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

Keestra, M.

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1 INTRODUCTION: FROM DYNAMICS TO STABILITY AND BACK AGAIN*

Hearing the babbling sounds of a baby can be as enjoyable to its parents as a song recital by an expert vocalist. Nonetheless, the babbling is a far cry from the expert singing in many respects, even though every singer will have started as a babbling baby and remains capable of such babbling. In a sense, then, increasing expertise in singing amounts to adding different modes of vocal expression to one's repertory and to enhancing one's control: controlling each mode of vocal expression separately and controlling which mode of vocal expression is to be used at a particular moment. The development along these two dimensions could at first sight appear to be paradoxical: if one enforces upon an agent an increasing number of factors to determine when to perform a particular task, one would normally expect this agent to lose control in comparison to his earlier performance of that – simpler – task and therefore show a deteriorated performance. This apparent paradox notwithstanding, development and learning appear to enable both the enrichment of a particular capability and the stabilization of the performance of that capability, which includes different modes of performing it. This part will focus on the aspects of such a process of development or learning that have to do with the stabilizing and expansion of a particular capability like vocal communication, preparing for our discussion in Part III of the diversity in our modes of performing intentional action. Such a process is complex, as it involves gaining expertise with certain elements of that function, increasing ability to combine different elements of the function with each other and eventually to have such ease with it that the function can be performed alongside other functions. Let us consider the singing example again to clarify this, describing how it becomes increasingly complex and integrated with other functions.

To begin with, babbling lacks language while singing usually combines musical with linguistic elements – sometimes even in a language other than the singer's mother tongue. Apart from these linguistic elements, the musical elements of singing are generally not distinguishable in babbling sounds: rhythm is lacking, dynamical structure is usually very simple and the tonal spectrum is rather narrow.¹⁴³ An expert singer, in contrast, has mastered a wide range of distinct rhythms, can apply large dynamical differences to the music and control his voice such that he has added octaves to his vocal range compared with novice singers and babies. Moreover, depending on the intended expression, an

* On pages 371, 373, and 375, figures I, II, and III offer simplified representations related to the arguments made in Parts I, II, and III respectively. Fig. II is particularly relevant as a representation of the main contents of section II.2.

¹⁴³ As for melody: research with French and German newborns demonstrated that these had already memorized the prosody or melodic contour specific to their mother's language and reproduced this in their own whining (Mampe, Friederici et al. 2009).

expert singer can control not just the pitch but also the timbre and projection of his voice, adding another dimension to his music. Being able to combine those musical elements and linguistic elements at will, an individual singer can impersonate in the course of a single recital a seductive Don Giovanni, a meditative Saint François, an amorous Tristan, a raging Pizzaro, a joyous Porgy, or a babbling (indeed, babbling) Papageno (or female parts for female singers, obviously). Finally, an obvious difference is of course that singing happens mostly in an ensemble with an accompanist or other singers, while babbling babies usually perform individually. Corresponding with this difference is the reproducibility which is desirable for expert song, enabling a musician to improve his performance individually, to adjust his interpretation of a song or improvisation at will and in detail, and to play together - often aided by a score of the music, from which he can sing at *prima vista*. Given these differences between baby babbling and expert song, it is remarkable that the two phenomena are nonetheless related, that the former is a necessary precursor to the latter and does remain on the singer's repertory, with the two standing in a developmental relation to each other. Our discussions in the previous part have provided us with some useful tools to explain and understand this curious fact.

The ingredients of mechanistic explanation, so we argued, are such that we can elucidate the dynamic modifications of a mechanism responsible for a cognitive or behavioral phenomenon. Given a mechanism's complex organization of components parts and operations and the mechanism's interactions with its environment, there are ample resources to account for such dynamics. Indeed, section I.5.6 presented four possible modifications of a mechanism: 1) the recruitment of a novel component part in the mechanism responsible for a phenomenon like singing, as when babbling gets combined with linguistic elements; 2) a dynamic change in a component operation of the mechanism, as when a singer is able to correct his pitch very fast; 3) a change in a mechanism's organization, as when singing has become so automatized that an opera singer can shift his attention to his stage performance; 4) a modification and expansion of the kinds of interactions with the environment, as when an expert singer is capable of colouring his voice such that it drowns out different types of accompaniment and fills music halls with different acoustics. These modification types will usually co-occur, as it is often impossible for a modification type to obtain separately. A relevant example is the fact that usually, a novel form of environmental interaction with another singer is only possible when some singing abilities have previously stabilized.

With these ingredients put in place, the question may arise whether a phenomenon that is produced by such a modifiable mechanism is not in constant flux. After all, the activities of a mechanism and the associated environmental and internal interactions

continuously affect its components and their organization, so how can we still expect it to perform stably? Indeed, these effects on the mechanism will not always be identical or consistent with each other, as every practising singer knows very well, hitting false notes all too often. Still, this modifiability does not preclude a singer from obtaining stable results in his singing after a period of practice. After repeating a vocal coloratura many times and in segments at first, the singer will then be able to reproduce it reliably. This stability of his performance enables him subsequently to speed up this part, to vary its dynamics, to transpose it a semitone when his duet partner forces him to do so and even to draw the specific facial expressions required by a stage director. Instead of having to struggle when singing this part from note to note, the singer now feels as if the coloratura has become a single unit, allowing for as much freedom with that coloratura as a novice singer may enjoy when singing just a single and easy note.

This phenomenon of increasing expertise with a certain cognitive or behavioral function or an aspect of such a function is familiar to all animals. Immediately after birth the functions to be developed and stabilized have to do with feeding and moving, followed by on-going processes of improvement of those functions and varieties thereof and of learning completely new functions. The set of functions that an animal can perform is constantly changing and generally expanding, with subsets becoming increasingly stable. Now that Part I has provided us with the tools to explain a particular function and its underlying dynamics, Part II seeks to analyze and explain how increasing expertise affects a cognitive function. For this, we will take up three accounts that all present different explanatory mechanisms underlying such expertise or skill learning. From our perspective, however, these accounts agree in that expertise has an effect on the responsible mechanism, an effect which we will consider in terms of 'kludge formation'.

To do this, we will first devote a chapter of this part to the definition of a 'kludge'. Since our intention is to argue that learning and development results in novel cognitive or behavioral response patterns on the basis of the dynamic changes in a responsible mechanism – characterized by a hierarchical and modular structure – that correspond to the formation of a novel kludge in it, this concept will play an important role here. We will then devote three chapters to cognitive phenomena that represent such processes. One of these will concern the development in children of domain specific or task specific brain circuits that can subsequently function as kludges, a process that has been referred to as 'modularization' (Karmiloff-Smith 1992). A second chapter will discuss so-called 'dual-process' theories, referring to two different and allegedly independent processes – or for some authors: systems – in the human brain, operating on different informational domains and according to different rules, which allegedly

leads to inconsistent behaviors (cf. Chaiken and Trope 1999 ; Evans 2008 ; Lieberman 2007 ; Smith and DeCoster 2000). Chapter II.4, finally, will discuss the theory that humans are capable of forming cognitive kludges not only by combining different capacities, but also by including external components like tools or symbol use in such kludges (Barsalou 1999c; Clark 1997). Discussing these examples will pave the way for Part III, which will be devoted to the complex process that is involved in action determination, including the use of language. This process is to a large extent carried out by a set of kludges, varying in their origin and functional properties, which contribute in multiple ways to the process of ‘sculpting the space of actions.’ It is to the definition and characterization of a ‘kludge’ that we now turn.

1.1 Kludges: mechanism adjustments and expansions

Above, we noted that due to development and experience, an expert singer has become capable of performing well and stably at more levels of specificity and complexity than a novice singer, also allowing him to expand his performance both in vocal terms as in other terms like playing a stage character or keeping track of an accompanist. This capability is dependent upon a process that yields a mechanism comprising ever more components of a type that we will from now on call ‘kludges’. As we noted in Part I, a mechanism generally has a hierarchical – or rather: heterarchical¹⁴⁴ - modular structure: it is characterized by a nested structure of components with relatively specific functions, each contributing to the mechanism’s performance as a whole. Such a hierarchical and modular structure can undergo several types of modifications, as we mentioned. Whether through normal development, via specific learning episodes or via common accumulation of practice, the modification of the relevant mechanism’s structure will usually involve the emergence of a ‘kludge.’¹⁴⁵ In such a case we may also refer to the implicated mechanism as being ‘kludged’ and the function it produces –behavioral or cognitive- as being a ‘kludged function.’ Even though a kludge bears some resemblance to what is commonly referred to as a ‘module’, we prefer the former term in order to avoid some of the undesirable associations with the latter term – about which more below. What then are the defining characteristics of a kludge?

¹⁴⁴ That is: a heterarchy with modifiable control relations – see footnote 96 in part I.

¹⁴⁵ The term ‘kludge’ or ‘kluge’ is common within the engineering domain, where it refers to what Marcus calls ‘a haphazard’ construction (Marcus 2008), or a ‘cobbled together’ solution in Clark’s terms (Clark 1987). Its origin and precise spelling is unclear. Marcus refers to the German word ‘klug’ for clever as a potential source (Marcus 2008), reason why he spells it without a ‘d’. Although the German association is thought provoking, spelling it with a ‘d’ additionally maintains the association with the English word ‘clutch’, referring to a mechanism that draws in an additional component for fulfilling a function.

To begin with, a kludge is a component of a mechanism, which must be characterized functionally. That is to say, when a kludge emerges we can observe this in changes in the performance of a particular cognitive or behavioral function or component function, related to a specific domain. As we will see below, usually the performance of such a function – which here implies also: component function, as it often applies to a specific function like keeping tone or singing a coloratura – happens with greater speed, stability and flexibility than it used to happen earlier by the subject. This was the case with much of the singing components discussed above, whether it was reading notes, singing coloraturas or other function components. Depending on the specific function, the functional properties that change due to its being performed by a kludged mechanism obviously will differ. Sometimes, for example, it may not be visible in changes in the kludged function, but we could perhaps witness from changes in unrelated functions that cognitive resources for the latter have become available due to the reduction in resources required for the former, now kludged function. Obviously, we may assume that changing properties in the kludged function are to some extent determined by the algorithmic processes or the neural implementation that are associated with this kludge formation. Let us turn to the second important aspect of what makes a kludge: its algorithmic processes.

The emergence of a kludge related to a specific function usually corresponds with a change in the algorithmic processes involved. Nonetheless, the second characteristic of a kludge is that we cannot directly derive from its functional – cognitive or behavioral – properties an ‘algorithmic’ theory in Marr’s sense, as discussed in section I.3.3.1. (Marr 1982). Indeed, the mere fact that development or learning affects the processes involved in a function like singing demonstrates that such a function can have a multiplicity of processes subserving it. One and the same functional result can be obtained via more than just a single process, involving different types of information processing, or representation manipulations, or dynamical processes. In singing, for example, practicing a particular difficult vocal phrase can involve its segmentation in smaller parts and gradually connecting these, or developing a mental image of the phrase and thus facilitating vocal muscular movements, or simplifying the phrase and gradually reinserting the difficult parts, or imitating a vocal expert’s examples which will often be sung with increasing speed. Clearly, all of the algorithmic processes involved are associated with other cognitive or behavioral functions, some of which are rather complex. Perhaps score reading is involved, which can help the segmentation of the phrase in smaller parts. Or careful listening is important, when imitation is involved. Not only can these algorithmic processes differ between subjects, these processes will generally also change as a function of the kludge formation. Indeed, in many cases the

formation of a kludge appears to result in a change of precisely this component, of the algorithmic processes involved in a particular function. This is the case, for example, when a response to a particular situation no longer requires complex cognitive and perhaps conscious processing but simply is given immediately upon perceiving a task specific stimulus due to its being habituated (Graybiel 2008). In many other cases and several of the examples to be discussed below, however, kludge formation is associated with specific changes in the representations that are relevant for the task at hand, like the musical representations in singing.

Now that we have argued that it is not possible to derive a specific algorithmic theory from the fact that a function and its underlying mechanism have become kludged, it is obvious that this also holds for the specific neural implementation of a kludge: its third characteristic is that there may be more than just a single option available for its neural implementation. As we learned in Part I, any investigation of the neural implementation of a function relies on the preliminary definition of its functional properties. Marr already pointed out that it may even be possible that one and the same function – characterized in his approach with a computational or task theory (Marr 1982) – allows different kinds of implementation. This is even more so with a function that is involved in such kludge formation, as this process implies the modification of the mechanism responsible for the function, even though the associated modifications may differ from case to case. Indeed, it may be the case that while most subjects will establish a kludge when learning to perform a particular function, like finding a note or singing a coloratura, the specific neural process that corresponds to its formation may vary between stages of the kludge formation process, or vary between subjects. This has partly to do with the fact that the performance of a particular function can rely on different cognitive or behavioral processes and consequently the underlying neural processes involved. Regarding those neural processes, in section I.5.6 we discussed that there are several ways in which an underlying explanatory mechanism can modify due to learning and development. In terms of neural implementations, we mentioned the option of structural changes of the responsible mechanism, or the option of connectivity changes within a mechanism of which the components and operations remain largely the same.

A fourth kludge characteristic pertains to the fact that there will be quite some variation between subjects or even within an individual subject during the intermediate stages of learning or development, even when a particular kludge formation might eventually lead to rather similar functional, algorithmic, and neural implementation properties. Particularly in experienced subjects, we can even assume that more than one kludge can be activated or employed for the performance of a particular function.

Indeed, one of the consequences of their being expert singers is that they are capable of engaging different kludges for the performance of a particular function, depending on some other, relevant functional properties. Perhaps in a situation where a singer is tired, his singing will primarily rely upon a particular kludge that allows him to perform his score well, even though this kludge allows less adjustment of tone to the sound of other performers, it leaving the singer less responsive to auditory input.

A further defining characteristic of a kludge is that it often consists of components – functional, algorithmic, neural – that are already present but are then ‘cobbled together’, a feature from which a kludge in fact derives its name (Clark 1987, cf. Marcus, 2008).¹⁴⁶ Thus, a kludge will often have properties suggesting that its emergence is primarily due to development or learning and not genetically determined or innate. Although a kludge generally consists of a mechanism modification in which development or learning were involved, it is usually the result of not just one but a combination of different constitutive forces. It may involve a modification of a speech component mechanism after a specific learning period, or it consists of a modified music score reading mechanism that involves the adaptation – or recycling (Dehaene 2005) – of among other things the Fusiform Face Area. As a result, it is often hard to determine the developmental, experiential, environmental and other factors contributing to such an emerging kludge.

A sixth characteristic of a kludge is that after its emergence it can itself become involved in subsequent developmental or experiential trajectories. Notwithstanding the fact that the emergence of a kludge involves the modification of a responsible mechanism, this newly emerged mechanism or mechanism component itself will probably play a role in subsequent developments. Indeed, although a kludge generally emerges from strongly associating components that were already in place, it may itself in turn become similarly involved in another kludge formation process. As a result of this, one can observe that some kludges have become so deeply entrenched in other mechanisms with specific functions, that its disturbance would have wide-ranging consequences and not be limited to the kludge’s specific functional characteristics.¹⁴⁷

¹⁴⁶ Concurring with this characteristic are several accounts of the development of cognitive and behavioral functions that involve extensive neural re-use in the brain (Anderson 2010), or the exploitation of previously established ‘neurofunctional architecture’ for new functions (Gallese 2008), or the ‘recycling’ of older brain circuitry for cultural inventions like reading (Dehaene 2005).

¹⁴⁷ Wimsatt and Rasmussen both point out that it may be useful to distinguish between the degree of ‘generative entrenchment’ of particular properties as a measure for their being involved in other, later developments, as it allows us to distinguish between properties with a more recent or an older evolutionary or developmental history (Rasmussen 1987; Wimsatt 1986; Wimsatt 2001). Karmiloff-Smith argues from a different perspective – about which more below in chapter II.2 – that functions that ‘modularize’ at an early age will have a greater impact when impaired than others, making double dissociations for modular components highly improbable (Karmiloff-Smith, Scerif et al. 2003). Her reservations against the common definition of ‘modules’ is one of the reasons we prefer the notion of ‘kludge’ in our argument.

It is not surprising that at times researchers harbor the unwarranted assumption that the components of a particular kludge must themselves have a ‘natural’ origin or be innate, instead of these also being the product of a previous idiosyncratic process of kludge formation.¹⁴⁸

A seventh and final characteristic of kludges that we need to mention is the involvement of external, environmental information in the process of their emergence and in their functioning. As a kludge often emerges after a period of specific experience or learning in which a subject engages in a particular manner with his environment, its functional properties – mentioned above as its first defining characteristic – often include environmental information. Such an inclusion can range from a kludge’s activation by a particular environmental stimulus to the inclusion of the properties of a particular tool in one’s body scheme.¹⁴⁹ Even though some kludges emerge at such a young age in subjects and involve the inclusion of such elementary environmental information that they have sometimes been interpreted as innate mechanisms, their properties cast some doubt on the strict distinction between a kludge’s being innate or acquired.¹⁵⁰

Now that we have spelled out these kludge characteristics, let us turn to the first of three examples in which kludge formation can be associated with observable changes in cognitive and behavioral functions. Since we will not find reference to ‘kludge’ or to kludge formation in this case, but rather to the concepts module and ‘modularization’ (Karmiloff-Smith 1992), we will start the next chapter with a short discussion of these concepts.

¹⁴⁸ An interesting example is the debate whether mirror neurons, involved in the mirror neuron systems that are taken to be responsible for many intersubjective processes, are innate or the result of a learning trajectory. It appears that consensus is increasingly in favor of an experiential basis of mirror properties (Catmur, Mars et al. 2011 ; Keysers and Perrett 2004).

¹⁴⁹ Iriki among others suggests that associated with this process of incorporating or assimilating of tool properties in one’s body scheme, an analogous process of ‘objectification’ of one’s body takes place, facilitating imitation and mutual learning (Iriki 2006).

¹⁵⁰ Wimsatt in particular has warned against this strict distinction between the innate or acquired nature of – what he calls – ‘generative entrenchments’. Elaborating on Mayr’s notion of closed and open behavioral programs (Mayr 1974), Wimsatt refers to the example of imprinting, which is a tightly constrained mechanism that nonetheless includes environmental information in its eventual emergence –potentially including information associated with ethologist Lorentz in his goose chicks’ imprinting mechanisms (Wimsatt 1986).