Cognition and Improvisation:
Some Implications for Live Coding

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ABSTRACT

This paper explores the perception that live coding is a "real-time" improvisatory activity. It posits the notion that because live coding requires less complex motor skills than instrumental improvisation it may be less susceptible to the influence of mechanical modes of musical expression. This hypothesis will explore the concept of goal states, models of memory and the function of reflexes and reactions as a means of mapping this territory and will provide a framework to understand the various perceptual domains with which a coder engages during a live extemporised performance. This exploration will engage in a comparative discourse relating live coding to instrumental improvisation, as a point of departure for the understanding of cognitive functioning in this rapidly developing performance paradigm.

1. GOAL STATES

In a healthy human being, perception works in such a way as to present a cohesive and flowing conscious experience. The resources associated with cognitive processing are managed by a plethora of neural processes in a manner that is optimised, for the most part, to keep us safe and healthy. This allows us to ebb and flow between mental states which might be processing sensory data in radically different ways but which are presented to us as a single, fluid experience. One of the key mechanisms in managing the various activities we synchronously engage in is the monitoring and maintaining of various goal states being held at any one time. Although many contemporary theories suggest goal pursuit is the result of conscious deliberation and desire (Gollwitzer & Moskowitz, 1996 ,Baumeister & Vohs, 2004), Ruud Custers posits a convincing argument that goal pursuit can be enacted outside of conscious awareness (Custers, 2009). This theory has been successfully tested using priming techniques and has led to the development of such concepts as nonconscious will (Bargh et al., 2001), implicit intention (Wood, Quinn, & Kashy, 2002), or implicit volition (Moskowitz, Li, and Kirk 2004).

Put simply, a goal state that is not afforded the spotlight of conscious awareness but which begins to rise in significance, will cause lower priority undertakings to have their monitoring diminished or maybe even terminated. Consider the metaphor of a driver listening to a play on the radio during a long motorway journey. For long periods of the journey the cognitive processes involved in the act of driving the car can be successfully filtered in order to pull focus on the narrative as it unfolds on the radio. The cognitive goal at this stage is to follow the narrative of the play and so conscious awareness is given over to this undertaking. As the driver passes a sign post, the 'radio play - perception' process is interrupted by the need to devote attention to the road sign as the goal of the 'journey process' has priority over the goal of the 'radio play process'. If another car suddenly brakes then the goal of the 'survival process' will be triggered by the brake lights of the preceding car and take precedence over the 'journey process' causing an action compliant with that goal state.

Many studies have concluded that affective priming can have a huge influence on goal motivation (Winkielman, Berridge, and Willbarger, 2005), (Aarts, Custers & Holland, 2007), It is quite possible that many of the goal states that comprise an improviser's practice are in fact instigated by non-musical and subliminal stimuli. After all, improvising performers are not shielded from their environment or their history for the duration of their performance and the conceptual and perceptual processes that drive their musical behaviour are fueled as much by implicitly held concepts as real-time sensory data. The conceptual and perceptual processes that determine the specifically musical goal states in improvised instrumental music and live coding are therefore likely to be influenced by factors outside of their awareness, not least of which is the short-latency dopamine signal, believed by some to play a role in the discovery of novel actions, an area of enquiry which could be very illuminated in this context but which is outside the remit of this paper (Redgrave and Gurney, 2006).

Sperber states that perceptual processes have, as input, information provided by sensory receptors and, as output, a conceptual representation categorising the object perceived (Sperber 1996). The notion that perceptual processes have as their input the continuous data stream of sensory information and that the outputs from these processes become an input to conceptual processes, can be used to formulate a model of improvised behaviour, where the parameter (sensorial) space in which the behaviour exists is split between the internal and the external. The function of memory acquisition and retrieval therefore has an important role in pursuing goal states (Avery and Smillie, 2013).

2. MEMORY

For improvised musical behaviour of the type exhibited by live coders, the notion of perceptual and conceptual processes governing their behaviour should be put in the context of memory, particularly as there are significant differences between the role of memory in live coding and improvisation using traditional instruments. Motor skill execution is of particular importance to instrumental performers but there is a consistency across all physical motor skills in the manner of acquisition (Newell, 1991). The process begins with the repetition of small units of activity, which may be undertaken and evaluated using multiple senses. In terms of a musical instrumentalist this obviously utilises audible feedback but also uses a visual and tactile mode of feedback too, such as observing and feeling finger movement on a fret board. The process continues by constructing larger units from the primitive units of activity and so placing them in a range of contexts. At this stage the parameters and variants in the activities and their triggers can be developed. The repetitive act is in effect embedding a neural program into semantic memory that can then be triggered and passed a range of parameters. The effect of this is to significantly lighten the cognitive load, as once the activity has been triggered the detail in the activity can be undertaken with minimal conscious control, responding only to changes in its parameter space. A pianist could practice a scale in this way and when the motor units had been fully committed to memory the activity could be executed without conscious control over each of the component parts. In fact conscious attention is regarded by some to be detrimental to the accurate execution of highly complex motor skills (Wulf, 2007). The motor program may have a speed parameter that the pianist can control but is perhaps unlikely to have a parameter to change the intervals between the notes. In this way a whole catalogue of functional units can be triggered and left to run, leaving enough cognitive capacity to be able to undertake other tasks.

There is a distinction that needs to be made between the acquisition and retrieval of the activity units and the mode and manner in which they are assembled into larger conceptual units. Pressing makes this distinction by describing ‘object memory’ and ‘process memory’ as the place where the two exist. Crudely speaking ‘object memory’ for an instrumental musician would hold the activity units associated with playing the instrument, often identified by the blanket term ‘technique’. The information required to make use of the instrumental technique resides in ‘process memory’. This is where the methods for what Pressing describes as ‘compositional problem-solving’ are held. Methods of sequencing and systems for manipulating the parameter space of an activity unit are stored in ‘process memory’ and retrieved in accordance with the particular mode of performance. It is perhaps worth returning to the notion of cognitive capacity in the light of the processing that ‘process memory’ feeds. Motor activities such as tying up a shoelace or having a shave are reasonably cheap on effort and attentiveness, because the pathway through the activity units is comparatively static and can be easily predicted. However, the computational overhead will increase with human activities that require a higher level of monitoring and real-time manipulation. In the former case it’s possible for a person to experience a sensation of ‘switching off’ or diverting attention elsewhere. However, in the case of creative activities, routines executed from ‘process memory’ are likely to be more dynamic, requiring monitoring and parameter adjustment thus making greater cognitive demands. In this case the brain has a complex resource management problem to address in order for the activity to be undertaken effectively. Activities such as game playing and musical improvisation fall into this category but, as with all other activities they exist on a continuum somewhere between the extremes of static and dynamic. Their position on the continuum moment-by-moment, is determined by the resource management of the brain but over a period of time can be influenced by the level of pre-programming, or practice that is undertaken. The instinct to efficiently resource cognitive activity can be a double-edged sword when engaging in a creative process such as improvisation. After years of encoding object and process memory it becomes possible for the whole 'creative' process to be undertaken by traversing chains of previously stored units of activity. Pressing summarises opinion on this matter when he stated that Fitts (1965) labelled this the 'autonomic phase', while Schmidt (1968) referred to it as 'automatization'. The result for the performer is a sensation of automaticity, an uncanny feeling of being a spectator to one's own actions, since increasing amounts of cognitive processing and muscular subroutines are no longer consciously monitored (Welford, 1976) (Pressing 1984). The significance of object memory for a live coder is therefore much less than for a traditional instrumentalist, although the sensation of being an observer is perhaps more vividly conscious, rather than reflexive automaticity.

The role of feedback in the perceptual loop, which gives rise to this type of experience, is important to consider. In this context, a close loop system describes the self-referential nature of activity units drawn from 'object memory' and subsequent evaluation for the purpose of error correction. Pressing describes one such feedback model, known as 'closed-loop negative feedback' (CLNF) (Bernstien 1967), in which an evaluation of intended and actual output is fed back to an earlier stage in the control chain. It is perhaps this process of evaluation that problematises the existence of closed and open loop feedback systems in improvisation. The submission by Pressing (Pressing 1988) that a consensus exists which suggests that both systems coexist seems reasonable, if one acknowledges that material drawn from process memory is also subjected to an evaluatory process, the result of which bears influence on the subsequent use of activity units. In this scenario, evaluation is undertaken at two levels simultaneously, but the nature of the evaluation is necessarily very different. It seems appropriate to apply the principles of closed loop theory to the evaluation of the primitive motor units, which suggest that a 'perceptual trace' of an activity unit is built up from its previous executions to form a template against which to gauge the success of its current execution. This theory (Adams 1976), is applicable to motor actions undertaken by improvising instrumentalists rather than live coders, because of the autonomous manner of their execution but is not sufficiently flexible to cope with this situation at the 'process memory' level. Pressing recognises why this should be the case when he asserts that in an improvising instrumentalist "the ability to construct new, meaningful pathways in an abstract cognitive space must be cultivated. Each such improvised pathway between action units will sometimes follow existing hierarchical connections, and at other times break off in search of new connections" (Pressing 1984).

The function of object memory and its relationship to motor skills in instrumental improvisation and live coding differs significantly due to the interfaces they employ to deliver the results of their creative practice using process memory. The overhead of encoding motor skills for live coding is less burdensome and consequently the cognitive resource gains of 'automaticity' are reduced compared with instrumentalists. It is true that the act of typing is a motor skill but there is less opportunity to build complex amalgamations of primitive units that facilitate direct control over the sound elements in a rich parameter space. That's not to say that fine control over sonic material is not available to live coders but the means of accessing it is more heavily reliant on process memory than pre-encoded units of behaviour from object memory. Although William James said in 1890, 'habit diminishes the conscious attention with which our acts are performed' (Pressing 1984) I am suggesting that live coders may be less susceptible to the influence of habit and mechanical modes of musical expression because the motor skills required are less complex than instrumentalists and consequently less of their behaviour is activated outside of their perceived conscious control or awareness. There is the possibility that habitual behaviour can develop via conceptual processes fed by process memory but in this instance there is a much greater opportunity for conscious intervention. Berkowitz surveys the various metaphors used by instrumentalists across a range of cultures to describe the ebb and flow between consciously controlled and automatic musical behavior during improvisation (Berkowitz, 2010). These are often characterised by a sensation of 'letting go' of conscious control and yielding to subconscious processes, described by Stephen Slawek as "an ecstatic state of effortless" (Slawek, 1998). The instrumentalist has at their disposal a vast resource of pre-encoded units of behavior which will sustain their music making once they have relinquished conscious control, which I would suggest is not available to the live coder. There is no doubt that live coders develop a repertoire of syntax and algorithmic schema they can call upon at speed and that the act of typing may become very fluid and intuitive but this is someway from Slawek's ecstatic effortlessness. Perhaps the automatic writing of the surrealists is the closest textual expression has come to engendering this state but the rigors of coding syntax would not permit such an endeavor in this context.

3. REFLEXES AND REACTIONS

I am suggesting that the live coding paradigm differs significantly from instrumental improvisation in its relationship to cognitive load. In instrumental improvisation the need to reduce the cognitive burden of conscious monitoring at high speeds is clear, but philosophically this can be a problematic notion for many musicians. Pressing identifies that speeds of approximately 10 actions per second and higher involve virtually exclusively pre-programmed actions (Pressing 1984). An informal analysis of jazz solos over a variety of tempos supports this ballpark estimate of the time limits for improvisational novelty. (Pressing 1988). It is probably fair to say that for some musicians there is a principle at stake in calling a musical activity improvisation that overtly draws on 'learnt' material. The saxophonist Steve Lacy, in conversation with Derek Bailey expresses his frustration accordingly when he says "why should I want to learn all those trite patterns? You know, when Bud Powell made them, fifteen years earlier, they weren't patterns. But when somebody analysed them and put them into a system it became a school and many players joined it. But by the time I came to it, I saw through it – the thrill was gone. Jazz got so that it wasn't improvised any more". (Bailey, 1992)

Although the causal relationship between the expression of ideas in code and the execution of those ideas by the computer is more asynchronous and less rigidly fixed to a timeframe than instrumental improvisation, live coding, like all other human activities, still has to exist within the confines of an available cognitive resource. It is important to emphasize that information being processed consciously at any one time is only a small subset of the overall cognitive workload that is being undertaken. Consciousness is a system that is fed information and sits beside and competes with a multitude of other biological systems for resources. That is not to say that if all other competing systems relented, consciousness's performance could be enhanced ad infinitum. Perhaps the most enduring observation relating to the limitations of consciousness is from 1965, when Miller suggested the magic number 7 +/- 2" (Miller 1956). This 'magic number' represents the amount of information threads or 'chunks' that could be retained in working memory at any one time. The theatre metaphor proposed by Baars suggests a spotlight of selective attention representing consciousness, into which actors move in and out, surrounded by the darkness of the unconscious, where all the other roles which facilitate the production reside (Baars, 1997). In Wiggin's adaption of Baars global workspace theory to a musical context, he asserts that his concern is not with what consciousness is, but what is presented to it. He presents a model of creative cognition in which the non-conscious mind comprises a large number of expert generators, performing parallel computations and competing to have their outputs accepted into the global workspace (Wiggins, 2012). What is not clear from this configuration is the passive/active nature of consciousness being stimulated, is this active conscious engagement or just passive awareness, this distinction is an important one in the context of live coding and instrumental improvisation because Berliner's 'creator – witness' mode of improvised behavior rather than the conscious agency needed for live coding (Berliner, 1994).

Another limitation that profoundly affects the performance of a conscious act relates to its speed of execution. In exploring this it is important to consider the differences between reflexes and reactions. Janet Chen Daniel of James Madison University explains some important distinctions, stating that only the simplest types of responses are generally regarded as 'reflexes', those that are always identical and do not allow conscious intervention, not to be confused by reactions, which are voluntary responses to a sensory stimulus. There is a long tradition of trying to quantify human performance in terms of speed of execution. In the nineteenth century one of the pioneers of experimental psychology, the German Wilhelm Wundt, developed a range of mechanical devices to measure reaction times. Probably the most well known was a device that became known as 'Wundt's complexity clock'. In 1965 German neurophysiologists Kornhuber and Deecke, discovered a phenomenon they called 'readiness potential' which suggested that the brain became active anything up to 1.5 seconds before an act was undertaken, in preparation (readiness) for the act to be performed. In the 1970s Benjamin Libet, professor of neurophysiology at the University of California Medical Center in San Francisco, took this research a stage further. Libet raised the question: if this time lag exists between preparation and the act, when do we become conscious of the act? It seemed obvious to him that there wasn't a 'one second gap' between deciding to do something and actually doing it. In 1979 he set up an experiment using Wilhelm Wundt's complexity clock to measure the time between the onset of brain activity, conscious initiation of an act and the actual act. Libet discovered that readiness potential started 550ms before the act, while the subject became conscious 20ms before the act. Libet concluded that 'cerebral initiation even of a spontaneous voluntary act of the kind studied here can and usually does begin unconsciously' (Libet 1985). From Libet's findings it became evident that the brain can process a response to an externally initiated act more efficiently than one that is internally initiated. Our reactions are therefore quicker than our actions. In both instrumental and live coding performance contexts a performer's reflexive and reactive behaviour will impact their musical output, but the nature of its influence may differ in each circumstance. The majority of live coders tend to perform as solo artists, unlike improvising instrumentalists and so for live coders perceptual processes monitoring the performance environment are more likely to include factors external to the music, such as room acoustic, lighting, audience reaction etc., alongside anything which may directly affect the substance of the performance. The time frame in which they codify their musical expression is not necessarily synchronous with musical time and so the imperative to conceptualise, encode and transmit musical material is relieved of the '10 actions per second' restriction that Pressing identifies as the limit of improvisational novelty. Instrumentalists are responsive to subsidiary effects in the performance environment too but also to the behaviour of others actively taking part in the performance, resulting in behaviour that is likely to be stimulated by perceptual processes and object memory. In many instances an improvising musician could happily engage in verbal dialogue with someone while continuing to play their instrument but a live coder would probably struggle to talk and code at the same time. It therefore seems plausible that live coders require at their disposal, more cognitive resource to engage conceptual processes and process memory, which will tend to produce behaviour that is reactive rather than reflexive.

4. CONCLUSION

Both instrumental and live coded improvisation exists in a context where there is an expectation that novel musical material will be produced in a temporal domain that is often referred to as 'real-time' or 'in the moment'. In order to achieve this, instrumental performers have to conceptualise, encode, transmit and evaluate musical material in a manner that is perceived as a single fluid action. This action comprises cognitive processes that are fed by sensory information, implicitly held memories such as motor skills and more executive conceptual functioning. The seamless action is a fragile parameter space that is susceptible to reflexive responses and conscious and unconscious responses to internal and external stimuli. The performance being undertaken always exists within the context of available cognitive resources and could be terminated in an instant should the need arise to divert resources to a higher priority undertaking. The relationship between the temporal aspect of this undertaking and the allocation of cognitive resource differs significantly for instrumental and live coded improvisation. In both instances there is a need to access 'technique' stored as object memory but the encoding process in instrumentalists is much longer and more systematic and the resulting resource plays a much more significant part of the activity, providing elemental units of pre-programmed musical behaviour. An instrumental improviser will dynamically move up and down a continuum that stretches between perceived conscious control of individual elemental actions and executive control of pre-programmed units of material. Moving between these modes of engagement is, for the most part, outside of the performer's perception. For the live coder the need to maintain the sense of a single fluid action doesn't exist. The elemental motor skills required do not have the same relationship with the production of musical gestures and consequently the evaluation and feedback cycle is not bound to the same temporal frame. As soon as the 'real-time' shackles are loosened the freed up cognitive capacity can be utilised in musical behaviour that is guided more by compositional considerations derived from process memory and conceptual processes, with a reduced sense of automaticity, rather than being driven by more mechanical modes of musical expression.

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