Tomaselli 2010).



This difference between levels of action representation and their differential entrenchment has also been demonstrated in human experts. For example, in studies of sports expertise, experts generally demonstrate a more differentiated hierarchical structure in their representations, which does contribute to their better performances. But even at the level of the 'basic action concepts' that occupy the bottom of these hierarchies researchers found that there was more correspondence between experts than between non-experts and novices, (Schack and Hackfort 2007 ; Schack and Mechsner 2006).<sup>353</sup> Such 'basic action concepts', however, are more difficult to transfer to another domain of expertise as throwing a ball in baseball and in cricket require motor actions that are quite different from each other. Nonetheless, as mentioned above, in some cases expertise can be transferred even to a different action modality, as when subjects had learned to perform a particular sequence with their fingers, which did facilitate sequence performance with their voice: apparently the sequence was represented as a template which could be filled in with the specifics of muscular information (Keele, Jennings et al. 1995).<sup>354</sup> Similarly, it has been found that sport expertise does rest upon the establishment of templates that can be employed by experts in a wide range of situations, even outside the domain in which they are specialized. Baseball and cricket experts, for example, were found to employ templates that contain representations of strategic positions of offensive and defensive players and their respective goals in each other's domains, even though they had no expertise there (Jessup 2009).

The advantages associated with this fact of differential entrenchment of action components will come to the fore once more when we will be discussing the proximal and distal intentions that an agent uses when planning his future and current actions more below. One of the main reasons will turn out to be the support that such action components offer to enhanced coherence and consistency in his actions. Let us take a short look at this characteristic before moving to the next level of the intentional cascade, to the proximal intentions.

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<sup>353</sup> These 'basic action concepts' refer to observable - and commonly observed - components of complex actions, like throwing up a ball and hitting it in a tennis serve. The concept is remotely connected to the philosophical debate about the question whether there are basic actions - bodily, mentally, causally or otherwise (Annas 1977). Here is not the place to go into that discussion.

<sup>354</sup> This is for the authors reason to talk about the 'modularity of sequence representation' (Keele, Jennings et al. 1995). Although Pacherie also talks about the modularity of motor intentions, she does include in those not just the sequence representation but also effector related information about biomechanical constraints and kinematic and dynamic rules that govern the motor system (Pacherie 2008), which Keele et al. consider as belonging to the 'effector system'. This does not preclude the possibility that these motor intentions indeed can be further decomposed, with the sequence representation being a relatively separate component.

### 2.2.4 Motor intentions and consistency of action

Motor intentions were found to consist of representations that contain information about environmental affordances and motor movements pertinent to a certain action (Pacherie 2008). It seems plausible to assume that such complex representations, when established, allow an agent to act consistently in a recurring situation. This consistency may indeed depend upon the kind of guidance mechanism that Frankfurt referred to, lingering in the background during the unwinding of an action, waiting to intervene only in case of a deviance or loss of control. We found in section III.2.1. Frankfurt explicating that guidance implies: “a certain consistency or steadiness of behavior; and this presupposes some degree of persistence” (Frankfurt 1988 84).<sup>355</sup> Admittedly, this quote refers primarily to behavior at longer stretches of time but we’ve meanwhile argued that long-term practice also has an impact on short-term actions and on the on-line mechanisms that provide guidance for an ongoing action. To the extent that an agent has over time established a sculpted space of actions, we may expect him to act particularly consistently when actions that pertain to that space are being employed.

In fact, our previous section suggests that we may distinguish between action components at different hierarchical levels, or their representations. The templates that we discussed earlier figure at a higher hierarchical level than the knowledge structures that contain very specific motor representations, which may fill up the empty slots in those templates. Indeed, the differential generative entrenchment of action components and their representations is directly related to the consistency an agent demonstrates between his actions: the more a particular component is entrenched, the more we should expect to observe its functional properties in these actions. As a result, we should expect consistency in action to be distinguishable at different levels of specificity, as well.<sup>356</sup> However, given that we expect an expert to be flexible in adapting to specific environmental conditions and changes, consistency is especially supported if experts indeed employ templates with free slots that allow for adaptivity.

Consistency obtaining at different levels of specificity has been observed in experiments. For example, in research that required subjects to decide how they

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<sup>355</sup> More below, we will discuss coherence in action and not just consistency. Though both terms indicate that an element satisfies a particular constraint or fits together with another element, coherence is usually taken to be more difficult to obtain as it is taken to involve a wider set of constraints than consistency (Thagard and Verbeurgt 1998). Even though it is debatable whether coherence is useful as a criterion to select scientific statements, its use in practical and ethical matters is more obvious as there is usually less consensus about which statements deserve support, or not (Millgram 2000).

<sup>356</sup> Approaching a comparable question from a dynamical theory perspective rather than from a mechanistic explanation perspective (which are said by the author to potentially complement each other), Kelso argues for the prevalence of ‘synergies’ in brain and behavior. Such synergies are structural and functional units that are ‘soft-assembled’ under certain conditions but gain stability over time and can then support coordination and control within an organism (Kelso 2009). Synergies can contribute to the theory of embodied cognition, positing that such soft-assembled units which span brain and body (and environment) can be employed in several functional domains (Anderson, Richardson et al. 2012, (Anderson, Richardson et al. 2012)

would play the ball after viewing a netball videoclip, experts and novices significantly differed in the correctness of their responses, demonstrating effects of expertise with a domain. However, within a sports domain it is possible to further distinguish positions. Indeed, expertise with certain field positions was reflected also in differences in correctness between the experts (Bruce, Farrow et al. 2012). Focusing on a still more specific movement, research with animals and humans has shown different levels of consistency that can obtain in movements for reaching and grasping a cup or other objects. Indeed, templates – called ‘schemas’ by the authors – were employed during reaching that did leave room for grip specification and even grip modification when object position was changing. Grip specifications were more specific in their motor representations and did allow less flexibility, testifying to their lower hierarchical position and limiting their involvement under multiple conditions (Jeannerod, Arbib et al. 1995). Consistency can also obtain with regard to a particular dimension of an action under different circumstances, as long as relevant representations are shared. For example, motor intention and motor imagery share largely the same representations, which is demonstrated by a remarkable consistency in the temporal structure of an action, irrespective of it being executed or imagined (Jeannerod 1994). Such specificity of consistency in motor intentions and its dependence on particular action representation components is also observable in patients who are incapable of verbalizing a grasping task and its representation and are correspondingly less capable of consistently performing it when a temporal delay between stimulus and response is given (Rossetti 1998). Apparently, consistency between actions does especially require knowledge structures like templates, that can be shared between different conditions as they allow further specification. Given the importance of objects and goals in many motor actions, it is relevant to note that action consistency is indeed supported by hierarchical representations of which different components can become activated relatively independently (Jeannerod, Arbib et al. 1995). The presence of different levels of specificity in this context implies that some levels of representation are more at a distance from direct motor control. This hierarchical structure of the action representations allows consistency of action to appear at several levels, as well.<sup>357</sup>

Generally, there is reason for an expert to rely within his domain of expertise on the motor intentions that he has established over time as research with expert handball players also shows. Given that these motor intentions are the result of much gathered experience, it is not surprising that the action option that experts first generate in response to a particular game position are usually better than options that are generated secondly or later (Johnson and Raab 2003).<sup>358</sup> Apparently, their motor intentions allow them indeed to perform consistently well, associating the recognition of complex

situations with appropriate responses. Moreover, the fast and implicit responses of an expert bring along the advantage that he is not distracted by the alternative solutions that conscious deliberation may suggest even in a situation where the constraints are such that there is little room for alternative solutions, as research of base ball catching demonstrates (Reed, McLeod et al. 2010).<sup>357</sup>

Such a difference between implicit processes, involved in motor intentions, and explicit processes does of course also lead to differences between the levels at which consistency between performances can be observed. Abstract representations become especially more generally available as templates for other modalities when an agent explicitly attends to these and grasps the abstract rule underlying a sequence, whereas a motor sequence can be learnt implicitly by merely repeatedly performing it and establishing relevant chunks as a result (Dominey, Lelekov et al. 1998).<sup>360</sup> Particularly at higher levels of the intentional cascade may we expect such abstract representations to play an important role. As a result, we may expect that when we are focusing on proximal and distal intentions, we will also observe other forms of consistency at those levels of action. More interesting, still, would it be if we could find interactions between different levels of the intentional cascade and influences of such interaction on the formation of kludges in the mechanisms that are responsible for cognitive processes and action. Before looking at those higher levels and such interaction, however, some neural evidence concerning motor intentions will be considered.

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<sup>357</sup> Obviously, consistency in responding to a complex situation is dependent upon the number of constraints that play a role in an agent's capability of pattern recognition and the specificity of the action option generated in response (Johnson and Raab 2003). This is the reason why an expert will act more differentiated in response to subtly differentiated situations. Moreover, the fast and implicit responses of an expert bring along the advantage that he is not distracted by the alternative solutions that conscious deliberation may suggest even in a situation where the constraints are such that there is little room for alternative yet optimal solutions, as research of base ball catching demonstrates (Reed, McLeod et al. 2010)..

<sup>358</sup> From a meta-analysis of research on decision making in sports emerged that most consistent effects of expertise were visible when subjects were asked to respond behaviorally to a stimulus and not when responding verbally (Travassos, Araújo et al. 2013). This confirms our notion that motor intentions are implicit and can only in a limited sense be explicitly verbalized.

<sup>359</sup> However, there are some other modulating factors involved in constraining the presence of an abstract representation of an action and its potential modifiability. For example, in some conditions there is a dominant limb effect for a particular action, implying an asymmetry regarding the effector of the represented action. This may be a consequence of task complexity influencing the tempo in which a translation of visuo-spatial characteristics to motor characteristics is carried out by practicing subjects, which is necessary for task performance. In any case, it does contradict the assumption that always an abstract representation is available and supports the transfer of a task to a different effector or modality (Panzer, Krueger et al. 2009)

<sup>360</sup> This is confirmed by research of a key sequence pressing task where participants did not detect the similarity of sequences in different tasks and did not demonstrate in their reaction times in the separate tasks an automatic transfer. However, the author remarks that differences in instructions can also lead to different processing modes and thus to differences in the transfer (Verwey 2003). Indeed, also evidence from a different strand of research, on imitation, shows that preceding task instructions - to observe or imitate - yield different mirror neuron system activation patterns, suggesting that task instructions prime or activate different neural networks, with potentially different tasks being performed by the same systems (Vogt, Buccino et al. 2007)

### ***2.2.5 Motor intentions and some evidence concerning their neural implementation***

Part I contained discussions of both Marr's and the mechanistic explanatory approach to cognitive neuroscientific research. Both approaches concurred that mechanisms and mechanism components presented as explanations for cognitive functions require at least three different types of analysis, these being an analysis of the task or function at hand, an algorithmic analysis of it and finally considerations of the possible implementation in a physical system – neural or otherwise. Although Marr himself may have been less explicit about how these types of analysis should be related to each other, in fact his work spurred future researchers to engage more with each other's work (Kosslyn and Maljkovic 1990). According to the mechanistic explanatory approach, insights pertaining to different levels of analysis and to different levels of mechanism can be used as 'mutual constraints', thus reciprocally limiting the theoretical options available at those levels (Craver 2007).

With regard to the current context, we're interested in evidence about implementation of the motor intentions' capability to integrate multiple kinds of information. Moreover, the neural implementation of these motor intentions should be such that modifications obtain due to learning and expertise, such that generative entrenchment can occur. Such entrenchment should have lead, among other things, to involvement in ever more processes, compared to less prominent motor intentions. Most of the evidence concerning motor intentions referred to in the previous sections stem from developmental or cognitive studies, from animal studies and from computational studies. These studies have suggested that certain types of representations and processes are involved in motor intentions. For the elaboration of more detailed and comprehensive mechanistic explanations, further insights concerning underlying neural component processes and parts would be required. Given the limitations of our task, the evidence presented below should only confirm that in concurrence with the structured organization and modifiability of motor intentions, so are the underlying neural activities structured and modifiable.

Just like we observed that the impact of expertise on motor intentions can be specified at multiple levels, so can we find neural implementations of this at the level of single cells but also at a more comprehensive level. Evidence shows, for example, that experience and expertise does affect the activation patterns of single cells in correlation with specific actions. In sequential actions, for example, single cells in prefrontal cortex have been found to be activated in correlation with particular steps of an action sequence that a monkey must perform (Mushiake, Saito et al. 2006). Intriguingly, a specific cell type - mirror neurons - is activated both by observation and

by performance of complex actions like grasping an object and bringing it to the mouth. Adopting Jeannerod's idea of motor representations being shared between conditions, it was immediately assumed that these cells would undergird an observation/execution matching system by representing a 'motor vocabulary' (Gallese, Fadiga et al. 1996 ; Rizzolatti, Fadiga et al. 1996). Such shared representations have meanwhile been investigated via studies of mirror neurons and mirror neuron systems that are involved in the representation of a huge variety of stimuli and actions, observed in virtually all perceptual modalities and during the performance of simulation, verbal or motor tasks (see recent reviews (Casile, Caggiano et al. 2011 ; Cattaneo and Rizzolatti 2009 ; Glenberg 2011 ; Keysers and Gazzola 2009)).

Just like motor intentions were found to represent not only motor actions but also to include representations of relevant environmental affordances for action, so do these neurons (and even large neural networks) have the perceptual-motor qualities that facilitate such interactions (Casile, Caggiano et al. 2011). Indeed, such mirror neuron activation supports the brain's function of anticipating future action outcomes, making it more likely that these will be consistent with previous experiences (Kinsbourne and Jordan 2009).<sup>361</sup> These neuronal activities exemplify how a relatively simple and low level component mechanism may play a crucial role in facilitating an agent to interact consistently and coherently with his environment without continuously demanding attention and conscious cognitive processing.

Such interactions between environmental conditions and motor responses occur also at a higher level of specificity. Have mirror neurons been associated with quite specific motor actions – or component actions - in response to particular stimuli, more comprehensive action responses to particular environmental conditions rely on larger neural networks. Habitual responses or habits, considered as an action sequence in response to particular conditions, refer not just to chunks of behavior but demonstrate the kind of flexibility that fits with our notion of templates. Such habits develop over time and rest upon a network involving loops between cortical areas and the basal ganglia, with striatal neurons playing a role as throughput (Graybiel 1998). The stronger these cortico-basal ganglia loops become, the less flexible are the habits with regard to both stimulus and response conditions (Yin and Knowlton 2006). Indeed, obsessive-compulsive disorders that are associated with uncontrollable and inflexible actions in patients, have been associated with these same loops (Graybiel and Rauch 2000). In such patients, the motor intentions associated with these actions are no

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<sup>361</sup> The motor representations that become activated upon the perception of an affordance can also include tool specific features when the subject has become familiar with that tool (Valyear, Gallivan et al. 2012).

longer integrated in the intentional cascade as other actions are.

For in most cases, chunked motor actions are still integrated in a larger neural network and consequently potentially affected by proximal and distal intentions. It is the prefrontal cortex that is held to be crucial for the integration of information that is involved in the various tasks that support the performance of action, like processing sensory information, associating information with motivational values and activating of necessary representations from memory (Forbes and Grafman 2010 ; Tanji and Hoshi 2001). Apart from a distinction between task-specific areas of PFC, hierarchical structures of the brain have been correlated with hierarchical structures in action representations.<sup>362</sup> It appears that the hierarchical structure of action, which we've argued brings several benefits along, is facilitated by a similarly hierarchical organization of its neural underpinning. Within the prefrontal lobe, motor memories are being stored along a gradient in terms of their complexity (Fuster 1997). Evidence shows how simple motor acts are being stored in the posterior premotor cortex, with anterior areas being more involved in complex forms of action control (Botvinick 2008).<sup>363</sup>

In sum, we can find in the brain relatively small mechanisms that are responsible for simple motor actions in response to particular stimuli and more comprehensive mechanisms that are associated with acquired motor sequences to complex environmental conditions. Remarkable is this fact that we find at several levels of specificity an integration of the perception and recognition of these conditions and the determination of a motor response – whether at the cellular level or at the level of neural networks. This reflects our previous observations of motor intentions at several levels of specificity, for example as chunks or more flexible templates of action responses. Although these contribute to an agent's sculpted space of action, other contributions are needed if more comprehensive action plans are to be integrated in this sculpted space. Consequently, although in many cases actions can be determined by relatively simple motor intentions and correlated with specific component mechanisms, proximal and distal intentions must often be involved as well. These intentions do not only modify an agent's motor intentions and their neural underpinnings indirectly via long-term

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<sup>362</sup> Obviously, there are several reasons to question such mapping of hierarchies onto each other, which easily slides into a kind of neo-phrenology (Uttal 2001). Such reservations notwithstanding, hierarchical models are not just constructs as several lines of research robustly support their reality (Cohen 2000).

<sup>363</sup> Botvinick and others have argued that hierarchical reinforcement learning can account for computational and empirical results of emerging hierarchy in action (Botvinick, Niv et al. 2009). Whether this model can do without the explicit representation of goals and without the model having a hierarchical structure itself has been questioned in (Cooper and Shallice 2006). Irrespective of this difference, these authors agree with respect to the prevalence of hierarchical structure in action and the fact that some action components are more prevalent than others.

processes of learning and exercise. On top of that, proximal and distal intentions often interact with the representations involved in motor intentions for the determination of an action, since motor intentions do not only receive top-down influence but in turn exercise bottom-up influences.<sup>364</sup>

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<sup>364</sup> Motor intentions are different from the simple stimulus-response couplings that can be found to underly habits which are also dependent upon a subcortical loop (Graybiel 2008). The response patterns of motor intentions are more complex and they are capable of being prepared by relevant distal intentions, which do not need to be continuously activated. Moreover, regarding the mirror neuron systems, evidence shows that not all perceptual information is immediately relayed to mirror neurons but some gates or filters appear to - sometimes implicitly - modulate that information, as we've discussed in (Keestra 2012).