# UNNECESSARY CONSTRAINTS: A CHALLENGE TO SOME ASSUMPTIONS OF DIGITAL MUSICAL INSTRUMENT DESIGN

*Adam Linson*
Faculty of Mathematics, Computing and Technology
Department of Computing
The Open University, Walton Hall
Milton Keynes, United Kingdom, MK7 6AA
a.linson@open.ac.uk

## ABSTRACT

The enormous range of possibilities for digital musical instrument (DMI) design is often limited by the adoption of unnecessary conceptual constraints. When considered in relation to DMIs, a careful analysis of the underlying concepts makes it possible to reject certain assumptions and thereby to expand the current range of acceptable possibilities for future designs.

## 1. INTRODUCTION

As Wessel and Wright point out, “skilled players of acoustic instruments ... [are] constrained by the sound production mechanism [of their instruments]. ... When sensors are used to capture gestures and a computing element is used to generate the sound, an enormous range of possibilities becomes available” [8]. Unfortunately, this enormous range of possibilities is often limited by the adoption of unnecessary constraints. These adopted constraints appear to result from various assumptions that lack a sound conceptual basis. The assumptions arise when the following concepts are confused or conflated: the physical universe and the human world; the model of competence and of performance; the object and the tool, and; the vehicle and referent of the metaphor. When considered in relation to digital musical instruments (DMIs), a careful analysis of these concepts makes it possible to reject certain assumptions and thereby to expand the current range of acceptable possibilities for future designs.

## 2. THE PHYSICAL UNIVERSE AND THE HUMAN WORLD

One issue that consistently arises in DMI design is *mapping*, which describes the relation between control input and sound output. With an interface, this relation is connected to a basic notion of causality: our intention causes a sensorimotor behaviour, which in turn, when parsed by a DMI as a control input gesture, causes a sonic output response. As simple and self-evident as this causal chain might seem, in fact, there is a significant point to be considered here, in that two issues are being conflated. One is the physical-mechanical sense of cause and effect witnessed, for example, in the movements of colliding billiard balls. The other sense is the translation of a person's thought into action, which has been theorised in countless ways and is beyond the scope of this paper. It can, however, be noted that these senses of causation cannot be considered equivalent. As the philosopher Hubert Dreyfus puts it:

> It has proved profitable to think of the *physical universe* as a set of independent interacting elements. The ontological assumption that the human world too can be treated in terms of a set of elements gains plausibility when one fails to distinguish between world and universe, or what comes to the same thing, between the human situation and the state of a physical system [3].

Since music performance is a meaningful human activity, it makes little sense to consider music-making *solely* in terms of the physical production of sound. The context for the intention to make a sound in a musical performance is a human situation, while the mechanics of the sound production are part of a physical system.

This is not merely an abstract point; it takes on practical significance when we consider the potential impact on DMI design. On the one hand, there is the design question of whether or not a new instrument conforms to expected physical behaviours and to our experience of interacting with the physical universe. On the other hand, there is the question of how our actions result in a sonic outcome that we imbue with musical meaning. This is particularly relevant to DMIs designed for improvised music, which, as George Lewis states, is “neither a style of music nor a body of musical techniques. Structure, meaning, and context in musical improvisation arise from the domain-specific analysis, generation, manipulation, and transformation of sonic symbols” [4]. When our design concern is with the potential *musical* effects we can achieve, the human-DMI interaction model must be situated within the wider context of the music being performed.

Paul Dourish, in his general consideration of embodied interaction, writes that “the key feature of interaction with computation [or with a DMI] is how we *act through* it to achieve effects in the world. ... The relevance of intentionality is that it provides us with a route to understanding how the elements of an interaction system can take on meaning for users in the course of activity" [2]. So if a performer can develop an understanding of how to use a DMI to bring to fruition musical intentions via physical interactions, it is not necessary for these interactions to be modelled on known interaction experiences in other physical skill domains, the most obvious of which is playing an acoustic instrument. In fact, abandoning narrow modelling constraints in the design can enrich the player's process of exploration, in line with Wessel and Wright's notion that "performers' intentions are elaborated upon by the discovery of new possibilities afforded by the instrument" [8].

## 3. THE MODEL OF COMPETENCE AND OF PERFORMANCE

The previous section describes a pitfall for interaction design that can lead to overly privileging our familiar experience of interacting with the physical world. A similar problem can result from a confusion of competence with performance. It is a common practice in some fields of social research to observe how humans act in the physical world and to extrapolate from the data a formalisation of what must be going on. Identified by Pierre Bourdieu and elaborated upon by Dreyfus, the common mistake is the supposition that "the rules used in the formalization of behaviour are *the very same rules* which produce the behavior" [3]. Dreyfus illustrates this distinction with the concepts of *competence* and *performance*:

> A man riding a bicycle may be keeping his balance just by shifting his weight to compensate for his tendency to fall. The intelligible content of what he is doing, however, might be expressed according to the rule: wind along a series of curves, the curvature of which is inversely proportional to the square of the velocity. The bicycle rider is certainly not following this rule consciously, and there is no reason to suppose he is following it unconsciously. Yet this formalization enables us to express or understand his *competence*, that is, what he can accomplish. It is, however, in no way an *explanation* of his *performance*. It tells us what it *is* to ride a bicycle successfully, but nothing of what is going on in his brain or in his mind when he performs the task [3].

We learn certain skills and develop expertise by gaining knowledge and experience relative to a specific domain. Some of these domains are part of the physical world, like riding a bicycle, while some are in the social world, like knowing what to bring to a social gathering.

In the performing arts, the general notion of a *performance* at times coincides with the specific use here. For example, in an improvised music performance, skilled experts are not strictly following a rigid set of rules, though one can identify rules that are apparently at work in order to aid in describing or comprehending the music. In such contexts, rules merely help us understand what we are analysing, but they do not necessarily correspond to *how* what we are analysing *came about*.

This scenario relates to DMI design in terms of human adaptability. Along these lines, when we visit a different culture, there may be very different notions of what to bring to a social gathering. If we remain in the new culture, we eventually manage to adapt and to conform, at least to a certain degree. Over time, we gain knowledge and experience that leads to know-how concerning what is considered appropriate. A handful of basic rules may help us avoid some common cultural missteps, but these are hardly a substitute for the judgment that comes with years of experience. In this sense, when a DMI resembles an acoustic instrument or generally behaves according to our expectations of other physical interactions, it might be easier to operate at first by following a few inferred rules. But it is not a necessary design principle to provide a smooth transition into playing the new instrument; learning and experience will be required for expertise with or without this transition. The ability to acclimate to new modes of interaction is a feature of human cognitive flexibility that should not be disregarded in the design process.

## 4. THE OBJECT AND THE TOOL

The divide between the mode of how we interact with ordinary objects of the physical universe and other potential modes of interaction can be understood in terms of phenomenology. Consider the difference between our perception of a tool that is bypassed while searching through a toolbox and our perception of a tool when we are engaged in using it for a particular purpose. As Dreyfus puts it, "what results is a system that represents the world not as a set of objects with properties but as current functions (what Heidegger called in-order-tos). Thus, to take a Heideggerian example, I experience a hammer I am using not as an object with properties but as in-order-to-drive-in-the-nail" [3]. This is significant because a DMI is meant to achieve a particular aim; as noted earlier, "we *act through* it to achieve effects in the world" [2]. In this case, there may be numerous ways to characterise the aim, or multiple complex aims, but nonetheless, the DMI is a mediating technology, not an end in itself. After all, *instrument* is nothing more than a glorified synonym for *tool*.

In terms of DMI design, the real significance of the object-tool distinction concerns the notion of intuitive interaction. While the idea of what is intuitive seems to be universal, the reality is that intuition is a part of expertise. The confusion arises when we forget that expertise is relative to a domain. Since the human experience of physical interaction is universal, we are all experts in our inhabitance of the physical realm and thus have intuition in this domain which has been developed over a lifetime [3].

But there are also experts in more specific domains or realms of activity; their intuition respective to those realms is distinct. For example, riding a bicycle, driving a car, and flying a plane, are all physical, and in this case, even more similar in that they are all versions of operating a transportation device. Yet it is trivial to state that there are those who are experts at one and not the other. The same goes for expert players of games or sports, such as chess, tennis, basketball, football, golf, and so on. When one has achieved an expert skill level at any of these activities, then one's decision-making processes while engaged in the activity result at least in part from know-how, another name for intuitive understanding or intuition [3].

Expert intuition is domain-specific and can be developed even with unusual modes of interaction. The claim that an instrument (or interface) is intuitive in virtue of its correspondence to a physical model of interaction is trivial. It is no more or less intuitive than an expert driver's feel for using the basic set of automotive controls to initiate and to sustain controlled large-amplitude sideslip manoeuvres known as "drifting" [1]. Drifting is a challenging, skillful mode of interaction with a car that while intuitive to an expert is in fact *counter-intuitive* to an ordinary driver.

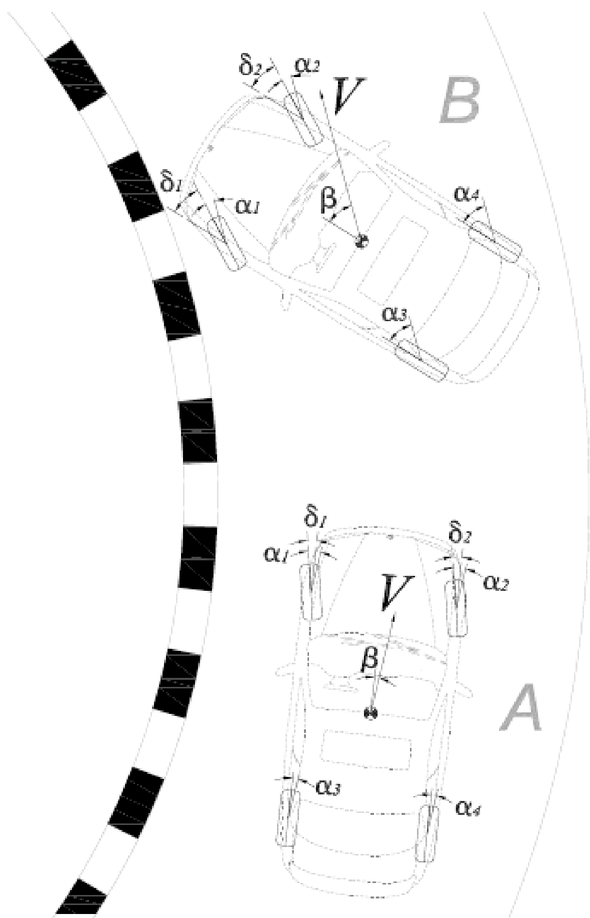


**Figure 1**. Two vehicles stabilised in a constant-speed, constant-radius left turn at two sideslip conditions. Vehicle A is performing a conventional turn, Vehicle B is drifting [1].

Though it is an object, a DMI is also a tool, and as such, it must be possible to learn how to use it and, with continued learning, to improve over time. At some point, regardless of its interaction properties, once we are able, we will be caught up or absorbed in performing with it. In virtue of this absorption, the instrument itself will, at least at times, phenomenologically "withdraw" or disappear from our immediate concerns. The object-character of a DMI may remain relevant in terms of portability and visual aesthetics, but the interaction design relates to its use as a tool. With respect to DMI design culture, it should be acceptable to design a complex tool for a complex purpose, or to use an imaginative mode of interaction for an artifact that need not behave in the manner of physical objects.

## 5. THE VEHICLE AND REFERENT OF THE METAPHOR

There is a benefit but also a danger inherent in taking existing knowledge and facilitating its application to a new domain, certainly when we are dealing with DMI design. The user interface, taken together with mappings and output sound, gives meaning to the instrument as a whole. Nonetheless, the direct point of sensorimotor interaction remains with the interface. Though new interfaces are in principle open to radical innovations, they are generally designed to take advantage of established human skills. In some cases, this comes down to the intuitions of ordinary physical interaction discussed above. In other cases, interaction with cultural artifacts is similarly familiar (*e.g.*, a typewriter or a piano).

Consider that early personal-computer-based word processors were analogically modelled on the typewriter, as was the digital piano on the acoustic one. It seems that in order for commercial manufacturers to reach the widest audience, it was in these cases advantageous to draw upon a culturally established skill. Since typewriters were culturally familiar, it followed that the word processor software, monitor, and keyboard, taken together, were designed according to the interaction model of the typewriter. This is an example of a user interface *metaphor* that takes existing knowledge and facilitates its application to a new domain – a common design principle in general, and one that is particularly common in DMI design. As Dourish notes, "metaphor is such a rich model for conveying ideas that it is quite natural that it should be incorporated into the design of user interfaces." But he provides an additional insight here that highlights a potential (and frequently encountered) confusion:

> The key to metaphors is the ability to manage the relationship between the metaphorical vehicle (the "file," "button," or whatever) and the referent (an actual set of bits or a function activation). The value of the metaphor is in suggesting some action, or simplifying how the action is carried out; but the action is to be carried out on the referent of the

> metaphor, not the vehicle. In addition, of course, the computational referent of the metaphor has a set of capabilities that the metaphorical object does not [2].

This last point is critical, because a designer should aim to fully consider the potential capabilities of a new instrument. Instead, some designers reach an artificial stopping point that ends where the metaphor ends, namely, the analogy to a physical object or cultural artifact. The important point here is that the capabilities of cognitive and physical interaction represented in the target design are not limited to those represented in the source model. Furthermore, as with computers and typewriters, DMIs present certain potentials that extend beyond some limitations of acoustic instruments.

## 6. CONCLUSION

Eventually, word processors evolved and became less like typewriters. Menus were added, additional key functions were incorporated, and so on. Users learned the new skills and became experts. There is some irony in the fact that today, a typical word processor is more complex and places more cognitive demands on a user than a typical DMI, twenty years after Joel Ryan wrote that "though the principle of effortlessness may guide good word processor design, it may have no comparable utility in the design of a musical instrument. In designing a new instrument it might be just as interesting to make control as difficult as possible" [6].

Ryan makes a crucial point here that, lamentably, is not reflected in current DMI design trends. Perhaps this is in part due to another general confusion, namely, that difficult to control does not mean impossible to learn. People still learn how to play difficult acoustic instruments, and how to operate complex machinery, to name a few examples. To paraphrase Donald Norman, a design should be *appropriately complex* with respect to the goals it is meant to achieve [5]. In short, instrument designers should not take a limited view of human cognitive capabilities with respect to coping with difficulty and complexity.

Observe that in a word processing environment, key combinations demonstrate an on-the-fly, dynamic repurposing of an input device. In a short time, one can learn to seamlessly transition between a stream of typing (real-time i/o), and, for example, a keyboard-triggered "select all" (control command) to highlight text. Keep in mind that this is not an augmentation of an existing function like capitalising a letter with the *shift* key (or sustaining a note on a piano with a pedal). Rather, it is a complete transformation of interaction mode that, unlike some DMIs, does not require a laborious loading of a new configuration. Yet in a survey of literature related to DMIs, it is clear that there is a dearth of research on the topic of on-the-fly, dynamic repurposing of an input device during live performance. (At present, there seems to be only one paper that addresses the subject in some depth [7].) The key-command example above demonstrates, among other things, that maintaining consistency and offering variance in control systems need not be at odds in DMI design, which suggests at least one way forward.

My intention in drawing out the various assumptions detailed above is not to criticise existing DMIs that have been designed within certain justified constraints for a particular purpose. On the contrary, there are many highly developed DMIs that have been designed according to physical interaction models, for example, and have profited from theoretical and empirical research with admirable results. The problem arises when we generalise from some particular cases or experiences, extrapolate purportedly universal constraints, and assume an objectively valid paradigm that is inviolable. No point on the spectrum of possible designs should become a teleological horizon or a conceptual prison. In this spirit, we should not hesitate to encourage radically innovative designs that challenge our assumptions and defy all expectations.

## 7. ACKNOWLEDGMENTS

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